

Aligning the 'right people' for a circular value chain

A method for collaboration in the Dutch
consumer electronics industry

Eneko Ayerza Insausti





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Master Thesis

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Preface

This graduation thesis is the culminating project of the past 2 years where I have been on the journey to become a MSc in Strategic Product Design. Throughout this journey I have understood what means to be a strategic designer and grown both professionally and personally. I realized the role design plays in working with and providing answers to complex challenges like the one this project covers.

Since being introduced to sustainability driven design during my bachelor, I realised my role as a designer was to work towards improving the current situation our world is in. Having conducted this thesis partly during the least warm summer of the rest of our lives made me believe even more that change needs to happen now.

With this thesis I conclude my academic career where sustainability has had a central role. Redesigning an iconic Bauhaus design to reduce its environmental impact during my bachelor thesis or conducting a research project analysing the role materials play in sustainable packaging have been some projects that show this sustainability focus. I have also focused on acquiring and enhancing my sustainability and circularity related skills by following courses such as sustainable design strategies, environmental and circularity assessment methods, and repair.

Additionally, I followed an internship where I focused on conducting Life Cycle Analyses (LCA) and being part of the sustainability journey of a consumer electronics company. By being closely involved in this journey and the strategy I found my motivation to pursue the topic of this thesis. When I was presented with the opportunity to conduct my graduation thesis within a framework that looked exactly into this topic, I had no other option but to take it.

In March 2023 this project kicked off. Over the past 6 months I have dived deep into the topic of circularity-oriented collaboration in consumer electronics. My main goal was to contribute as much as I could to such a complex topic. Along the process I have understood aspects not only about the topic, but also about myself as a designer and as a person. Working in a state of ambiguity and complexity can be tiring at times but I am grateful to have been able to experience it and apply my strategic design skills.

In this thesis I have been able to make a small contribution to the understanding and expansion of the circular economy, and hopefully provided some inspiration for the readers to make their own part in reaching a better future.

Enjoy reading.

Yours sincerely,

Eneko Ayerza Insausti

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I also want to extend my gratitude to all the organizations and companies that I have been in contact with throughout the process. Thank you for opening your practice to me and allowing me to get a glimpse of your day to day. I would like to specially thank the company that opened their doors and welcomed me in their offices to test my design. Your openness and enthusiastic attitude have really improved the outcome of this project.

I cannot overlook the help received from Garoa. Your help in making sense of all my work, even in your busiest moments kept this project in movement. You really have been a third mentor throughout this project.

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Finally, and most importantly, I would like to send my immense gratitude to those that share my journey daily: my friends, close and afar, family, and housemates. Thank you for always being up to hear my incessant talk about the graduation project. To my family, for always supporting me and believing in me. Your support has encouraged me to chase my ambitions. Eskerrik asko, bihotzez.

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To all of you, and those that have not been explicitly stated, my most sincere gratitude. I hope this project can do your support sufficient justice.

- Eneko



Executive summary

Electrical and electronic devices are a focal point of resource sustainability agendas due to their rising demand, critical resource usage, and waste management challenges. Within this devices, consumer electronics are characterized by a fast innovation speed and short product life cycles and are part of a highly competitive market with many players and a high impact on society. All these aspects make them a great candidate for the implementation of circularity principles to promote a sustainable development. However, transitioning to circular practices necessitates systemic change and collaboration among diverse stakeholders, what requires taking a value chain perspective. Resources for collaboration in the consumer electronics industry that take a value chain approach following the principles of a circular economy are limited. Therefore, new tools and methods are needed to support organizations in creating circular value chains by collaborating with other organizations.

The main goal of this project is to help organizations in the Dutch consumer electronics industry set up an aligned value chain based in the Circular Economy principles. This is tackled by creating a method to guide them in this effort. To find actionable insights, a literature review was first conducted. The review covered the current state of the circular economy transition within the consumer electronics industry and the Netherlands, alignment dimensions, and barriers and drivers for the adoption of circular strategies. The literature revealed that alignment dimensions are linked to specific barrier/driver categories, that a the same time are linked to the organizational boundaries. Then, semi-structured interviews with representatives from various positions within the consumer electronics and other electronic value chains were conducted. These interviews underscored the importance of organizational roles within value chains, emphasized circular economy awareness and environmental impact, and identified context-specific drivers and barriers, particularly related to resource availability and mindset. Collaboration emerged as a crucial factor, necessitating shared responsibility, the use of success stories to attract partners, and clear partner selection criteria. The interviews reflected a prevailing product-centric perspective in the industry, with services receiving significantly less attention.

These insights were applied in the development of the Circular Value Chain (CVC) method, designed to assist Original Equipment Manufacturers (OEM) in establishing circular value chains for consumer electronic products. CVC is a seven-step iterative process that considers design organizations and OEMs as initiators of the value chain. It begins with a self-evaluation, followed by drafting an initial Product-Service System proposition, to then envision an ideal circular value chain. It is then followed by assessing and selecting suitable partners and aligning them for an effective collaboration. Various tools were designed and incorporated in the method in the form of circular value chain archetypes, an assessment card and spider diagram, and a table of selection guidelines. Other tools were also adapted from literature to aid the self-evaluation, drafting of a PSS proposition and alignment activities. Overall, CVC adopts an organizational approach, involving different teams guided by an expert strategic designer to achieve the goal of creating circular value chains for Product-Service Systems.

This project holds practical and academic significance by providing insights into aligning partners within circular collaborations using a value chain perspective and offering a theoretical framework for future research. The designed method and tools bridge existing research implementing a value chain perspective, enhancing their industry applicability and the relevance from a circularity perspective. The included tools focus on assessing partners based on organizational roles and facilitates informed decision-making. Collaboration within value chains is vital for advancing the circular economy and achieving sustainability, and the CVC method supports this through a value chain perspective, role definition, and selection of the 'right people'. While testing shows high potential, further refinement is needed for practicality and information inclusion. In sum, the design outcome offers an initial version of a method that should be further explored and iterated on to help OEMs in the Dutch consumer electronics industry set up aligned value chains.

Figure 1. E-waste (Obtained from Freepik)

Glossary

Key terms and abbreviations used throughout this report are defined and described in this section.

Key terms

Value Chain

Internal and external stakeholders in the value-creation process that encourages a full-lifecycle perspective.

Organizational Alignment

Agreement between organizations because of shared interests or aims

Consumer Electronics

Electronic devices such as televisions, computers, or smartphones, bought for personal rather than commercial use.

Sustainable Development

The development that meets the present needs without compromising the ability of future generations to meet their own needs.

Collaboration

Organizations working together to reach the same goal.

Barrier

An issue that prevents the implementation of circular principles.

Driver

An issue that encourages the adoption of circular principles.

Circular transition

The adoption of strategies that follow the principles of the Circular Economy

Role

The function assumed by an organization within a value chain

Product-Service System

A mixed offer of products and services

OEM

An organization that makes parts and/or products to be sold under another brand.

Transition / Shift

Adoption of circularity principles and strategies to move away from a circular economy

Abbreviations

CE

Circular Economy

OEM

Original Equipment Manufacturing

CVC

Circular Value Chain

PSS

Product-Service System

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1. Introduction

The following chapter offers an overview of the project. First, it introduces the context and problem framing of the thesis. Then, the goals and research question are introduced, followed by an explanation of the framework this thesis uses. The chapter is closed by offering the project approach as well as a general overview of the content.

1.1. Context

Due to their rising demand, critical resource usage, and waste management challenges, the discourse on resource sustainability has recently focused on electrical and electronic devices (Parajuly et al., 2020). These products are one of the most important application areas for critical resources and have a short life cycle, which creates an ever-growing waste stream that is rich in valuable materials (Stenvall et al., 2013). Even though regulation is in place, such as the directive 2012/19/EU on waste electrical and electronic equipment, the electronics industry remains an inefficient industry where many resources are wasted and where severe environmental impacts are created, as already described by Osibanjo & Nnorom (2007).

The EU as well as the Dutch government show a strong interest in circularity in their sustainability-related regulation (Ministerie van Infrastructuur en Waterstaat, 2023). These actions, amongst others, are expected to play a role in driving the shift to adapt the industry to the future scenario (Tura et al., 2019). However, the shift in practices needs to come from all stakeholders present within the value chain, since the circular economy presents a paradigm that requires a systemic change (Brown, 2020). Currently existing relationships within organizations are generally reduced to the actors within the direct activities of said organizations, as depicted in the example in Figure 1 (Cimprich et al., 2022).

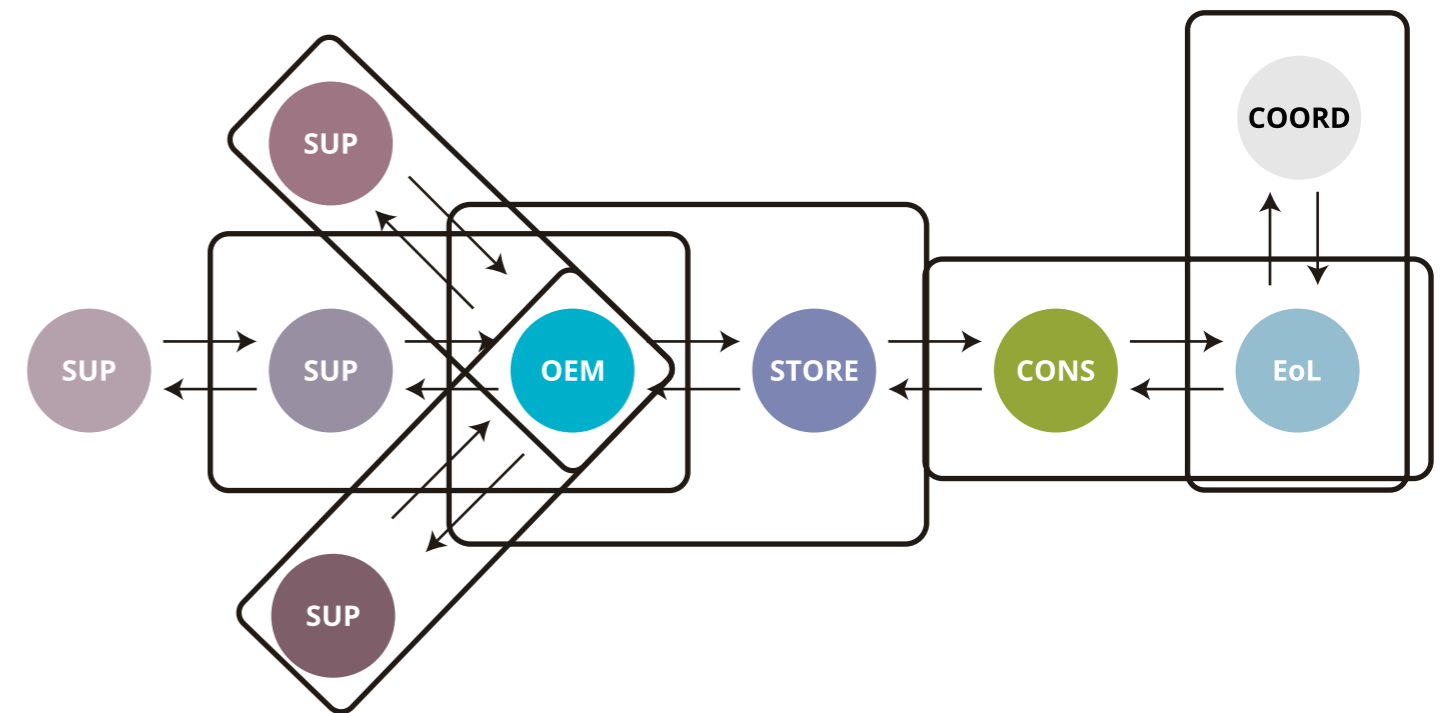


Figure 2. Current relationships between stakeholders in the value chain, with collaboration silos.

1.2. Problem definition

The consumer electronics industry, characterized by a fast innovation speed and short product life cycles, is part of a highly competitive market with many players and a high impact on society (Dutch Research Council, 2021). Research by Hanemaaijer et al. (2023) shows that the transition to a circular economy is in an early stage, and there being a big number of stakeholders involved in the whole ecosystem. As the shift toward circularity seems imminent, collaboration is gaining more relevance, not only within supply chains but also with other agents in the market, such as regulators or competitors (Singh et al., 2021). Each one of them might have different circular motivations and goals which can lead to misalignment in targets, timelines, and actions (Brown et al., 2019). Moreover, the generation of sustainable development through circularity requires a systemic approach that organizations are not used to and do not know how to adopt (Brown, 2020). This is not only reduced to the systemic approaches, but also to the knowledge and guidelines to implement circularity principles in their practice (Bocken & Geradts, 2020; Hina et al., 2022; Kühl et al., 2023; Salmenperä et al., 2021).

Significant research has been conducted surrounding the Circular Economy in the last years. However, collaboration related to the circular economy has been approached less. Regarding this topic, and tackling the problems that might emerge during collaboration for Circular Oriented Innovation, Brown et al. (2021) created a process model that organizations could follow. Frameworks and processes to set up and analyse possible strategies have been created that are focused on intraorganizational strategies, such as the one by Blomsma et al. (2019) or Pollard et al. (2021). Indicators for analysing the CE stage of organizations have also been established by multiple authors such as Acerbi et al. (2021), Rossi et al. (2020) or Kravchenko et al. (2020).

However, no specific resources have been found for

the consumer electronics industry that tackle how organizations can collaborate to set up a new value chain based on CE principles. Authors such as Velter et al. (2020) find that new tools and methods to support organizations in establishing and overseeing value networks that contribute to a circular economy are yet to be created. Considering this, Brown et al. (2021) suggest the need for a way for companies to assess who the most adequate partners would be to conduct circular oriented collaboration. As a whole, interventions in specific parts of the collaboration process have been done, such as the evaluation of circular maturity levels by Acerbi et al. (2021), or tools for finding potential partners in creative sessions (Brown, 2020), but the more complete models such as the one by Brown et al. (2021), still miss the value chain perspective.

1.3. About this project

Ultimately, the end goal of this project is to help organizations in the Dutch consumer electronics industry set up an aligned value chain based in the Circular Economy principles. For that, this thesis focuses on creating a method to guide them in this task by defining clear and detailed steps, and tools that use clear language known to the organizations.

In order to reach this goal and structure the research, the following Research question has been defined:

How can organizations set up an aligned circular value chain for consumer electronics?

The general research question has been divided into the following sub-questions in order to have a more thorough answer:

1. How can organizations align their practices?
2. What makes a value chain circular?
3. What are the barriers and drivers for circularity experienced by organizations in consumer electronics value chains?

Framework of the project

Circular economy

In this project, the implementation of a Circular Economy is understood as a means to achieve a sustainable development. Therefore, circularity characteristics are inherently linked to sustainability, with all its restrictions. As numerous definitions of Circular Economy can be found, the following definition by Kirchherr et al. (2017) has been selected for this project, since it clearly states the sustainability features of CE:

“A circular economy describes an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.” (pp. 224-225)

Circular Circuits: NWOP Perspective project

This project is conducted within the framework of the NWOP Perspective project Circular Circuits. The programme strives to design next generation electronics for a circular economy (Dutch Research Council, 2021). The objective is to overcome economical, technical, and societal barriers related to extending product lifespan, reusing, repairing, refurbishing, and recycling through the development of new electronic components, product-service designs, business models, and recycling technology. It includes partners from different fields, such as manufacturers, end-of-life organizations, regional governments, economic organizations, and knowledge institutions. The assignment will follow the framework established by the perspective project and will keep the end goals of it in mind:

- Reducing negative effects on the environment and human health throughout the stages of production, usage, and End of Life.
- Strengthening the resilience of supply chains to ensure a steady provision of raw materials and components.
- Optimizing the performance of products and the value of materials by adopting circular design and business models, closing material loops, and fostering collaboration in the value chain.

1.4. Research approach

The present research aims to study how collaboration between different organizations in the consumer electronics industry can be enabled when setting up an aligned circular value chain. For this, the research followed the 'double diamond' approach introduced by the British Design Council (2005).

The project is divided in 4 different stages as follows. First, the problem was explored in order to fully understand it and find interesting points of action. For that, literature about multiple relevant topics was reviewed and semi-structured interviews were conducted. The findings from this stage were used to define the context in a thorough way, as well as to define what the scope of the design was going to be, and what specific part of the problem was going to be tackled.

The next stage, the design phase, was guided by the scope established in step 2. Here, the method and necessary tools were created based on the insights obtained from research. The tools were iterated first to check their complexity and usability. Lastly, the method and tools were tested with a company and the insights and feedback were integrated to finalize the solution.

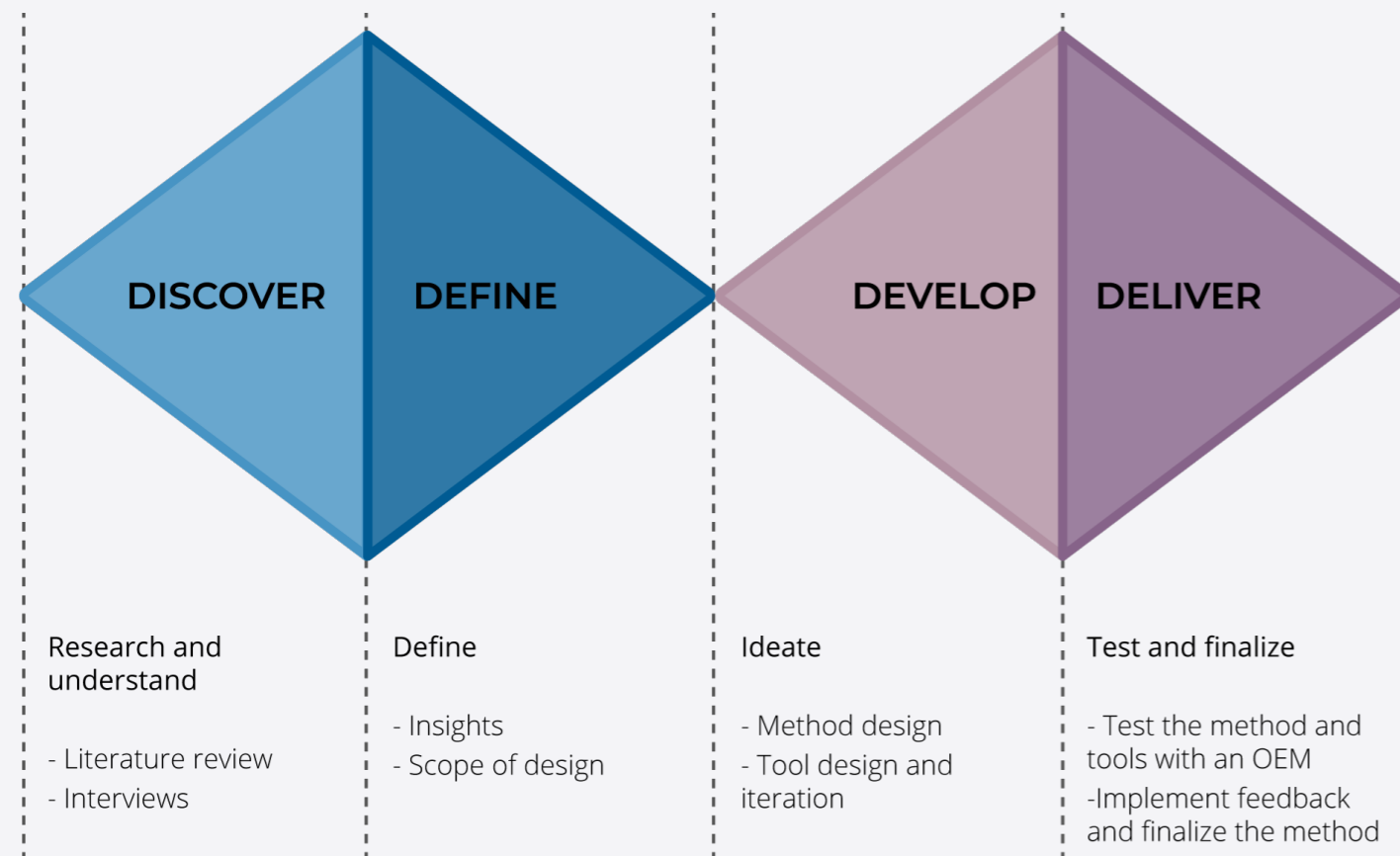


Figure 3. Research approach: double diamond.

1.5. Content overview

The present report was not written following the historical evolution of the project. Instead, it offers the necessary information to understand the final result. Ergo, it offers the content relevant to the scope of design resulting from the define phase explained in the research approach., and will proceed as follows:

Chapter 2 offers a summary of the methods used throughout the different steps of the thesis. Chapters 3 and 4 offer the insights of the research, covering the literature review and the expert interviews, respectively. Chapter 5 summarizes the insights that have been used in the final design solution. Chapter 6 elaborates on the design process, presents the insights obtained in the test with an OEM, illustrates the decisions behind the final design outcome, and thoroughly explains the outcome offering all the steps and tools defined for the method. In chapter 7, the results of the project are discussed, including the limitations of the research, the limitations of the design outcome, academic and practical relevance, and recommendations for future work. Lastly, chapter 8 closes the report with a conclusion around the project and a personal reflection.

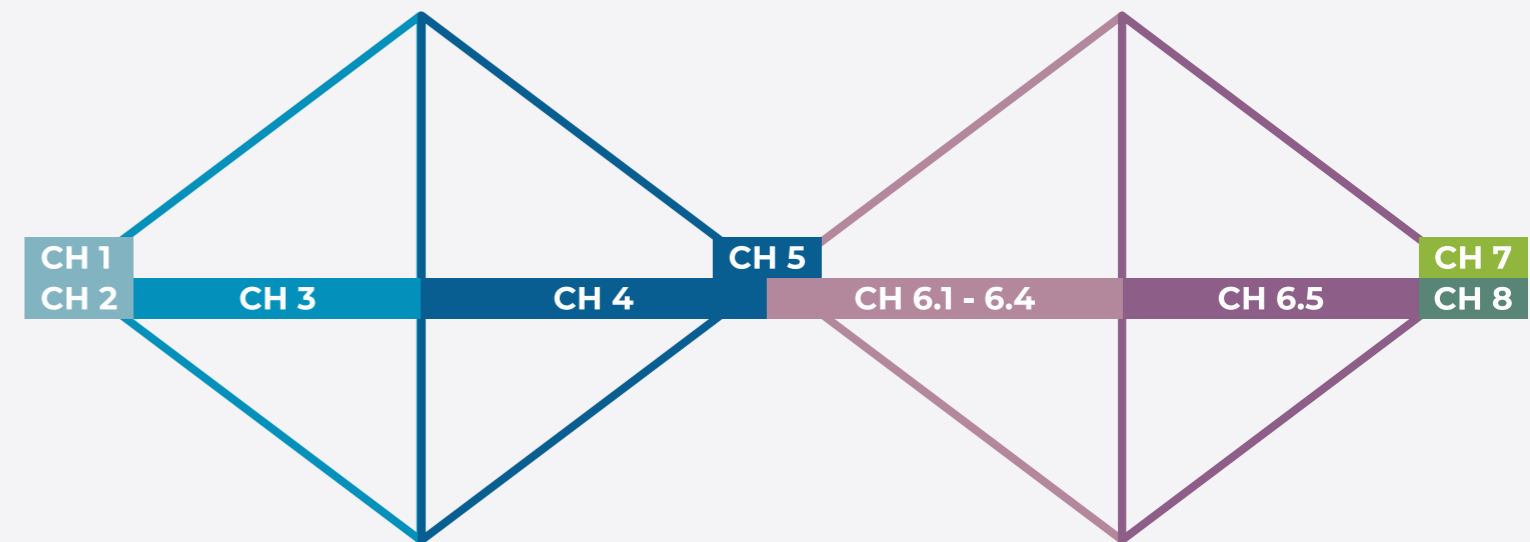


Figure 4. Content overview per chapter

2. Methodology

In order to answer the established research question and sub-questions, 4 different activity groups were conducted throughout the duration of the project. In the following section, an overview of the methods used in each action is presented. The methods are further detailed in each section of the report in order to facilitate the flow of reading.

2.1. Literature review

The aim of the first phase of the process was to understand the context and the topic of the project. An extensive literature review was conducted on the current stage in the transition to the circular economy and the issues that emerge in the adoption of its principles. Apart from this, theory on organizational collaboration and alignment was included to understand the principles by which it is governed. The insights and knowledge obtained from literature were used to generate the framework for the later stages of the project. This framework was built based on the numerous barriers and drivers for the transition, the understanding of the circular economy, and the different types of boundaries and alignment that came out of the review.

2.2. In-depth semi-structured interviews

The second phase consisted of bringing the framework built in the literature review to the context of the project by investigating case studies. This exploration investigated the understanding of circular economy, the organizational strategy related to circularity and sustainability, the barriers and drivers for its adoption, characteristics of ongoing collaboration projects and possible future scenarios. Multiple examples were used in this phase by first collecting data from company reports, websites, publications, and other communication, to generate an initial understanding of the cases. Main data and insights were obtained through semi-structured interviews. Through this approach retrospective information as well as real-time experiences were able to emerge (Gioia et al., 2013). The interview guide, in appendix C, was built with topics obtained from the literature review and example questions from other scholars (Brown et al., 2019, 2020; Rizos & Bryhn, 2022).

2.3. Design phase

The ideation of the design phase consisted of many parts. The steps of the method were based on literature, what was missing in literature, and derived from interviews. A set of tools were also designed based on the insights obtained in the first two phases of the project (literature and interviews). One of the tools was tested and iterated on by making a cohort of 4 students from the TU Delft Industrial Design faculty that had knowledge on organizational terminology and the CE use it. A set of guidelines was created based on this tool and implementing literature insights on it. A set of archetypes was designed based on descriptions from literature and including insights from interviews. Lastly, two tools were obtained directly from literature. A thorough explanation of the design phase can be found in chapter 6.

2.4. Evaluation and test

In order to evaluate and test the usefulness and adaptability of the design outcome to the Dutch consumer electronics industry, a company from the interview section was selected, based on their needs and their attitude. During a guided workshop, representatives of the company tested part of the method and used the tools to then give feedback on the designed method so as to make it more adaptable to the industry. Subsequently, the feedback and suggestions were categorized and implemented in the solution to make it easier to use and more adapted to the end users.

3. Literature Review

In this chapter, insights from the conducted literature review, the first part of the research step, are offered. It offers the following topics related to the sub-questions:

First, contextual information of the state in the transition to a circular economy is offered.

Organizational alignment principles are explored (sub-question 1).

Lastly, barriers and drivers for the adoption of circular strategies are divided into (sub-question 3)

3.1. Current state of circularity in the consumer electronics industry

As mentioned in the introduction, the Circular Economy has gained considerable interest among society, businesses, and administration in recent years. Nevertheless, despite the growing awareness and interest, the implementation of circular principles in the current economic system is not as advanced as it could be. The consumer electronics industry is no exception to this scenario.

As the Ellen MacArthur Foundation reported in 2018 (Meloni et al., 2018), currently adopted strategies can be divided in four topics. First, the adoption of repair, refurbishment or upgrade strategies can be found in different companies. These can be conducted by users or specialised technicians (Meloni et al., 2018), but in some cases options present such a high price or cost, that combined with the uncertain success of the repair, prevent it from happening (Svensson-Hoglund et al., 2021). Component and material recovery is another topic highlighted by Meloni et al. (2018). While recovery of components is already being done by companies in authorised refurbishment activities or by users on alternative platforms (e.g. eBay), the low standardisation of components and fast technological change hinder the full reuse of components. Material recovery, on the other hand, is affected by the continuously developing recycling strategies, where recovery rates are increasing, and environmental impacts are decreasing (Meloni et al., 2018). However, it is also negatively affected by the variability in reliability of the recovered materials (Urbinati et al., 2021). Additionally, a small number of companies have implemented reversed logistics for product take-back systems (Meloni et al., 2018).

Even though consumer electronics present a global value chain (Evans & Vermeulen, 2021), "embedding a sustainable circular economy requires a knowledge of local contexts to devise considerate technological, social and economic interventions" (Velenturf & Purnell, 2021, p. 1452). Therefore, it is necessary to assess the current state of the transition to a Circular Economy in the Netherlands.

The Dutch government has set forth a plan to achieve a fully circular economy by the year 2050, with a goal of reducing raw material consumption by half by 2030 (Ministerie van Infrastructuur en Waterstaat, 2023). In the latest Integral

Circularity Report, Hanemaaijer et al. (2023) indicated that the current policies and trends are insufficient to meet the established targets, and progress towards achieving them has been limited. Despite leading European resource efficiency (Mhatre et al., 2021), the country has shown no corresponding decrease in resource use, primarily due to the growing prominence of service-oriented sectors in the Dutch economy (Hanemaaijer et al., 2023). Secondary materials supply is, similarly, far from reaching the current needs of Dutch organizations (Hanemaaijer et al., 2023). Together with the heavy dependence of the Dutch economy on imported resources, with up to three-quarters of necessary materials being sourced from other countries, as well as a high number of consumer electronic products being imported (CBS-Statistics Netherlands, 2022), the industry presents a high complexity for the transition.

The successful transition to a Circular Economy relies heavily on the adoption of circular business models by companies and organizations, as stated by Velenturf & Purnell (2021). While there has been some progress, with over 130,000 companies adopting at least one circular strategy by early 2022, this represents only 6% of the total number of businesses, and 75% of them are conventional businesses specialized in repair (Hanemaaijer et al., 2023). Together with the insufficiency of existing policies, which mainly rely on subsidies and voluntary agreements, and miss an adequate responsibility and power division, the decision-making of relevant parties is hindered, and in result, so is the adoption of circular business models and strategies (Hanemaaijer et al., 2023).

In conclusion, the current state of the Dutch consumer electronics industry presents a global linear value chain that is hampered by the lack of necessary responsibility, power division and role definition for stakeholders. Currently adopted strategies fall short of adequately addressing the needs of a circular economy, due to only a small number of organizations adopting them, with little to no collaboration among them.

3.2. Dimensions of the alignment strategies

The problem definition and current state of the industry sections show how collaboration is becoming increasingly relevant in the context of circularity. Singh et al. (2021) noted that the transition “necessitates a concerted effort from a broad range of stakeholders that work to create enabling conditions for effective collaborations” (p.928). However, for this collaboration to succeed, the alignment of their interests, is crucial (Hina et al., 2022). The process model designed by Brown et al. (2021), where they establish the need for involving the right people and aligning upon a common circular drive, shows how vital this alignment is for an effective implementation of circular practices.

The effectiveness of such collaboration heavily relies on each stakeholder’s organizational boundaries (Velter et al., 2020). The work by Velter et al. (2020) suggests that the process of alignment can be conducted through boundary work, which involves exploring, challenging, disrupting, and adjusting organizational boundaries. Although organizational boundaries are rarely explicit, they can be conceptualized in 4 types: efficiency, power, competence and identity (Velter et al., 2020), as illustrated in Figure 3. Velter et al. (2020) highlight that sustainable and circular business models are closely related to identity boundaries since they inherently respond to the organization’s values and norms. Nevertheless, all four categories impact the alignment between organizations.

Velter et al. (2020) also establish that the process of alignment needs to cover three distinct dimensions between an organization and its collaborators: Normative, Strategic, and Instrumental.

At the normative dimension, it is necessary to redefine the purpose of the organization and prioritize sustainable value. To achieve this, collaborators must engage in discussions about value propositions and develop a common understanding of value. Alignment at the normative dimension serves as a basis for decision-making and alignment at the strategic dimension (Velter et al., 2020).

At the strategic dimension, organizations must determine which external factors should be internalized and consider how stakeholders can contribute to this effort. Similar to the previous dimension, alignment on the strategic level

guides the implementation at the instrumental dimension (Velter et al., 2020).

The third dimension of alignment, the instrumental, defines the organizational activities and processes. Incorporating sustainability-focused values into an organization may require modifying existing activities and processes. The magnitude of such changes is more substantial and long-term in nature than alignment without a specific sustainability focus. This may involve introducing new approaches to product and service design, implementing alternative distribution channels, and adopting innovative pricing schemes (Velter et al., 2020). Based on the work by Velter et al. (2020), it can be established that any method or tool to set up a value chain oriented to collaboration needs to take into account the aforementioned alignment dimensions as well as the organizational boundaries within which the alignment needs to happen, visualized in Figure 4. Working with the organizational boundaries also gives a guide as to effectively depict an organization and its characteristics, which can be leveraged by tools for collaboration.

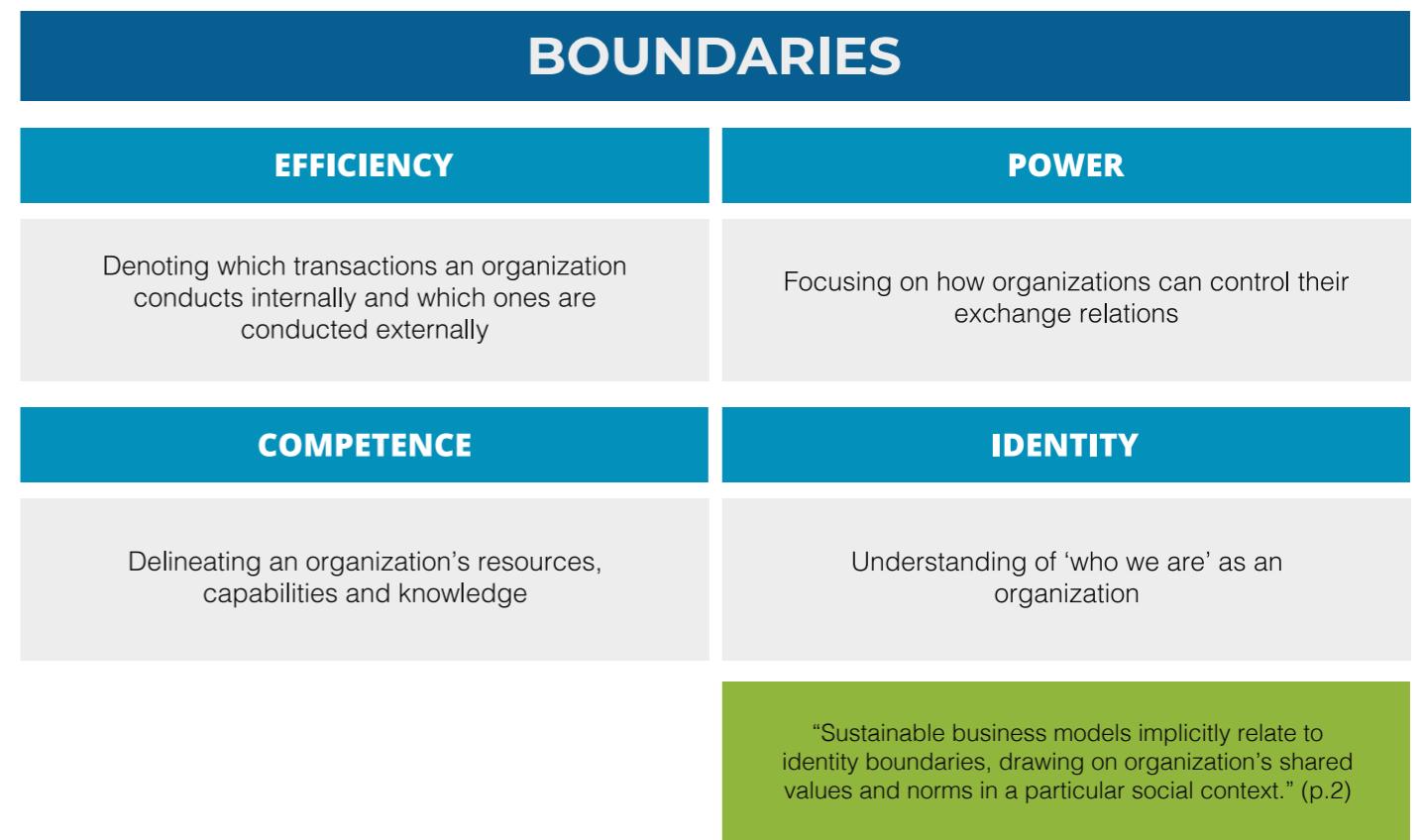


Figure 5. Alignment of different organizations within their boundaries (Based on Velter et al. 2020)

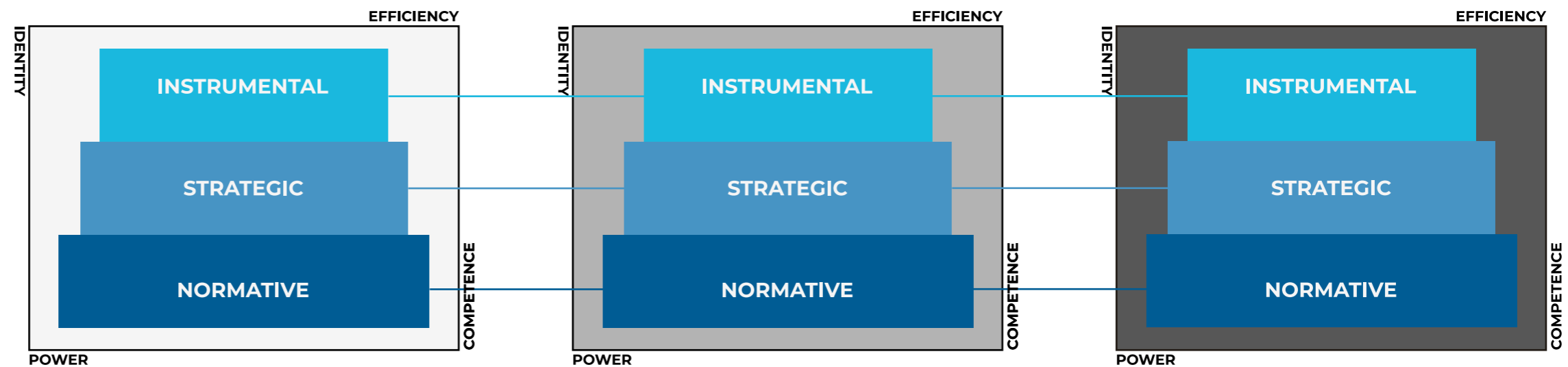


Figure 6. Alignment within organizational boundaries

3.3. Barriers and drivers for circular strategies

As explained in the problem definition and the current state of the industry sections, the adoption of circular principles in the consumer electronics industry is in nascent stages. However it is important to define what a circular value chain is. In this case, following the chosen definition for circularity, a circular value chain would follow the characteristics on a meso level that the circular economy would present on a macro level. Therefore, when adapting those characteristics to the value chain, it would require all members that are part of it striving for a sustainable development collaboratively, creating environmental quality, social equity and economic prosperity (Kirchherr et al., 2017).

In order to answer the main research question and help organizations set up aligned circular value chains, it is helpful to know which obstacles they face when implementing circularity principles, and what drivers there are for doing so. Literature shows different approaches when analysing them, but generally case studies are used to generate a set of drivers and barriers. Since there is a wide range of research done on the issue, 194 drivers and barriers for the adoption of circularity practices were found in literature and can be found in appendix A. The following section presents the most relevant ones for the present project.

In order to further understand the barriers and drivers for the implementation of circular practices, research has created different categories, some more abstract than others. After thorough analysis, this project will follow the categorization established by Tura et al. (2019), where drivers and barriers are divided in 7 sub-categories: Environmental, Economic, Social/Consumer, Institutional, Technological, Supply Chain and Organisational. This categorisation, unlike others, highlights the environmental aspect on its own as one of the relevant categories for a company to be prevented from or to be motivated to adopt Circular Economy strategies. Moreover, it contains relevance from a value chain perspective as well. The categorization shows the contextual factors of the chain such as sustainable and economical paradigms, governed by institutional factors, with consumers being part of the value chain. All this is facilitated by the technological capabilities of the organizations within it, that are dependent on supply chain dynamics, and consider individual organizational elements.

Barriers

Environmental

Jaeger & Upadhyay, (2020) found that firms occasionally present doubts around how sustainable the Circular Economy is, and how effective it is on protecting environmental issues such as scarce resource depletion.

Economic

One of the main barriers to implementing circular practices in companies is the higher costs involved, including start-up costs (Bocken & Geradts, 2020; Jaeger & Upadhyay, 2020; Kühl et al., 2023; Rizos & Bryhn, 2022; Russell et al., 2020; Salmenperä et al., 2021; Urbinati et al., 2021) that is usually made worse due to the lack of resources (Hina et al., 2022; Kühl et al., 2023; Salmenperä et al., 2021). The uncertainty and risks related to how profitable CE activities can be (Rizos & Bryhn, 2022; Russell et al., 2020; Salmenperä et al., 2021) are linked to the lack of tools for measuring long-term benefits (Salmenperä et al., 2021; Tura et al., 2019) in a highly competitive marketplace that hampers the transition (Jaeger & Upadhyay, 2020).

Social/consumer

Linear consumption patterns are a big hindrance on the adoption of CE practices, and are affected by the buy-new mentality (Ranta et al., 2018; Rizos & Bryhn, 2022; Salmenperä et al., 2021), or the ownership mentality (Hina et al., 2022; Werning & Spinler, 2020). These patterns are also affected by the lack of awareness and misconceptions about the CE (Bocken & Geradts, 2020; Brown et al., 2019; Hina et al., 2022; Rizos & Bryhn, 2022; Russell et al., 2020; Salmenperä et al., 2021; Tura et al., 2019). Furthermore, the transition is hindered by inadequate market dynamics where consumer engagement is limited (Hina et al., 2022; Rizos & Bryhn, 2022; Tura et al., 2019), creating an uncertain response and demand from them (Kühl et al., 2023; Salmenperä et al., 2021; Tura et al., 2019).

Institutional/policy

The institutional and policy category governs the context within which value chains need to evolve. In a case of a global value chain, such as the one that consumer electronics present, a heterogeneous regulatory scenario is caused due to regional differences in regulation (Salmenperä et al., 2021). Furthermore, governmental support in the form of public funding is lacking (Hina et al., 2022; Salmenperä et al., 2021; Tura et al., 2019), and unsatisfactory ecodesign requirements for circularity

(Rizos & Bryhn, 2022), combined with the absence of quality standards (Bocken & Geradts, 2020; Kühl et al., 2023) offer insufficient guidance to organizations. The guidance is further impeded due to the linear long-term procurement, which offer a negative example for companies to follow (Salmenperä et al., 2021).

Technological

The lack of circularity-oriented product design hinders companies' transition to circular practices. Products are often not designed with circularity in mind (Hina et al., 2022; Jaeger & Upadhyay, 2020; Salmenperä et al., 2021; Werning & Spinler, 2020), and information about their design and production is limited (Jaeger & Upadhyay, 2020). The lack of information is also related to the understanding of the circular economy (Hina et al., 2022; Salmenperä et al., 2021; Tura et al., 2019), and its complex integration (Brown et al., 2019). Organizations also struggle identifying new business model opportunities (Bocken & Geradts, 2020; Hina et al., 2022; Kühl et al., 2023) and lack tools for upscaling them (Salmenperä et al., 2021). These are critical issues in the implementation of circularity in consumer electronic value chains due to the current mentality of consumers (see social/consumer) and uncertain economic aspects (see economic).

In order to upscale circular initiatives, recovery processes need to be redesigned (Werning & Spinler, 2020). This is challenged by the lack of systemic planning in circular material use (Salmenperä et al., 2021). Additionally, transitioning from pilot programs to profitable commercial operations is a significant leap (Salmenperä et al., 2021), explained by the fast path of innovation in consumer electronics (Dutch Research Council, 2021), as well as the resource intensiveness (Jaeger & Upadhyay, 2020).

Supply chain

Modern supply chains have become complex and face multiple restrictions (Jaeger & Upadhyay, 2020), involving a large number of customers and partners, often requiring high levels of customization to meet individual needs (Urbinati et al., 2021). This is highly relevant for consumer electronics, as they present high compartmentalization and geographical scattering (Hina et al., 2022; Rizos & Bryhn, 2022; Salmenperä et al., 2021; Urbinati et al., 2021). In order to cater to all customer and partners when transitioning, companies may need to redesign their logistic systems (Werning & Spinler, 2020)

The lack of collaboration within the supply chain is a big

hindrance for the transition (Kühl et al., 2023; Rizos & Bryhn, 2022; Tura et al., 2019). Here, ownership, sharing of costs and benefits (Hina et al., 2022; Rizos & Bryhn, 2022; Russell et al., 2020), information exchange, trust and shared motivations (Brown et al., 2019; Hina et al., 2022; Jaeger & Upadhyay, 2020; Rizos & Bryhn, 2022; Salmenperä et al., 2021), are issues to be worked upon to generate sufficient commitment (Brown et al., 2019; Russell et al., 2020; Salmenperä et al., 2021). Simultaneously, the industrial adherence to linear models (Hina et al., 2022; Tura et al., 2019) and resistance to change activities that maintain those models (Brown et al., 2019), can result in a lack of suitable network support and partners (Bocken & Geradts, 2020; Kühl et al., 2023; Salmenperä et al., 2021; Tura et al., 2019). Position and power within the supply network and existing contracts with those partners also create lock-in within the linear practices (Brown et al., 2019).

The lack of a common language (Brown et al., 2019; Salmenperä et al., 2021) and shared understanding of a CE vision across partners (Brown et al., 2019) further impedes the transition. Different working cultures (Salmenperä et al., 2021) and incompatible business models (Hina et al., 2022) pose additional hurdles to change.

Organizational

Within the organizational barriers for the adoption of circular practices, silo thinking (Bocken & Geradts, 2020; Tura et al., 2019; Werning & Spinler, 2020) and unclear communication with unclear responsibility division further impede progress (Hina et al., 2022). Internal obstacles also include a lack of environmental culture (Hina et al., 2022; Rizos & Bryhn, 2022), insufficient knowledge and skills in circular economy (Salmenperä et al., 2021; Tura et al., 2019), and sustainable value creation not being on target (Bocken & Geradts, 2020). Research highlights progress evaluation being crucial, but being hampered due to a lack of tools and indicators (Rizos & Bryhn, 2022; Salmenperä et al., 2021; Tura et al., 2019).

Organizational barriers often stem from a short-term focus, prioritizing short-term growth (Bocken & Geradts, 2020; Werning & Spinler, 2020) and exploiting current capabilities (Bocken & Geradts, 2020). Circular practices clash with existing linear operations and goals (Bocken & Geradts, 2020; Kühl et al., 2023; Tura et al., 2019).

Drivers

Environmental

In the environmental category, authors found resource scarcity (Urbinati et al., 2021), specially for critical resources in consumer electronics (Parajuly et al., 2020), and promoting and improving environmental quality as issues that drive the transition to the circular economy (Hina et al., 2022; Tura et al., 2019).

Economic

Circular practices are associated with enhanced competitiveness (Rizos & Bryhn, 2022), new revenue opportunities (Brown et al., 2019; Rizos & Bryhn, 2022; Russell et al., 2020; Tura et al., 2019), new business development, innovation, and synergy (Brown et al., 2019; Tura et al., 2019), which serve as drivers for the adoption. The adoption is further enabled by allocating specific resources for CE initiatives, such as strategic long-term sustainability projects, and sustainable business model innovation (Bocken & Geradts, 2020).

Social/consumer

Scholars have identified growing societal awareness of environmental and climate change issues as a key motivator for adopting circular practices (Rizos & Bryhn, 2022; Russell et al., 2020; Tura et al., 2019). In turn, consumer demands for responsible production and consumption methods also drive the transition to circular practices (Brown et al., 2019; Hina et al., 2022; Rizos & Bryhn, 2022).

Institutional/policy

As mentioned in the barriers section, the existence of regulations and standards are significant drivers for the CE (Brown et al., 2019; Ranta et al., 2018, 2018; Rizos & Bryhn, 2022; Russell et al., 2020; Tura et al., 2019; Urbinati et al., 2021), along with economic incentives to increase the demand for circular services and goods (Hina et al., 2022; Ranta et al., 2018; Rizos & Bryhn, 2022; Russell et al., 2020; Tura et al., 2019; Urbinati et al., 2021).

Technological

The accessibility of new technologies and their implementation are critical enablers of circularity. Such technologies encompass tools for innovation (Rizos & Bryhn, 2022; Urbinati et al., 2021), or solutions for reverse supply chains (Brown et al., 2019; Urbinati et al., 2021). These new technologies also require the adoption of new knowledge and capabilities, such as the ability to design

circular products (Hina et al., 2022; Kühl et al., 2023), and material, resource and knowledge availability (Hina et al., 2022). Furthermore, implementing proofs of concept, encouraging experimentation, and piloting at scale are suggested to overcome potential hesitation (Brown et al., 2019), especially in industries with numerous players and similar product propositions like the consumer electronics.

Supply chain

Collaboration and transparency play integral roles in the successful implementation of CE principles. Organizations can establish long-term relationships with partners (Rizos & Bryhn, 2022) within supply chain networks (Rizos & Bryhn, 2022; Salmenperä et al., 2021), fostering open communication (Tura et al., 2019) and cross-functional collaboration (Bocken & Geradts, 2020).

Partnerships, particularly those with geographical proximity (Hina et al., 2022; Kühl et al., 2023; Urbinati et al., 2021) might require, managing reverse supply chain networks (Tura et al., 2019) and supply chain redesign (Hina et al., 2022). These partnerships make use of resources and capabilities available thanks to multi-disciplinarity (Tura et al., 2019). Lastly, similar to consumer pressure, stakeholder's pressure for sustainable resource consumption drives the adoption of circular practices in organizations (Hina et al., 2022; Ranta et al., 2018).

Organizational

Scholarly literature suggests that internal factors such as management and internal company awareness (Bocken & Geradts, 2020; Rizos & Bryhn, 2022; Urbinati et al., 2021), support (Rizos & Bryhn, 2022), and understanding of sustainability demands (Tura et al., 2019) play a key role in the implementation. The implementation needs to encompass a shift in strategy, integrating circularity into strategy and goals (Bocken & Geradts, 2020; Tura et al., 2019), adopting a long-term orientation (Bocken & Geradts, 2020), developing CE related skills and capabilities (Tura et al., 2019), and committing to change the business model (Ranta et al., 2018).

In addition to these internal factors, external factors, such as the perception of a company's values and the desire to enhance reputation (Rizos & Bryhn, 2022) and to differentiate themselves from their competitors and strengthen their brand (Tura et al., 2019) also drive adoption of circular practices. All critical factors in an industry that is inherently consumer oriented.

Analysis of barriers and drivers

Five general topics can be identified based on these connections: resource-related issues, product and material recovery, mindset, engagement and misconceptions, and specific issues. The specific category encompasses a larger number of issues that do not have clear links to the other categories. Among the interconnected topics, the most prevalent is the issue of resources, encompassing knowledge, money, and technology, which is found across almost all categories.

Resources exert a significant influence on the economic, technological, and supply chain categories. Product and material recovery also features in most categories, particularly in the technological and supply chain. Furthermore, engagement and misconceptions, along with mindset-related issues, hold significant relevance within the social/consumer and organizational categories.



Figure 7. Relationships found within the categories of drivers and barriers found in literature based on 5 topics. Frequency of drivers and barriers measured in area. (Own creation)

Key insights from barriers and drivers

The following insights have been generated from the barriers and drivers found in the literature review:

- The categories of technology and supply chain exhibit the highest number of barriers and enablers. This is likely due to the current emphasis of the circular economy on end products and the surrounding capabilities that facilitate their production. Focusing interventions on tangible elements like products, could be the best approach for short-term implementation and adoption of circular economy practices.
- All categories are interconnected through five overarching topics. Posing interventions or addressing issues in one of the categories or barriers could potentially have an effect on issues in other categories. Thus, the choice of intervention topic, such as resource-related issues, determines the importance of specific categories and issues for achieving a more effective impact.
- The topic of resource availability comprises a significant number of issues across most categories. This indicates a substantial opportunity for intervention, as it provides numerous actionable insights and potential for broad effects across various categories.
- Specific driver and barriers offer high potential benefits for the context of this project. Due to the heterogeneous regulation, lack of know-how, unsatisfactory ecodesign requirements and insufficient guidance, the consumer electronics industry will really benefit from a set of homogeneous guidelines that tackle the issue and offer a way to efficiently collaborate. These guidelines should focus on enabling information exchange, offer a suitable network and share understanding. They also need to include a short-term aspect, as well as a long-term aspect to cater to the current needs of the organizations without disregarding the needs of the transition.

3.4. Key takeaways from the literature review

The three parts of the literature review show commonalities between the covered topics. Barrier and driver categories have similar characteristics to the 4 boundary types presented by Velter et al. (2020). At the same time, they can also be related to the 3 alignment dimensions studied in section 3.2.

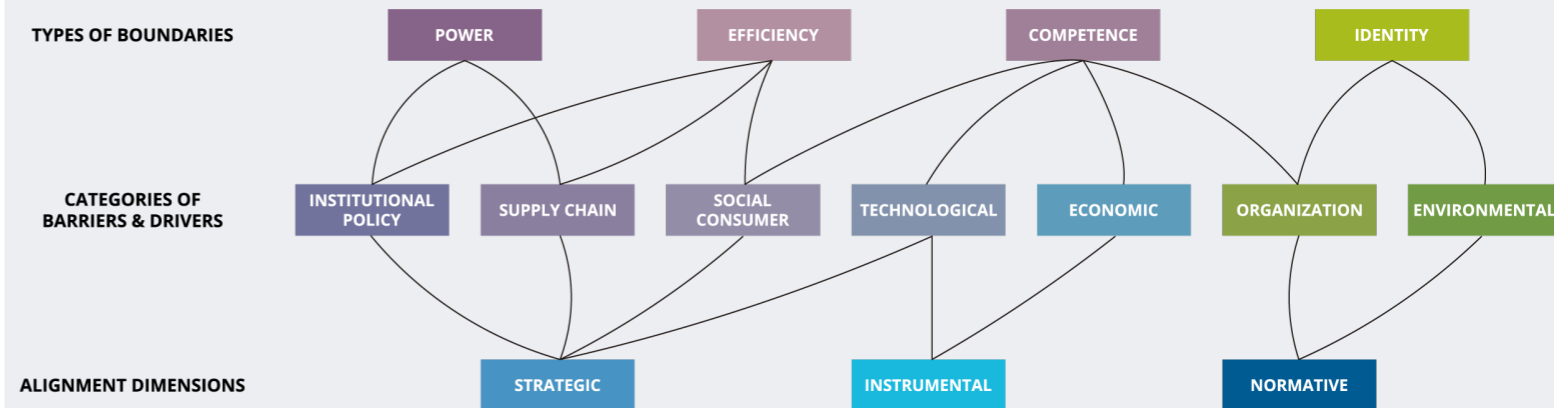


Figure 8. Relationships found in the literature review

- The relationships shown in Figure 6 offer a framework for the project where value chain alignment activities can be conducted considering the drivers and barriers related to each alignment dimension.
- As suggested by the current state, alignment dimensions and the barriers and drivers for the adoption of circularity practices, collaboration between organizations needs to be promoted as well as aided. This collaboration will benefit from the creation of tools and guidelines that take into account the necessary information for organizational alignment as well as the barriers they might experience throughout this process. The designed tools and methods should also exploit the drivers for circularity as a means to ease the transition and provide benefits for the organizations within a value chain, especially those mentioned in the key insights from barriers and drivers.
- Additionally, due to the current understanding of the circular economy by organizations in the consumer electronics industry, the intervention should take a product centric approach in order for organizations to adopt it more effectively. Lastly, due to the high interrelation between all the aspects of a value chain, as shown in the drivers and barriers section, interventions in specific topics might have potential effects in other issues, which offers an opportunity for influencing the complete value chain.

4. Interviews with experts from the industry

The literature review presented in section 3 of this report provided a large number of useful insights to guide the project. It also provided a framework to ground the next steps in. Moving toward a deeper understanding of the specific details of the Dutch consumer electronics industry, semi-structured interviews were conducted. Overall, representatives from 7 organizations positioned in different steps of the value chain were interviewed.

The goals of the semi-structured interviews were the following:

- Understand the position and role each company has within their value chain, as well as how their business model works.
- Understand their viewpoint around the circular economy
- Understand how circularity is integrated in their strategy and how their activities reflect it.
- Identify the barriers and drivers they experience and see for circularity in their current activities.
- If collaboration happens, see what the characteristics of this collaboration are. If not, what is preventing collaboration from happening.

4.1. Method

The interviews were semi-structured, and were guided by an interview guide that can be found in Appendix B. The interview started with an introduction to the research, followed by an introduction of the participants of the interview. Then, questions about their understanding of a circular economy were asked. This was followed by questions regarding the participant's organization, including, for example, what their position in the value chain is, how circularity is embedded in the strategy, or how their collaboration with other organizations is shaped. Afterwards, drivers and motivations for pursuing circularity were discussed, followed by barriers and differences in practices. Lastly, a more speculative approach was taken, where questions regarding a fully circular future were probed.

The interviews were recorded and transcribed. They were later analysed and coded using atlas.ti based in the categories and insights from the literature review. The most relevant insights were then used to specify the results of the literature review and to find the biggest opportunities for intervention. The insights from each interviewee can be found in Appendix C.

4.2. Setup

The selection of organizations was done following a non-random purposive sampling. The organizations were selected through the NWOP Perspective project Circular Circuits, mentioned in the introduction of this report. Representatives from 10 organizations were contacted for the interviews. 8 responded and due to time constraints 7 organizations were interviewed. In total, 10 representatives were interviewed in 7 interviews that lasted between 1 and 1.5 hours. 6 out of the 7 interviews were conducted online using video-conference software, and the remaining one was conducted face to face.

Some of the included organizations worked outside the consumer electronics industry and focused explicitly on Business-to-Business orientation. However, they were considered relevant for the study since their opinions were considered either as a reference, or because they have a relevant impact within the industry in the Netherlands. Details of the interviewed organizations, labeled A-J, can be found in table 1.

Table 1. Overview of interviewees

Company	Interviewee(s)	Industry	Product Category	No. of employees
1	A Product Design Engineer and Head of Sustainability	Lighting	Emergency Lighting	30>
	B Technical Director			
2	C Repair Solutions Consultant	Electronics	Consumer Products	250>
3	D Hardware Development Team Lead	IT	Hardware and Software	1.200>
	E Software Project Manager			
4	F Chief Technology Officer	Electronics	Smart Mobility Semiconductors IoT	1.100>
5	G Fellow Scientist	Lighting	Lighting and Services	>11.500
6	H Strategic Advisor	Waste Management	Ewaste Collection and Recycling	50>
7	I Compliance and Sustainability Manager	Smelting	Precious Metals	6000>
	J Market Intelligence and Business Research Manager			

4.3. Insights

Position and role in the value chain

Most of the interviewed companies had distinct positions within the value chains they were part of. Some of these roles were more closely related to a circular economy than others. However, after analysing the insights, a relationship between the position within the value chain and the role within it could be observed.

Table 2. Approach taken by the interviewed organizations and effects on them

Role	Position in the value chain	Approach	Effect on circularity
Design and manufacture of electronic products	=	Externalizing mass manufacturing and establishing criteria for products.	Reduction of direct influence over decisions.
		Criteria is established fully by consumer and focus on design and manufacturing.	Decision-making power in issues like sustainability is outside the organization.
Enablers of circularity by providing one of 9R principles	External party that intervenes in one or multiple points of the value chain.	Consulting for reparability + offering tools for repairing to companies. Independent repair guidance and tools for consumers.	Making repair easier even if the original manufacturer does not have it in its plans.
		Coordinate the connections between organizations.	Overcome gaps in the collection system of WEEE thanks to having an overview.
	End of life recycling / material refining and smelting	End recipient of products/parts and recycle them to offer them back as secondary raw materials to any industry that might need them	Redistribution of scarce materials Open-loop recovery
		Help organizations recycle materials and reintroduce them back in their products as secondary raw material.	Short, closed loop

Therefore, the following roles can be extracted from the interviews:

- Design and/or manufacture
- Enabler of circularity by providing one of the 9R principles:
 - Repair services
 - Coordination of EoL solutions
 - Recycler (close or open loop)
 - Refurbisher

In general, the position within the value chain affects the role of the organization within it, and vice versa. It is also necessary to highlight that multiple roles can be taken within the same position, and that this will have an effect on the rest of the value chain.

Circular Economy understanding

One of the goals of the interviews was to gain an understanding of the viewpoint held by the interviewed organizations concerning the circular economy. The findings showed different interpretations and distinct emphases on different aspects of the circular economy.

In Figure 8, the different interpretations are shown by order of abstraction level, going from micro (material level) to macro (political and economic paradigm). This highlights how the circular economy can have different interpretations and how a homogeneous understanding could benefit the transition, as shown in the barriers and drivers section from literature. Another relevant subject closely related to the embedding of circular principles within the organizational strategy emerged during the majority of interviews. This subject was awareness around sustainability topics and the sustainable impact of the organization. Different ideas related to awareness were obtained from participants, some related to elements already positively affecting circularity and others necessary to improve.

Awareness & Sustainable Impact

Another relevant subject closely related to the embedding of circular principles within the organizational strategy emerged during the majority of the interviews, namely awareness around sustainability topics and the sustainable impact of the organization. Some topics within awareness were mentioned as positively affecting circularity, whereas other issues needed to be worked on further.

Awareness that is currently promoting circularity consisted of different topics. Firstly, consumers gaining awareness around e-waste was mentioned as positive by some interviewees. Likewise, the awareness of individuals within the organization, as well as that of their suppliers, regarding the organization's impact, was also acknowledged. These observations are linked to the organizational mindset shift coming from awareness and training programs, as mentioned by other interviewees.

However, there were still areas of awareness identified by interviewees that require further enhancement. Some representatives emphasized that information around reuse and refurbishment needs to be clarified for organizations to be more aware of their impacts. The importance of organizations recognizing that they can leverage their existing technologies in novel ways to foster circularity and sustainable impact, was also mentioned as an issue to work further. Furthermore, several participants stated the need for a clear definition of the circular economy, so that decision-makers realize that is not as simple as it seems and that it involves more than just carbon emissions.

Being aware of the company's sustainable impact emerged as another relevant topic during the interviews. This sustainable impact can be divided in various facets according to the interviewees. Some organizations treat sustainability the same way as they do other topics related to their activities, including it as another trade-off. Social and economic considerations were also mentioned alongside the environmental as integral components of sustainable impact. Additionally, some interviewees emphasized their commitment to promoting consciousness regarding the full range of impacts generated by their practices, and that they try to encourage people to act according to these principles. The interviews also revealed that the nature of these impacts varies depending on the scope and focus of the impact analysis. Despite some companies displaying awareness of multiple impact types, the most commonly referenced analysis is the measurement of CO2 emissions, using lifetime extension as a means for prevention. Lastly, participants mentioned that all these impacts are communicated through sustainability reports.



Figure 9. Understanding of the circular economy by interviewees

Barriers and drivers for circular strategies

The framework built in the literature research showed that knowing the barriers and drivers for the adoption of circular practices is necessary for the alignment within the value chain. In order to discover context-specific drivers and barriers, the interviewed organizations were asked about their experience. These issues were then classified following the categorization from the literature review. By contrasting and aligning the experiences with the list from literature, a new set of drivers and barriers was generated. This way, context-specific insights from literature were obtained, and new insights were added. These insights, served as actionable points to design for. This section presents some of the insights that were related to the research question. A complete drivers and barriers list can be found in appendix D.

Barriers

Barriers-Environmental

Interviewees mentioned the big ecological impact of reverse logistics as one of the largest environmental barriers for the circular economy, especially in a globalised supply chain like the consumer electronics one. Another highlighted barrier was that correctly knowing and measuring the carbon footprint is complex.

Barriers-Economic

The upcost that more sustainable and circular activities, products, or solutions present, as well as competitors taking advantage of the situation, resulted in unfair competition experienced by some participants.

"We are always in a weak financial position compared to illegal trade" - interviewee H.

Representatives of multiple companies also mentioned that their circular solutions were still in a venture phase or were not even started because of them not being able to create a profitable business out of it.

"We don't know how to make money out of it" – interviewee G.

Lastly, participants highlighted organisations lacking the necessary resources for the implementation of sustainable solutions to be one of the main barriers for the CE, especially in the case of small and medium enterprises.

Barriers-Social/Consumer

Regarding social or consumer-related barriers, interviewees expressed the following. Firstly, the uncertainty and high price of repair solutions prevents the consumer from choosing this option.

"You don't want to pay 200-300€ for a repair that doesn't perhaps ensure you success" – interviewee C.

Several participants also expressed that the end-of-life stage of the product is confusing for consumers. This is due to the low transparency of the different options and the difference in cost between them.

Barriers-Policy/Institutional

The main policy and institutional barriers found by the interviewees revolved around lack of definition and clarity, as well as policy being detached from reality. The lack of definition relates to the term 'Circular Economy', where each community (scientific, regulatory, industry) uses it differently, as well as the roles each organization should

take within that economy, which are also undefined.

Barriers-Technological

Some participants mentioned the lack and complexity of knowledge as a big impediment, expressing that the lack of guidelines prevented them from advancing.

"I had no clue where to start" – interviewee B.

Another relevant barrier was that quality and function take a higher relevance than sustainability when considering trade-offs, quality tests and functionality being the bottlenecks for decision making. The lack of know-how when leveraging the whole potential of their technological capabilities was additionally highlighted barrier for circularity.

"Organization X doesn't have that knowledge. They don't even know what they're looking at... Only Y can do it" – interviewee G

Barriers-Supply chain

Within the supply chain category, the lack of transparency and information exchange was viewed as an important obstacle. The small number of manufacturers for certain elements results in a need for considerable power for a shift to happen. If the majority of stakeholders within a given value chain is not asking for a change, it will not happen.

"You're probably gonna be manufacturing your device where everybody else is doing it" – interviewee C.

The constraint some organizations experience because of contracts, exclusive technology or lengthy relationships presented another barrier for circularity. This is further worsened because the industry is not fully developed yet. Lastly, the lack of ownership of a product once it is sold makes traceability throughout the chain complex and prevents its recovery.

Barriers-Organizational

One of the biggest barriers for the implementation of sustainable and circular ideas was the lack of prioritization within organizations. The lack of know-how and guidelines for this implementation likewise provided an obstacle, one that is made worse when it finds internal pushback. This resistance can come from a lack of interest, or from activities that have been conducted for years and are hard to change.

Drivers

Drivers-Environmental

When looking into possible drivers for implementation of circular and sustainable principles, interviewees highlighted the wish to become more environmentally friendly. They also mentioned the wish to reduce their negative environmental impact.

Drivers-Economic

The main economic drivers mentioned by the interviewees were, firstly, profiting from new opportunities while reducing the involved costs. For example, by avoiding the ever more expensive extraction of minerals. Having specific resources for the implementation would similarly drive the adoption of circular practices according to the interviewees. Second, participants stated that implementing circularity principles would be driven by parts having a higher remaining value when reaching their End-of-Life..

Drivers-Social/Consumer

The biggest driver found by the participants involved having enough market demand for circular propositions. Moreover, they highlighted that a behaviour shift driven by awareness among consumers has a positive influence in the adoption of the circular economy principles.

Drivers-Policy/Institutional

Concerning the policy and institutional category, participants found that regulation is one of the most important drivers for the adoption of circularity ideas. Whether it is regulation related to waste or to raw materials, companies will adopt circularity and sustainability faster with regulation in place. Various representatives mentioned that they try to be ahead of regulation with the intention of being front-runners and adopt strategies before regulation comes in place.

Drivers-Technological

Technological drivers mentioned by the organizations concerned taking advantage of existing technological solutions and adapting them to enable circularity, such as turning assembly lines around for disassembly. Various participants emphasized that having a measurable and structured process effectively facilitates adoption.

"We started really random and now it's getting more and more structured" – interviewee A

Drivers-Supply chain

From a supply chain perspective, interviewees highlighted that stakeholder pressure helps with the adoption of circular initiatives. In addition, they highlighted that aligned business models and approaches to sustainability drive the shift, in turn making stakeholders familiar with the concepts and promoting circularity principles. Likewise, they experienced positive impacts on the implementation when trust was established between organizations, especially when it came from big organizations.

"It's nice to experience that they're really taking us serious in this" – interviewee A.

Drivers Organizational

Interviewees highlighted many drivers from an organizational perspective. Firstly, they emphasized the drive and willingness to take risks as potential boosters for adopting circularity principles.

"We need dare devils" – interviewee G.

Moreover, having an open company culture that nurtures from external input and inspiration, together with the ability to adopt changes, were mentioned as an important driver for the implementation of circularity. Additionally, similarly to policy, establishing specific roles and incentives within the organization related to circularity aided the inclusion of these principles in the organizational strategy. Lastly, it is worth mentioning that circularity is also driven by organizations seeking differentiation from others that present linear ideas.

Conclusions of barriers and drivers for circular strategies

Similar to the barriers and drivers found in the literature, the categories of technology, supply chain and organization present the highest quantity of content. When analysing the obtained topics in the same 5 groups found in the literature review, it can be seen that the 7 categories present topics in almost all categorizations. In this case, resource related issues present a high presence in almost all categories, as well as mindset. The former gains relevance in the technological and economic categories, while the latter is more present on an organizational level.

Due to the disparity of number of topics of these two groups compared to the rest, when choosing the focus of the intervention in the value chain, these resource and mindset issues should be taken as focal points



Collaboration between organizations & promotion of circular principles

The scope of this project entails setting up new value chains rooted in collaboration to set up new value chains, and considering the pre-collaboration phase is highly relevant in accomplishing this process (Brown et al., 2021). Therefore, a subsequent goal of the interviews was to understand what the characteristics of current collaborations were. Participants were asked about this topic specifically and the following section offers key insights obtained from the interviews.

Shared challenges

Interviewees highlighted that when pursuing sustainability or circularity-oriented collaboration, stakeholders should consider the emerging topics and issues as challenges and not problems. From their own experiences, such a mindset usually offers a better starting point than expected. They also stated that sustainability needs to be considered as a common problem that needs to be solved between the two (or more) partners that are collaborating. Consequently, the benefits and liabilities have to be shared between said stakeholders by making them clear.

“Sustainability is not a negotiation. It’s a shared problem”

– Interviewee D.

Necessary criteria

When setting up new avenues for collaboration, there needs to be clear and consistent criteria for selecting collaborators, and said criteria need to be consistent along the entire value chain. When it comes to setting up successful collaborations, new business models and relationships are necessary. However as the barriers showed, these similarly need to be aligned. For that alignment to come true, conversations need to be backed up with data and they be based on shared knowledge and rules.

Whilst some organizations state that working closely with your current partners and companies you have a relationship with is vital, others think that persuading and influencing organizations you don’t have a relationship with is the approach to follow. However, and even if both approaches are quite different, many of the interviewees stated that in most of the collaborations, someone takes the most active role.

Success stories

A specific type of collaboration, the one looking to build success stories, was highlighted during the interview process. An example of these collaborations involve big organizations collaborating with small and medium companies that have a higher adaptability in order to create success stories. This might happen inside an organization too, where some participants highlighted how their organization established “sustainable champions” to both inspire the rest of the organization, as well as to look for potential collaborations outside the organization. In sum, these collaborations are used to set an example and attract more partners for future collaborations.

Promotion

Another relevant topic that emerged during the interviews was how organizations that take said active role promote circular ideas and propositions. This promotion can be categorized in the following 6 types:

1. Advocacy group
2. Business incentives to encourage adoption
3. Using current activities to enable the circularity of your partners
4. Shift together with partners, help them on their adoption
5. Educating future generations
6. Persuading through conversation

Figure 10. Relationships found within the categories of drivers and barriers found in interviews based on 5 topics. Frequency of drivers and barriers measured in area. (Own creation)

4.4. Key takeaways from the interviews

The interview phase commenced with 5 goals. Firstly, it aimed to understand the position of each company within their value chain as well as their business model. Secondly, it sought to clarify their perspectives on the circular economy and their values. Thirdly, it aimed to gain an understanding of how circularity is integrated into their strategies and operational activities. Fourthly, it aimed to identify the issues that drive or hinder the adoption of circular practices. Lastly, it intended to understand the characteristics of collaboration between organizations. Several insights were obtained from the interview process:

- The role each organization takes has different effects on the outcome of their activities. It is also notable that an organization might take different roles within the same position in a value chain, highlighting the need to focus on the role rather than the position.
- Awareness around the circular economy and the organization's environmental impact is highly important for the organizations in this context.
- In relation to the experienced drivers and barriers, they are highly related to resources and mindset, whether they are external or internal. The issues selected as most promising in the barriers and drivers as derived from the literature were also made more evident and relevant for the context. The lack of guidance and know-how are critical issues to design for. Exchanging information, obtaining a suitable set of collaborators, and sharing understandings, are aspects the solution should cater to.
- Collaboration has multiple characteristics that need to be considered. Establishing sustainability in collaborations as a shared problem that all partners need to take part in. In order to do this, organizations in the industry can make use of success stories to attract partners and show advances. However, once attracted, the organizations need to be provided with concrete criteria to select collaborators consistently throughout the value chain.
- Looking into the promotion of circularity principles, the most relevant ones for the scope of this project are using current activities to enable the circularity of your partners, and shifting from linear to circular strategies together with partners, helping them in the adoption.
- When analysing the topics that were covered during the interviews, conversations happened to be highly product-centric. The word product was used 72 times more than the next one, company. This confirms insights from literature that show the current understanding of the circular economy to be highly product centric. The top 5 topics are as follows: :
 - Product (242)
 - Company (170)
 - Material (132)
 - Sustainability (127)
 - Business (109)
- Another striking insight is that during the interviews, services were mentioned 80% less than products (40 times service, while product being 242 times). This could result from the organizations focusing their actions mostly on tangible products. A biased framework resulting from literature that guided the interviews towards product-centrism could possibly be the reason behind this as well, considering one of the organizations is well-known for having a well-established product-service proposition.

5. Research Conclusions

The conducted research showed multiple actionable insights that could be leveraged to help organizations set up an aligned circular value chain. However, due to the time and scope limitations of the project, only a set of the insights was selected for the design solution. The main research insights to take in the next steps are the following:

- The solution should include the interrelations between the 3 different topics covered in literature: organizational boundaries, barriers and drivers for the adoption of circularity principles, and alignment dimensions. In sum, it will leverage the relationship between the alignment dimensions and the categories of drivers and barriers to offer the necessary information for the collaboration. As shown in the relationships in Figure 6, by analysing issues related to the technological category, competence boundaries can be explored to align in the instrumental dimension, or organizational issues to define identity and competence boundaries to align in the normative dimension. The most relevant categories for the scope of this project are the issues pertinent to the supply chain (such as information exchange or lack of suitable network), technological (with issues like lack of know-how or insufficient technological capabilities), and organizational (need for long-term perspective or organizational culture).
- A big number of barriers and drivers were found both in literature and interviews. However, due to the constraints of the project, a smaller selection was used. This selection of barriers included the lack of information and knowledge, lack of guidelines, lack of a common language, and the lack of tools to measure progress that organizations experience. Selected drivers encompassed creating networks and partnerships, open collaboration, supply chain redesign, and the willingness to integrate circularity in the company strategy.
- As seen in the interviews and context, the definition of roles is highly critical in the transition. Therefore, role-definition needs to have a central position in the solution. Within these guidelines, a set of roles should be offered for end users to follow or identify. These roles should include the ones derived from interviews such as design and/or manufacture or enabler of circularity (repair, refurbisher, recycler, coordinator of EoL solutions). A lack of clarity and guidance emerged both in literature and interviews. Thus, any intervention that sought to aid organizations when setting up a new value chain needs to provide clear guidelines and criteria for the OEMs and relevant organizations to take as reference.
- A lack of clarity and guidance regarding circularity was found both in literature and interviews. Thus, any intervention that seeks to aid organizations when setting up a new value chain needs to provide clear guidelines and criteria for the OEMs and relevant organizations to take as reference.
- The insights pertinent to collaborating that came up during the interviews should be taken as a reference when proposing a design intervention. Hence, the solution should focus on establishing clear criteria sets, and leveraging success stories as a means to attract partners and set the value chain up.
- Lastly, a product-centric approach should be used in the final design due to the current understanding of circularity in the industry. In this case, the product would be central to collaboration and alignment, but a product-service system would be envisioned around it. This is because literature shows that a product-service system is more efficient in achieving the sustainability features of the Circular Economy (Kühl et al., 2023).

6. Designing a method for setting up a value chain for consumer electronics

The following chapter presents the design process of the present thesis. First, the development of the method is elaborated on. Then, the process of designing the tools is offered. Results from a test of the results are then offered. Lastly, the final design outcome of this thesis is offered.

6.1. Method

When designing the method and complementary tools, a design process was used to answer the research question:

How can organizations set up an aligned circular value chain for consumer electronics?

The design process followed a parallel and iterative process where the method was designed simultaneously to the necessary tools for each step.

Figure 9 shows how the process of the design phase unfolded, and they are further elaborated in the following section.

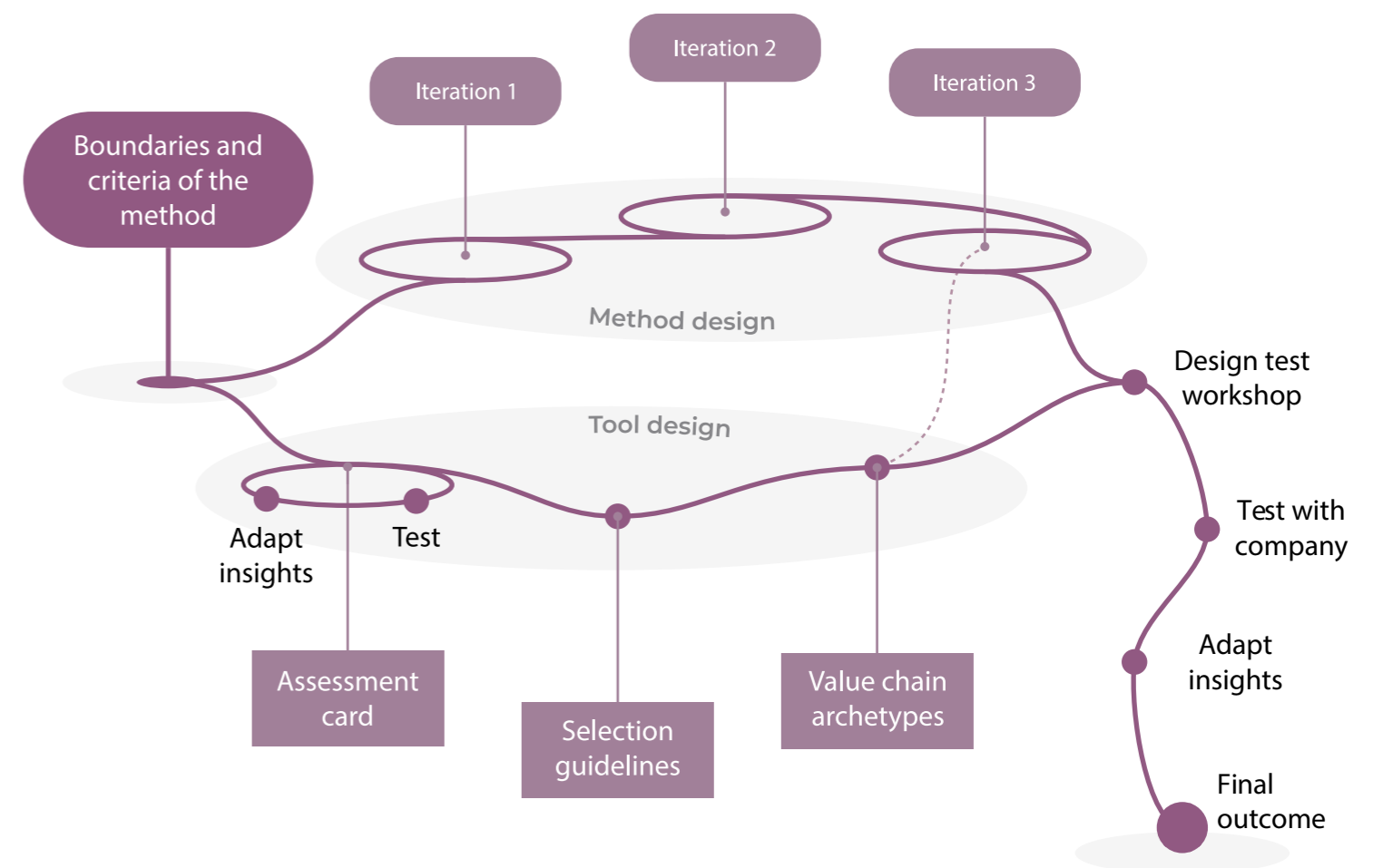


Figure 11. Design process and conducted actions

6.2 Method Development

Having analysed the insights from the research phase, the boundaries and criteria of the final method were defined:

- The end deliverable is directed to an OEM that wants to set up a new circular value chain for a product or product category they design and or manufacture. It should also be usable when adapting an existing value chain.
- The project considers the OEM to be the **Initiator** of the value chain. This means that it is the organization that starts the set-up of the value chain and that establishes the initial set of goals, and has the most active role in the beginning, following the insights of the interviews. In this case, the OEM would also act as coordinator of the value chain and have enough resources to implement the necessary strategies. The reason for this is that OEMs have a privileged position in the current consumer electronics industry, as they establish the design criteria for the products and therefore affect the sustainability and circularity of them. As interviewee C mentioned, the number of manufacturers is small, and they have a high influence in the end characteristics of parts and products in the consumer electronics industry. Moreover, they have a central position in a linear value chain, which allows them to have a better overview of the players in it and therefore, it's easier to exert an influence.
- The project will be based in the Dutch consumer electronics industry. Therefore, it will mainly take as a reference information obtained from organizations located in the Netherlands. However, considering the global supply chain of electronics, it will take into account as much as possible this aspect of the industry.
- The solution will consider that circularity is included in the strategy of the OEM and that awareness within the organization is reached and training and knowledge gaining efforts have been implemented.

Iteration 1

After establishing the boundaries and criteria of the final method, methods for collaboration within value chains were analysed. Specifically, the ones established by Holmberg & Cummings (2009) and Brown et al. (2021) were used as a starting point. Both of these works touched upon partner assessment and selection, with or without a circularity perspective. However, and important for this thesis, they did not include an overall value chain perspective. The first version of the method consisted of 4 steps deeply related to both works. Figure X shows the description of the steps in the first iteration as well as the links to the work by Holmberg & Cummings (2009) and Brown et al. (2021). It is worth mentioning that the steps 3, 4 and 5 from Brown's process model have been combined into one single step that involves the setup and negotiation. This decision was made to simplify the understanding of the method and the different steps, since the 3 steps involved negotiating and aligning upon 3 different aspects of the collaboration. This resulted in the division: self-evaluation, assessment, setup/negotiation. Hence, a clearer division than: self-evaluation, assessment, develop shared circular purpose, develop decision-making, develop value capture model.

In this iteration, the first version of the assessment card was created (see tool development section).

From discussion with the supervisory team, it was concluded that the initial proposal lacked the product-centrism and used too much high level content to effectively implement it in the industry. It was also determined that a selection step was missing before setting up the value chain. Lastly, it was concluded that including the role definition after partner assessment was contradictory and added even more complexity, seeing as the assessment would not have a basis to start with. Therefore, it was suggested to include the role definition prior to the assessment.

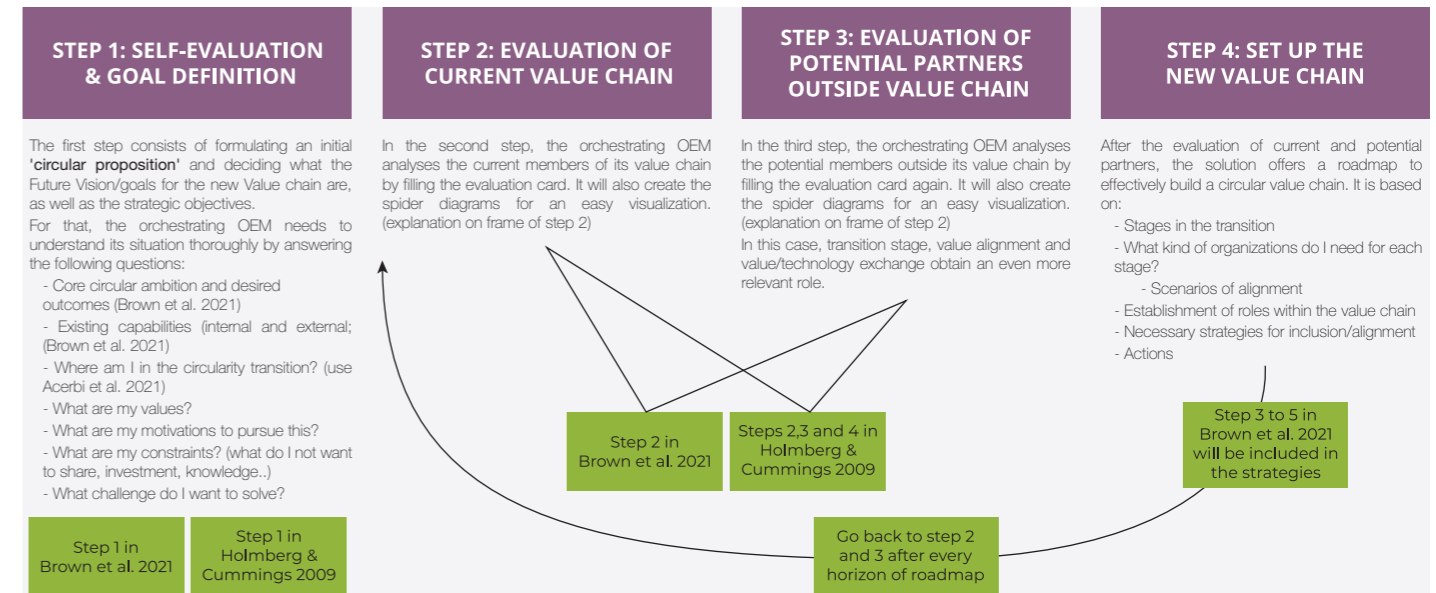


Figure 12. First iteration of the method

Iteration 2

Implementing the insights of the first iteration, new steps were added to the method, and current ones were modified. In this case, following Brown's (2021) work, 6 steps were defined. Following step 1 of the first iteration, a product-service system draft step was added to provide the product perspective that the previous method was lacking. Then, steps 2 and 3 of the first iteration were combined, as the assessment section was found more intuitive if organizations were divided by roles and not by whether they were already in contact with the initiator or not. Following this, a selection step (now step 4) was added, creating the guidelines for said selection (see tool development section). The fourth step of the first iteration was then divided into 2 steps, approach and alignment of selected organizations, and conducting the collaboration. This last step was added because the setup of the value chain was divided in 3 horizons in the selection guidelines, following the roadmapping guide by Phaal & Muller (2009). This meant that the method should also include at least 3 iterations and required conducting the collaboration until reaching the value proposition of each stage.

In this second iteration, even though major improvements were made, the assessment was still missing a starting point based on the roles, a main outcome of the research phase. Therefore, the need to add an additional step became evident. Apart from this, feedback from the supervisory team also highlighted that the iterativeness of the steps was not intuitive in the method yet, and that the step of alignment needed to show this iterativeness explicitly.

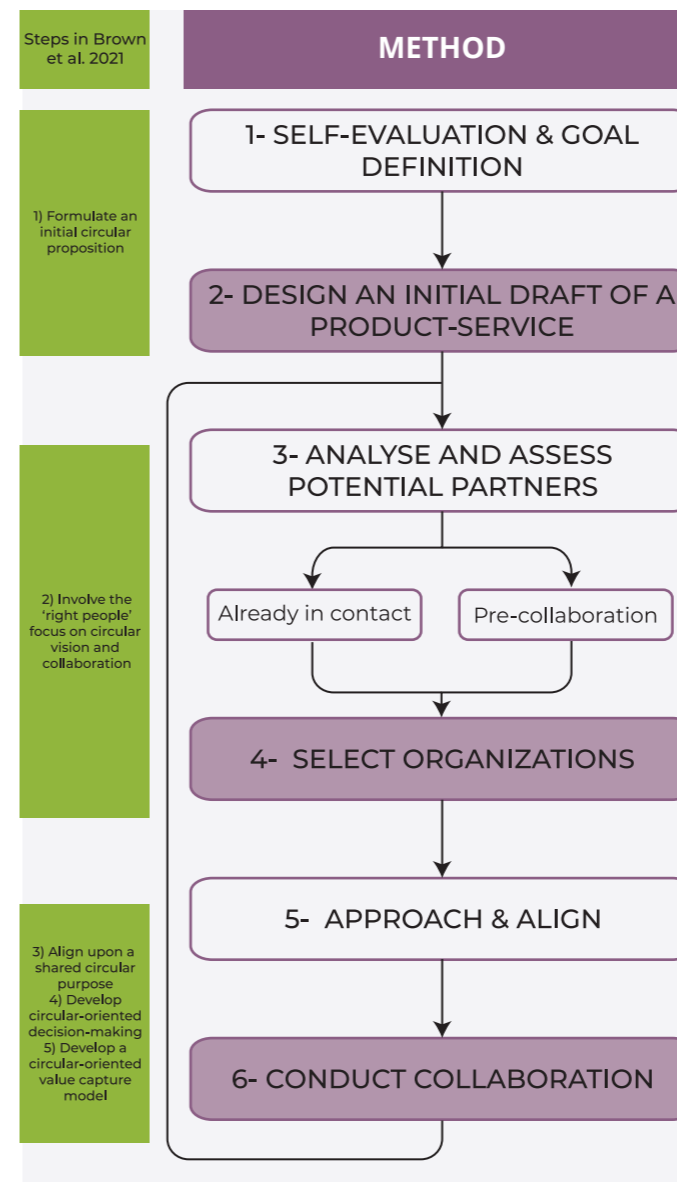
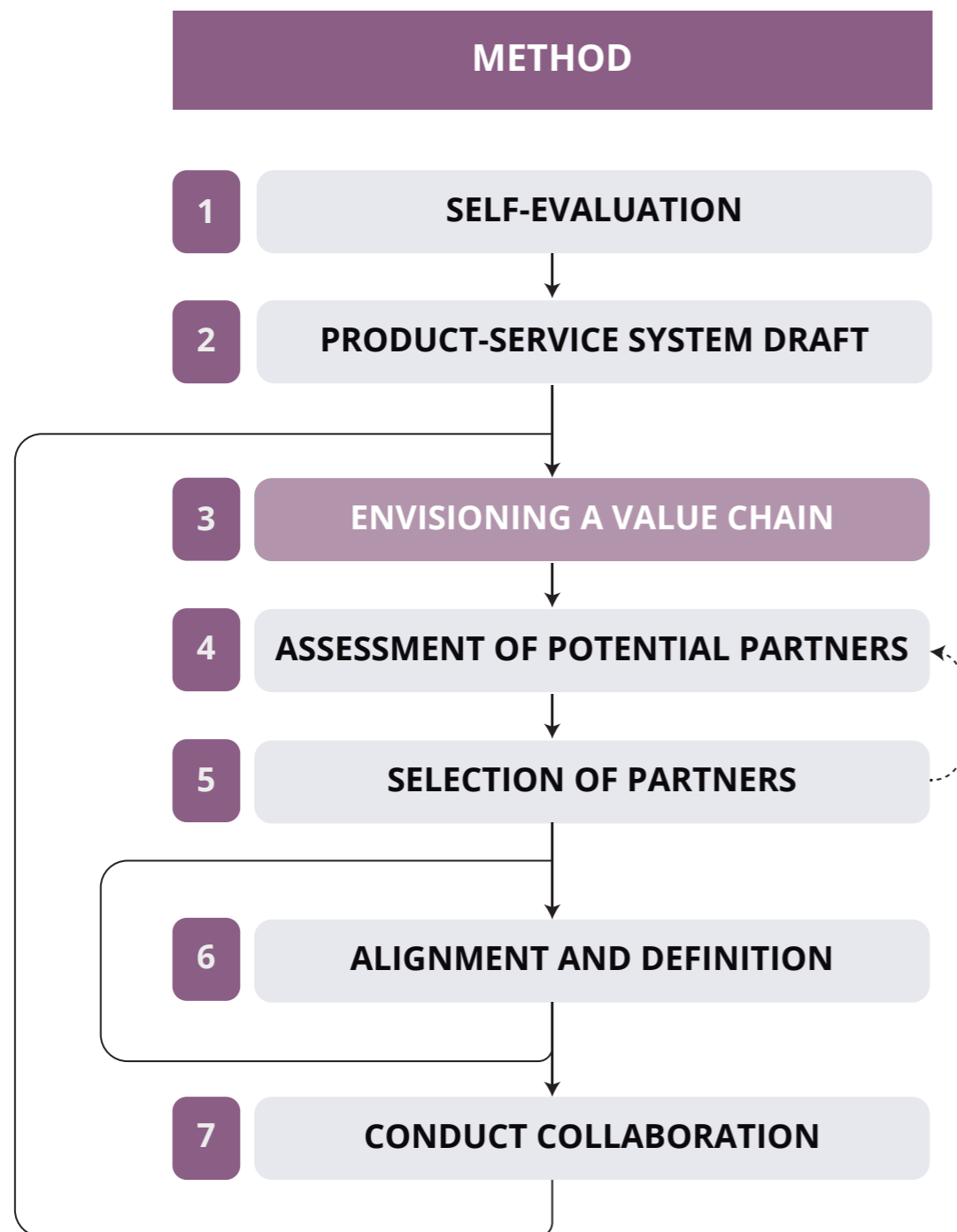


Figure 13. Second iteration of the method

Last iteration before test

In the last iteration of the method, before conducting the test with an organization, a last step was included. This step made explicit both the value chain perspective as well as the role definition aspect. This third step completed the method that would later be tested. In this iteration, another tool was created as an aid, in the shape of exemplary value chains, based on the work of Tukker (2004). Lastly, the iterativeness cycles were made explicit within the method.

Figure 14. Last iteration of the method before company testing



6.3 Tool Development

As said in the method part of this section, the development of the method was parallel to the development of aiding tools for each step. This section discusses the tools that have been developed or adapted for this method and context in particular.

Circular Maturity Level Matrix

The interviews showed that awareness and sustainable impact were highly relevant for the actors in the context of this project. Even though the creation of tools for measuring the sustainable impact of an organization is out of the scope of this project, from the definition of a circular economy by Kirchherr et al. (2017), it can be extracted that the individual organizational circularity implementation affects the overall value chain. Therefore, a matrix to measure the circular maturity of an organization was developed based on the work by Acerbi et al. (2021).

This matrix translated the description of the 5 maturity levels into 3 general categories for measurement: implementation of sustainable or circular activities, performance assessment, and information sharing. This way, the analysis of the maturity level was made more tangible for organizations. This matrix is used in step 1 to analyze the initiator's maturity level and is also included in the assessment card of step 4 to measure other organizations. By including a circular maturity level matrix in the method, the insight from the interviews showing that the measurement of sustainable impact varies per organization is tackled. The matrix offers a shared understanding of circular maturity that can be adapted to every organization.

CIRCULAR MATURITY LEVEL					
	Linearity	Industrial CE plotting	Systemic Material Management	CE thinking	Full circularity
Sustainable/circular oriented activities	Take-make-use-dispose Only sustainable/circular practices consist in legal responsibilities (Waste management and limited usage of toxic substances)	Interested in changing partially. Pilot experimentation pushing performance closer to resources sufficiency.	Adoption of CE in a more extended perspective. "R-cycles" become a standard practice. Systemic identification of possibilities. Entire company is involved, and operative level takes an active role.	Company not only able to internally recirculate resources but has also understood the potential in defining stronger partnerships with external stakeholders. Industrial symbiosis networks and an attempt to establish a closed-loop supply chain.	The firm is fully immersed into the circularity paradigm and committed to achieving social, economic, and environmental positive performances in all the products, processes and operations.
Performance assessment	Only monitored to mitigate additional costs rather than to find new opportunities in a circular scenario.	Detailed analyses to diagnose resource bottlenecks and to evaluate different processes parameters in terms of material and energy consumption.	Every resource used by the company is internally analyzed to think about possible future reintroduction into R-cycles. LCA is implemented to keep critical processes under control. Monitoring of the circular performance.	LCA is performed as common practice on all the production processes and products developed internally.	Exploitation of synergies among forward and reverse logistics and among local value chains by sharing a mutual vision leading to the co-creation of new value circles within manufacturing networks.
Information sharing		Experimentation goals and results are shared within the company boundaries across different hierarchical levels - engage employees in the transition.	Initial attempt to share results with value chain partners. Initial adoption of ICT to optimize material management and make operations more sustainable.	ICT used in a more integrated manner.	ICT are highly integrated into operations to support interaction. Strategic, tactical and operational levels of the company are aligned with a systematic and proactive follow-up of the circular transition.

Figure 15. Circular Maturity Matrix (Adapted from Acerbi et al., 2021)

Assessment Card

In order to provide organizations with the necessary criteria to assess partners and their adequacy for circular oriented collaboration, the relationships between the 3 topics from literature were leveraged (see figure 6) . Since the end goal of the method is creating aligned value chains, the criteria would need to cover all 3 dimensions of alignment defined by Velter et al. (2020). For that, specific topics from the barrier and driver categories have been used as reference. The included criteria have been selected from the research insights and present both the product centric approach expressed by the interviewees and the emphasis given to some topics.

Each criteria set is elaborated on as follows:

STAGE IN THE CIRCULARITY TRANSITION

When building a circular value chain it is very important to know how your possible partners have implemented circularity in their organization. The matrix elaborated in the previous section, has been included in this card in order to understand the maturity level of the potential partners. Same as the developed matrix, the card includes the following 3 dimensions of the maturity level:

Implementation of sustainable/circular activities:

In this section, the level of circularity principles is measured. The extent to which circularity strategies are implemented in their operations as well as the existence of open or closed loops for resources are the assessed issues.

Performance assessment: In this criteria, the measurement of sustainable impacts as well as the circular performance are assessed.

Information sharing: In this third element, the extent to which the organization shares the information using ICT is measured, both to obtain a systematic follow up of the implementation of circular practices, as well as to share their results transparently.

These 3 information pieces help in establishing the competence and efficiency boundaries and align in the normative and strategic dimensions, by leveraging topics relating to the supply chain and the technological categories.

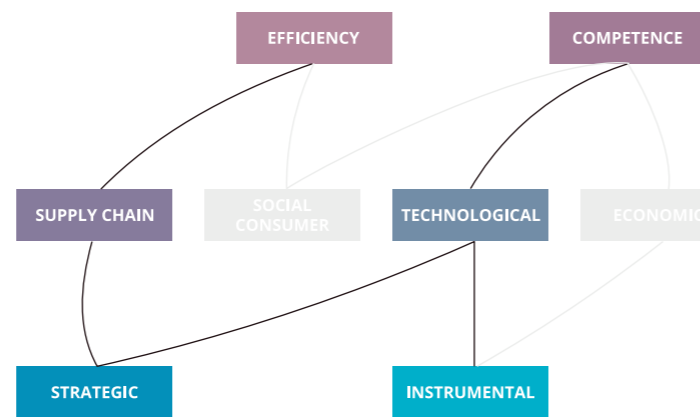


Figure 16. Literature relationships used in "stage in the circularity transition"

DESCRIPTION

This section can be used to describe the analysed company and highlight information that is relevant and might not be included in the rest of the categories.

TECHNICAL CAPABILITIES

According to Brown et al. (2019) Rizos & Bryhn (2022), and Urbinati et al. (2021), as well as the interviewed organizations, having the adequate technical capabilities is very important for companies pursuing circularity. This topic was highly emphasised by the interviewed OEMS, which emphasised their decision-making basis in the technical capabilities of partners (see interview insights). Therefore, knowing what kind of technology, solutions, or options an organization is able to offer is vital. This information is useful to establish the competence boundary and align in the instrumental dimension.

ORGANIZATIONAL VALUES

According to research, different working cultures (Salmenperä et al., 2021), as well as varying understandings of the Circular Economy (Brown et al., 2019), prevent the transition to a Circular Economy. This was similarly highlighted by the interviewed organizations. Velter et al. (2020) also highlight the alignment of organizations in 3 different dimensions. The normative dimension deeply relates to the organizational values, and therefore these need to be aligned. This information is useful to establish the identity boundary and align in the normative dimension

FOCUS

When approaching the organizations to start the alignment, the most predominant organizational focus can be highlighted in the card. This way, the discourse can be adapted to cover the needs of the partners.

POSITION AND ROLE

When deciding where to fit an organisation in a value chain the interviews showed the high relevancy of the position it would take, as well as the role(s) it could fit within this position. This information is useful to establish the efficiency boundary and align in the strategic dimension, by leveraging an issue that came up in the supply chain category.

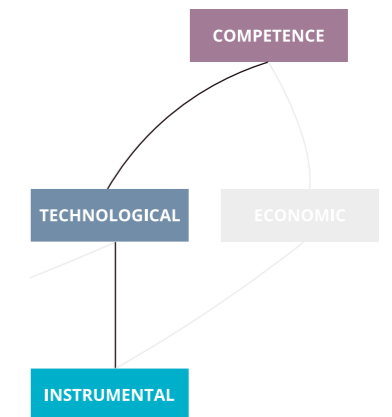


Figure 17. Literature relationships used in "Technical capabilities"

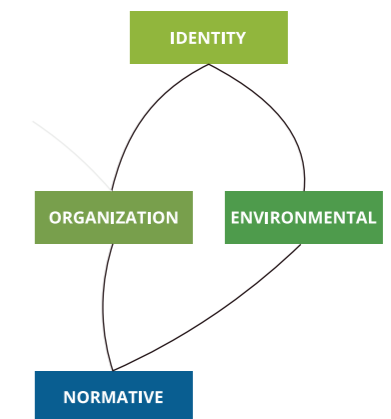


Figure 18. Literature relationships used in "Organizational values"

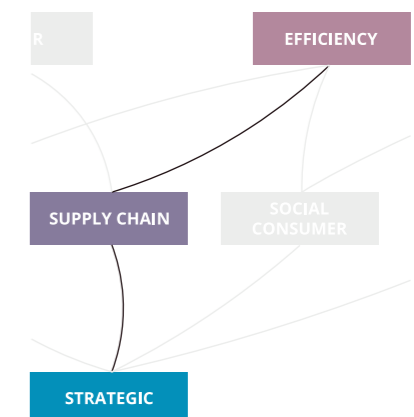


Figure 19. Literature relationships used in "Position and role"

SIZE AND INFLUENCE OF THE ORGANIZATION

Brown et al. (2019) highlighted how the power within the supply network affects the implementation of circular practices. Multiple interviewees mentioned this influence as a factor to consider too. These interviewees also mentioned that the influence of the organizations is directly correlated with their size too. This information is useful to establish the power and efficiency boundaries and align in the strategic dimension by again leveraging an issue emerged in the supply chain category.

ALIGNMENT OF BUSINESS MODEL

Hina et al. (2022) and multiple interviewed representatives highlight that Business models of partners need to be aligned for collaboration to be successful. Therefore, measuring the level of alignment between partnering organizations gains more relevance. This information is useful to establish the efficiency boundary and align in the strategic dimension, by using an issue found in the supply chain barriers.

LENGTH OF PARTNERSHIP

According to the interviews, the length of the relationship between partners is a decisive factor. These relationships are important for organizations and altering them poses a risk for their activities. Brown et al. (2019) also highlights that these might also be cause of existing contracts that result in lock-in. This information is useful to establish the power boundary and align in the strategic dimension by leveraging an issue that came up in the supply chain category.

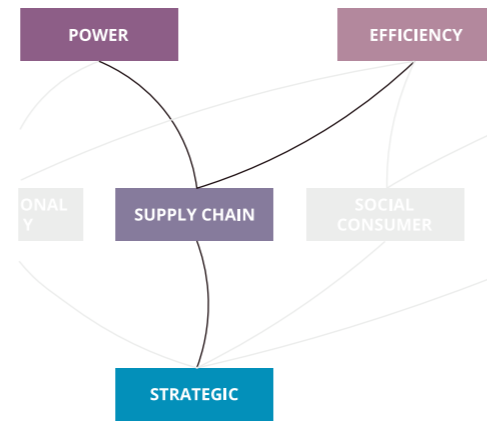


Figure 20. Literature relationships used in "Size and influence of the organization, alignment of business model, and length of partnership"

DEPENDENCE ON PARTNERS

Multiple interviewees highlighted that their activity was highly dependent on the partners in their value network. The long relationships with them, as well as them being the only ones that could provide the technology have a high impact on their activity. Therefore, in order to evaluate how fit a company is for your circular value chain, as well as to know what approach to take in the future, it is highly relevant to evaluate it is highly relevant to evaluate to evaluate both companies' interdependency. This information is useful to establish the power, efficiency and competence boundaries in order to align in the strategic and instrumental dimensions, by taking advantage of an issue that came up in both supply chain and technology categories (Figure 19).

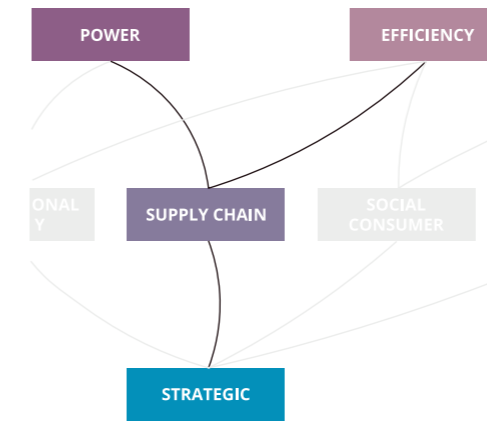


Figure 21. Literature relationships used in "Dependence on partners"

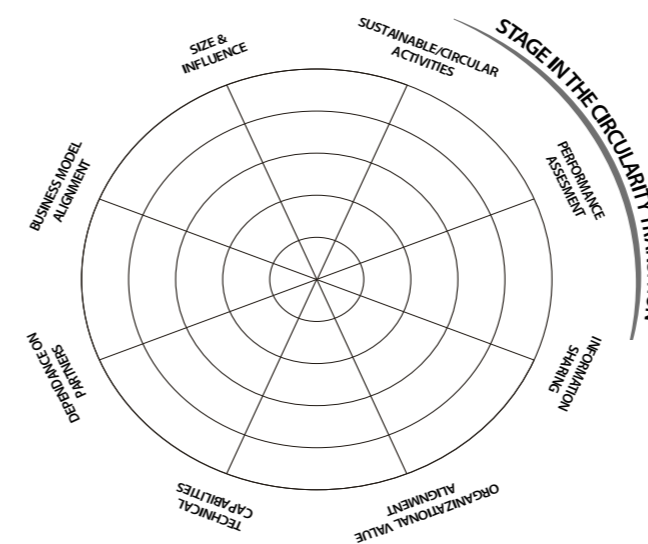


Figure 23. Spider diagram

These elements were then translated into an **assessment card** (Figure 20). Additionally, a set of instructions was defined in order to guide the users of the card. The card was also translated into a spider diagram for further simplification (Figure X). To fill the spider diagram, a matrix that described all 5 levels of the diagram was developed. These descriptions were extrapolated from the 5 levels defined by Acerbi et al. (2021), together with the definitions by Ellen MacArthur Foundation (2013) and adapted for each section of the card.

Testing

These assessment tools were tested with 4 master students from the TUDelft Industrial Design Engineering faculty that had knowledge on organizational terminology and the CE. These tests were conducted by making the students assess an organization of their liking independently and helping them whenever they stumbled across any problem. The feedback from each individual test was implemented before conducting the test with the next student.

Last iteration before company testing

After all the test sessions, the final assessment card was established. Visual aids for the position and size were added in the card. A logo placeholder was also added in order to identify the assessed organization easier. Apart from this in order to make the instructions even easier, examples on how to fill the role, size and influence parts were added. A set of organizational values and their definitions were also added to the instructions, obtained from the work of Van Der Wal & Huberts (2008).

Figure 22. First assessment tool

Figure 24. Assessment tool iteration before testing

Selection guidelines

In order to select the organizations, a guiding table (Appendix K) was designed based on the topics of the card as well as the research outcomes. The table follows the work by Phaal & Muller (2009) establishing 3 horizons and a future vision for the setup of the value chain. The Future Vision follows the selected definition of the circular economy by Kirchherr et al. (2017) and the properties established by the Ellen MacArthur Foundation (2013) in order to define the characteristics of the value chain.

The guidelines consist of 6 information types: time horizons, value proposition of the horizon, the circular maturity of the value chain in that phase, value alignment of the organizations within the value chain, requirements related to the topics of the assessment card, and spider diagrams of the ideal organization to conduct the value proposition of each horizon.

The 3 different time horizons were defined by applying the insights from research to Phaal & Muller's (2009) framework and following the phases established by Ceschin (2014) for sustainable product systems. Ceschin's phases were used to define the value propositions of each horizon by combining them with the interview insights.

As mentioned in the collaboration insights from the interviews, the use of success stories is a promising way of starting the setup of the value chains. The short-term serves as an experimentation horizon and is the kick-starter of the value chain. In the second phase, the scaling up of the success story, the barrier found by Salmenperä et al. (2021) needs to be tackled. The third horizon consists of the logical step between scaling up and reaching full circularity by focusing on closing the loop.

As stated in the Assessment card development, the circular maturity level offers clear criteria to establish the point in the transition the value chain is in. Therefore, the maturity level offered in the guidelines can be used to guide the activities of that horizon as well as to measure the implementation.

Another key aspect that emerged from research was the need for value alignment in collaboration, which is often a barrier for effective circularity implementation due to clashing company cultures (Salmenperä et al., 2021). Therefore, and since it highly impacts the normative

alignment, which is the grounding for the overall alignment (Velter et al., 2020), it is important to highlight it.

Lastly, since the partner selection is based in the assessment card, the guidelines include a description of the most important requirements based in the topics that the card covers as well as other information that is relevant for the stage. The 2 selected promotion modes that emerged from the interviews have been included in these guidelines for the cases where organizations can't let go of partners, in order to transition together. In order to make these criteria more visual, the ideal organizational spider diagrams were also included. This results in a faster relationship between the assessment results and the selection.

The selection guidelines are built based on the selected literature as well as the developed assessment tool. Therefore it is subject to the limitations they present.

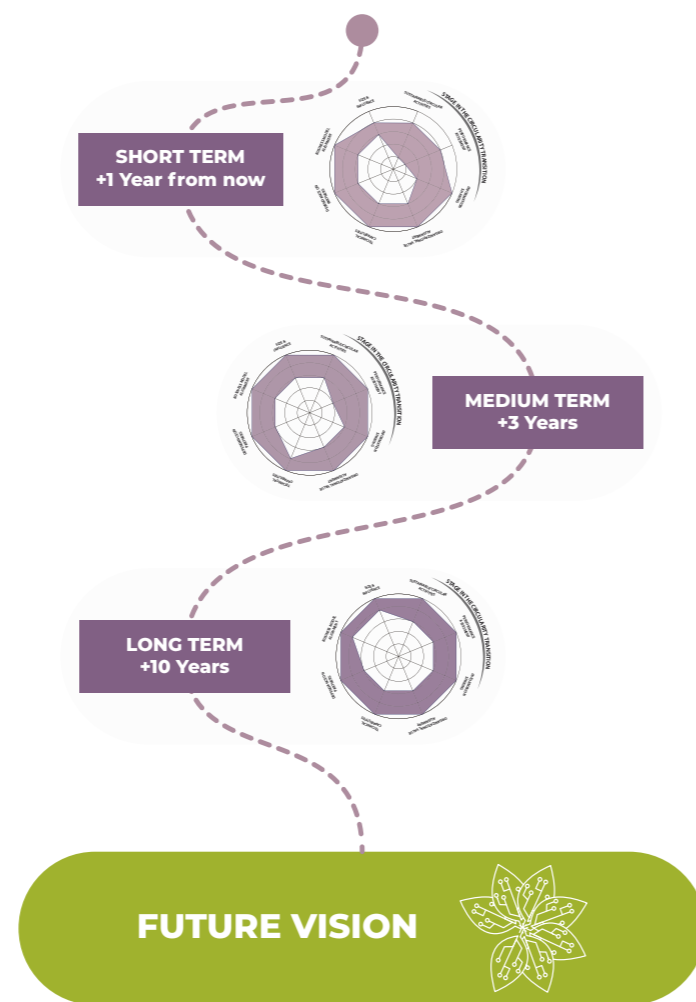


Figure 25. Path of the guidelines

Value Chain Archetypes

At the last iteration of the method, the need for envisioning the value chain and pertinent roles emerged. Literature showed that organizations were mostly aware of the organizations and roles within their range of activities (Cimprich et al., 2022). This surfaced a need for some exemplary value chains as well as the roles within them. A set of archetypical value chains was generated based on the descriptions by Tukker (2004) for Product Service Systems. These descriptions were taken as a reference, and a value chain example was designed for each one of them using the roles that emerged from interviews as well as from the strategies defined by Blomsma et al. (2019). This way, these archetypes and the included roles answer the need for role definition that emerged in most of the interviews.

8 different value chain archetypes were generated following a cascading structure as defined by the Ellen MacArthur Foundation (2013). Here, apart from the roles mentioned by Tukker, recycling, refurbishing, and repairing roles were included in order to close the loops. These roles were obtained from the report analysing the circularity in the consumer electronics industry by Meloni et al. (2018), as well as from the roles that emerged from the interviews.

These archetypes are the initial iteration of examples and are based on a theoretical perspective. In order to ensure the reliability in terms of their impact on a sustainable development level, a tested practical dimension needs to be included.

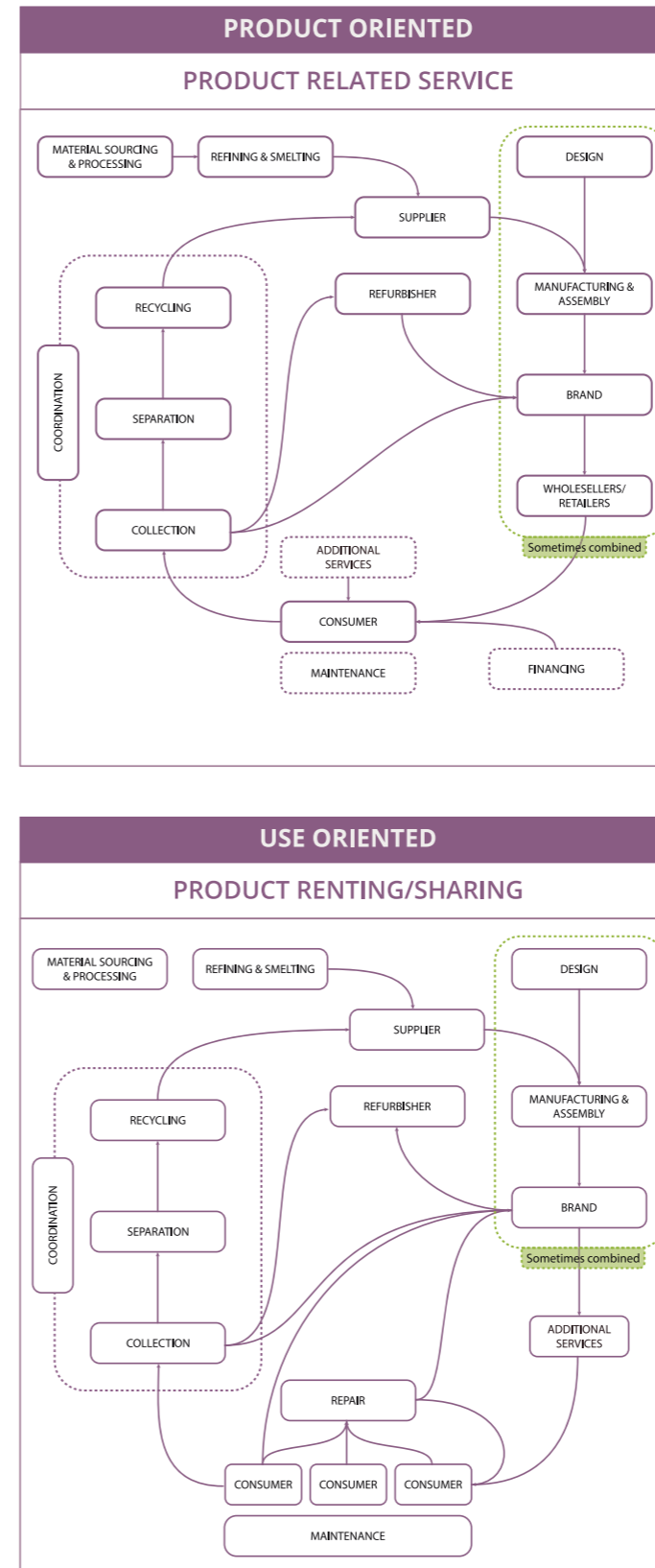


Figure 26. Product related service and product renting/sharing value chain archetypes

6.4 Testing with an OEM

After designing the methods and necessary tools, a test session was conducted with an OEM that was originally contacted for the interviews and that is part of the project consortium. The main objective of the session was to evaluate and test the method and generated tools and obtain first hand industry feedback to improve its relevance. An overview of the participants is offered in table 3:

Table 3: Overview of participants of the session

Industry	Product Category	Participants
Lighting	Emergency Lighting	Product Design Engineer and Head of Sustainability
		Technical Director

Structure of the session

A 2-hour session was conducted at the OEM's main offices, but due to the time limitations, only some critical steps were tested. Therefore, 2 main goals were established for the session:

- Test how method helps OEMs to envision a value chain following circularity principles and establish necessary roles for it.
- Test how the OEM is able to assess and select partners for the previously established roles.

As extracted from the goals, the focus of the session rested on envisioning a value chain and assessing potential partners. An initial explanation of the overall method was first given to the participants in order for them to understand the process as well as how the content would be used theoretically. Steps 1 and 2 were defined before the test, and were based in the interview insights of the same organization. However, the drafted PSS was discussed during the session before diving into the first test, so that the participants would see the value in it and add any information that they would like to work with. Participants were then given the value chain archetypes to start envisioning one that was in line with the discussed PSS (step 3). After envisioning a value chain for the drafted PSS, participants selected a role that they found critical in order to start the setup. Once the role was selected, the participants assessed 2 potential partners that could fit that role, following step 4. Participants then were asked to translate the assessment to the spider diagram. First without the matrix and then with it, to test if the matrix gave new guidance that changed their current perspective or if it was unnecessary. Step 5 was then introduced and explained, and participants lightly discussed if the analysed organizations would fit in the ideal profile of the first horizon. Steps 6 and 7 were not tested because they required a time span that exceeds the one this project has. Finally, participants filled the evaluation form and provided feedback on the method and tools.

Evaluation

The following section summarizes the main conclusions from the test, based on the observations done during the session, the comments made by the participants and the feedback forms.

General evaluation

The participants filled an evaluation form that contained quantitative measures of the usefulness, help offered, implementation, and intuitiveness of the method and the tools covered in the session. Seven-point Likert scales were used for the evaluation. However, due to the small number of participants, the form was used as a conversation starter and as a help for reflexion, rather than a quantitative analysis form. The form can be found in Appendix E.

The quantitative questions considered the following aspects:

- Potential to help organizations set up circular value chains
- Intuitiveness of method and tools
- Help envisioning the value chain
- Help in identifying potential partners
- Necessary information to assess and select potential collaborators
- Ease of implementation
- Usefulness of the method



Figure 27. Testing session with an OEM

The method presented high potential for setting up value chains according to the participants. They also saw enough possibilities for implementing it in their organization, as long as training was provided to the people using it. The usefulness was also highly evaluated, which is in line with the rating of the first question.

The intuitiveness of the tools and methods was considered to be adequate, but same as before, guidance was considered necessary. Step 3, *envisioning a value chain*, was the one evaluated more positively, together with the tool created for it, which were highly appreciated by participants both to understand their current situation as well as to think of future scenarios.

Lastly, even though the partner assessment tool was positively evaluated, and the contained information was found very helpful, participants mentioned that some more information should be included. Nevertheless, they did not make explicit what this information should consist of.

The most valuable insights, nonetheless, came from observations and comments during the session, as well as from the final qualitative questions and open conversation.

When it comes to general usability, it was observed that when using the method, participants needed guidance. They also highlighted that the method requires training and explanation. Therefore, one of the main insights is that the method requires a **strategic designer as a facilitator** in order to handle all the different inputs and keep the abstraction levels understandable.

Regarding the Implementation on their current way of working participants suggested that for the method to be really useful, it needed to involve all sectors of the organization. This would make the method not only specific to the research and development team, or the design team, but rather a **complete organizational method** where each step would involve different teams.

"I think it's really helpful for management, project managers, product development, procurement, and for sales"

– Head of sustainability

"Depends on the people that are working with it. For example, for step 4 you need to work with procurement"

– Head of sustainability

Step 3, *envisioning a value chain*, showed promising insights. The value chain archetypes sparked conversation around both the current state of their value chain, as well as the envisioned value chain for the drafted PSS. The archetypes helped participants with identifying the roles in their current value chain and the challenges they present for circularity. Once this was done, they realized how their current approach needed to change in order to fulfill potential roles of the archetypes, which links back to step 1. Participants also highlighted that the outcome of this step was highly dependent on a good PSS draft, since the roles that are envisioned to be part of the value chain are highly affected. The archetypes also helped the participants think of value chain and PSS propositions that they had not think of before.

However, when envisioning the future value chain, complications emerged due to the complexity of developing future visions. The level of abstraction was hard to grasp without guidance, what proves that a facilitator with Strategic Design skills, as well as future visioning skills is necessary. Due to the characteristics of the product category of the company, the participants highlighted the need to focus on the short term as well as in the long term.

When it comes to the assessment of the potential partners for a specific role (in this case a supplier) the step was conducted without much guidance. The instructions showed to be of enough guidance to fill the content. Since the selected organizations were already in contact with the potential partners, filling the card was no complicated task. Participants discussed the pros and cons of each assessed company while filling the card, and the comparison happened organically throughout the process.

The biggest insight of the assessment step was concerning the spider diagram. Filling the spider web diagram without using the matrix resulted on a different profile than when following the descriptions of the matrix. Therefore, it can be concluded that the matrix offers a new perspective on the selection of partners, probably due to the lack of extensive knowledge around what is best for circular collaboration. Lastly it was also highlighted that the spider diagram served as a conclusion or confirmation of the assessment.

“Depending on what PSS you make you would have different outcomes of roles”

– Technical Director

“These (V.C. Archetypes) are very good cause they help the discussion. You need the discussion to see where you could change things”

– Technical director

“We have to do both. For a new product we have to think ahead but we will not benefit from it the next ten years”

– Technical Director

“The spider diagram shows what I already concluded, that we work with them for their technical capabilities”

– Technical Director

Insights and improvement points from the session

One of the main insights of the session was that, as the method is mostly organizationally-oriented, a clear delineation of what team to involve in which step is highly beneficial. However, it also became clear that a successful implementation of the method requires a facilitator that is able to manage a high level of abstraction and manage the priorities of the teams within the organization, without overlooking the final goal of the method. Therefore, strategic designers would be ideal to guide and facilitate organizations that are using this method.

Moreover, it was shown that a thorough evaluation of the current state of the value chain(s) they are part of is very relevant and should be included in the beginning of the method. The tool created for the envisioning the value chain step present potential for this, since participants used the offered archetypes to discuss both their current value chains and a potential future value chain.

The tools that were tested were highly appreciated by the participants and proven to be useful both to spark conversation and to conduct the method. The participants highlighted the benefits that both the assessment card and the value chain archetypes would bring into their current practice and showed their interest on including them in their process (e.g. quality management). However, they suggested to include a new item in the assessment card that would hold competitor and alternatives of the analysed organization to ease comparison between potential partners.

Lastly, and related to the outcomes of the research, participants mentioned that it was very hard to think ahead when envisioning the value chain and that a short-term aspect should be included. However, this aspect might create a scenario where the possible ambitious envisioned value chain might be challenged by a current less circular perspective.

“The method is quite high level but it can help you structure your sustainable journey”

– Head of Sustainability

“The tool in step 4 is really helpful for us because we were looking for a set of guidelines to select partners”

– Head of Sustainability

“You can implement it in your quality management system for your audits”

– Head of Sustainability

6.5 Design Outcome

This section presents the design outcome of the project, after implementing all the feedback and insights. It offers a detailed explanation of the method that has been designed to help OEMs set up a new aligned value chain based in circularity principles for one of their products. The method takes as a reference already existing work that covered some aspects of the solution but lacked when answering the complete problem space. Due to the time and scope limitations of the present project, the outcome is a method that should be developed and tested further in order for it to reach its full potential. Therefore it should be considered as a starting seed for a complete method to set up circular value chains. However, for the sake of an easier understanding of the developed outcome, the limitations of each step and tool will be elaborated in the discussion section.

As elaborated in the method development, the structure of the method is based on the work of Brown et al. (2021), and adds new steps that were found necessary. Tools from other scholars such as Moon et al. (2013) have also been included to cover the needs of the method and adapt it to the needs of the consumer electronics industry. It follows all the criteria established in section 6.2, and is designed to use when those conditions are fulfilled. This means that the method is meant to be used in situations where an OEM can take the initiator function because it possesses all necessary resources, both power and financially. It this way leverages the position OEMs currently have in the consumer electronics industry, where product characteristics are mainly defined by them (see interview section for more information).

An overview of the whole method is first shown. Next, each step is explained separately and in detail, elaborating on the goals and tools of each step. The method is not to be taken as a rulebook but rather a guide that organizations should adapt to their needs. All the tools in complete form can be found in Appendixes F to L.



CVC

A method to set up Circular Value Chains



The Circular Value Chain (CVC) method is a **product-service system centric** approach that offers organizations in the consumer electronics industry guidance when setting up a new value chain for a product, following the principles of the **Circular Economy**. These value chains focus on collaboration between partners to foster the implementation of circularity in their practices and promote a sustainable development.

The method considers **design organizations and OEMs as the initiators** of the creation of the value chain and includes the rest of possible organizations further upstream and downstream. It focuses on the assessment and selection of the 'right' partners that could potentially fit in the necessary roles for an envisioned value chain, as well as in the alignment of said partners to transition into a suitable collaboration.

The method takes an **organizational approach** involving different teams in each step of the way. These teams are guided and facilitated by an expert strategic designer that manages the abstraction levels and the priorities of each team in order to achieve the final goal: setting up a circular value chain for a Product-Service System.

The visualization shows the ideal flow of the method with two main loops: the alignment iterations and revisiting the envisioning after reaching the value proposition of the stage. However, there might be cases where the alignment step is not successful and a new partner to align with has to be selected (revisiting step 5) or new organizations need to be analysed because there was no suitable partners to select from (revisiting step 4).

OVERVIEW

CVC is an iterative method that guides organizations in evolving and transforming their value chain towards a fully circular ecosystem that uses all resources efficiently and reduces the environmental impact to the minimum. CVC follows a **multi-step process** as described below.

The process starts with a **self-evaluation step** where the initiating organization understands the internal goals and motivations to pursue circularity. Apart from this, the initiator evaluates their circularity maturity level using the Circularity Maturity Scale, and define the role they could take in a circular value chain.

Then, the initiator needs to **draft an initial product-service system** proposition that answers and translates the goals and motivations defined in the first step. An initial set of criteria should be established for the drafted system, but room for adaptation and negotiation needs to be present.

The third step encompasses **envisioning a value chain** that will enable the proposed product-service system and define the necessary roles that partner-organizations would need to take in order for it to be viable. However, in order to envision this ideal value chain, and facilitate the future thinking exercise, the initiator (and collaborators in further iterations of the method) needs to bring the drafted PSS to their current value chain(s) and analyse all the possible problems that might emerge with the existing constraints. Once this exercise is done, the organizations can envision an ideal value chain and the pertaining roles if those restrictions would not exist.

Next, an **assessment of potential organizations** that could fit the defined roles is conducted. The company evaluation tool serves as a guidance for this stage by offering the necessary information to realize the upcoming steps, comprising an evaluation card and a simplified visualization of the organization.

The **selection of the 'right' partners** from the categorization done in the previous step, is enabled by a set of criteria offered in a guide that defines three value propositions in the evolution of a value chain.

Subsequently, the selected organizations need to be approached, upon which an **iterative alignment process** is commenced. In this step, all partners need to align on how they are going to collaborate, define what the exchanged value will be and specify the PSS proposition that was drafted in the second step.

After this, the **collaboration** is ready to begin, and the value chain can be set up. Once the value proposition of the present horizon is fulfilled, all partners should go back to step 3 together and follow the steps together, revising the already formed value chain. This is continued until the value chain becomes fully circular, by using all resources efficiently and with a minimum environmental impact.

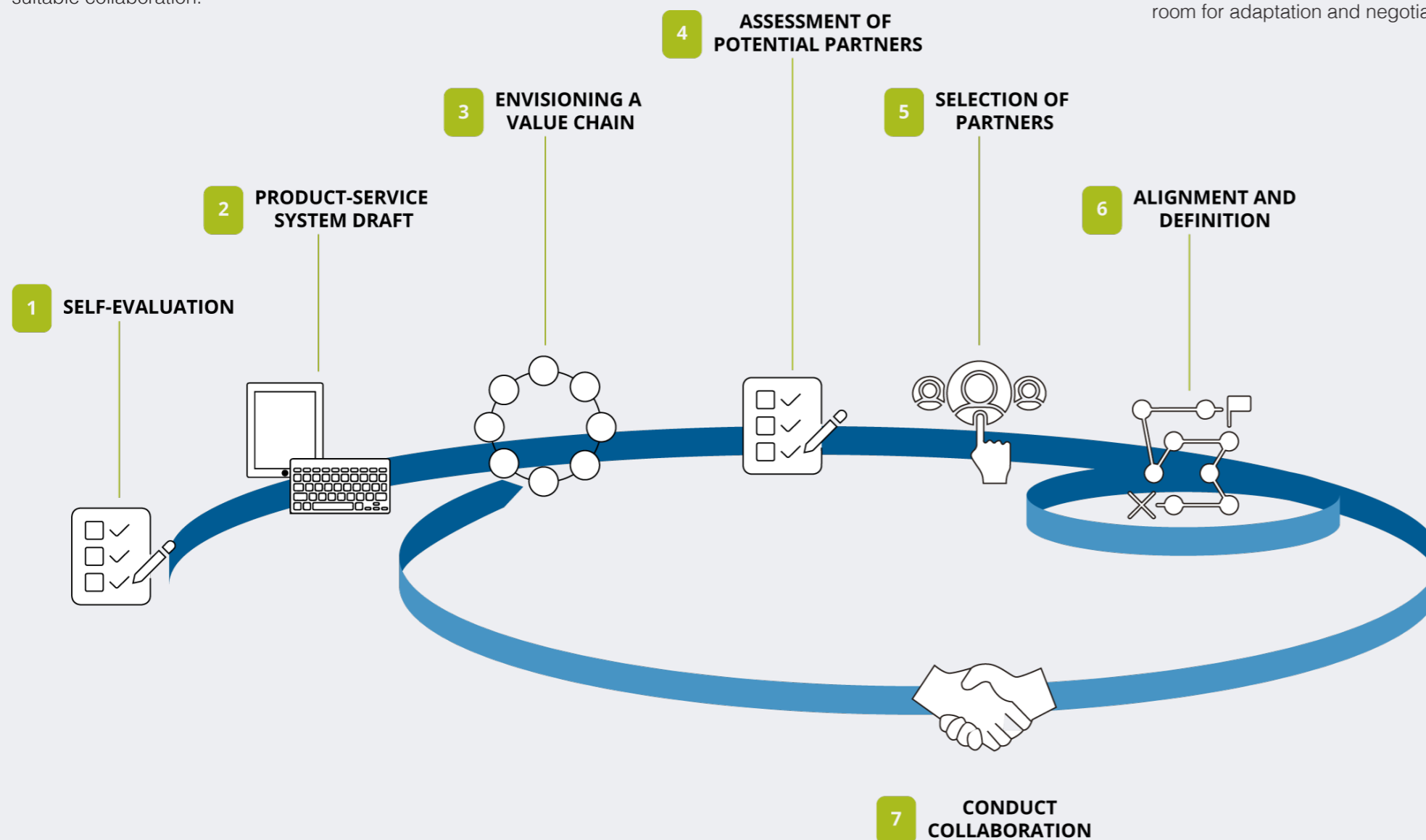


Figure 28. The CVC method

STEP 1

Self-evaluation and goal definition

The first step of the method establishes the necessary grounding for the initiator to pursue circular practices. Here, the initiating organization needs to evaluate their stance towards circularity and make strategic decisions on how to pursue the upcoming collaboration. This step, combined with step 2, is based on the first step of the process model by Brown et al. (2021) called 'formulate an initial circular proposition'. It consists of 3 main actions: evaluation of circular maturity, defining motivations and goals, and role definition.

Evaluation of circular maturity

In order to know where in the circularity transition the organization is, evaluating its circular maturity is the start of the first step. For this, the circular maturity scale matrix by Acerbi et al. (2021) is used. The matrix can be found in the tools of this step.

Defining motivation and goals

Once the circular maturity of the organization is evaluated, motivations and goals of achieving a higher maturity can be established. Clarifying the motivations that the initiator has to pursue setting up a circular value chain, as well as establishing the goals they want to obtain with are vital in order to guide the method. These two elements will provide the foundation for the initiator's commitment, and will be necessary for the alignment stage, especially for the normative alignment dimension (Velter et al., 2020). It is necessary to define what are the red lines the initiator would not cross, as well as its own boundaries for the collaborations that will happen down the road. However, the organization should be aware that their boundaries will potentially change, in order to allow for a more efficient collaboration and align completely in the future (Velter et al., 2020).

Role definition

After defining motivations and goals, the initiator needs to define what role they would be willing to take in the future collaboration. Nevertheless, it should be aware that the role might evolve throughout the collaboration and when setting up the value chain. For example, an OEM might start purely as an OEM but slowly uptake the role of refurbisher as the collaboration evolves.

TEAMS TO BE INCLUDED

- Management and Strategy
- Sustainability management

ROLE EVOLUTION FOR OEMs

- From manufacturing to refurbishing
- From manufacturing to remanufacturing
- Manufacture while ensuring optimal recyclability of the product and all its parts/material
- Manufacture using as many secondary parts and materials as possible

OUTCOME

- Circular Maturity
- Motivations, goals, and boundaries for conducting the collaboration
- Role within the future value chain

Figure 29. Circular Maturity Level Matrix

STEP 1 - Tools

CIRCULAR MATURITY SCALE

A matrix to measure the circular maturity of an organization was developed based on the work by Acerbi et al. (2021). The matrix translated the description of the 5 maturity levels into 3 general categories for measurement: implementation of sustainable or circular activities, performance assessment, and information sharing. This way, the analysis of the maturity level was made more tangible for organizations. This matrix is used in step 1 to analyze the initiator's maturity level and is also included in the assessment card of step 4 to measure other organizations.

CIRCULAR MATURITY LEVEL					
	Linearity	Industrial CE plotting	Systemic Material Management	CE thinking	Full circularity
Sustainable/circular oriented activities	Take-make-use-dispose Only sustainable/circular practices consist in legal responsibilities (Waste management and limited usage of toxic substances)	Interested in changing partially. Pilot experimentation pushing performance closer to resources sufficiency.	Adoption of CE in a more extended perspective. "R-cycles" become a standard practice. Systemic identification of possibilities. Entire company is involved, and operative level takes an active role.	Company not only able to internally recirculate resources but has also understood the potential in defining stronger partnerships with external stakeholders. Industrial symbiosis networks and an attempt to establish a closed-loop supply chain.	The firm is fully immersed into the circularity paradigm and committed to achieving social, economic, and environmental positive performances in all the products, processes and operations.
Performance assessment	Only monitored to mitigate additional costs rather than to find new opportunities in a circular scenario.	Detailed analyses to diagnose resource bottlenecks and to evaluate different processes parameters in terms of material and energy consumption.	Every resource used by the company is internally analyzed to think about possible future reintroduction into R-cycles. LCA is implemented to keep critical processes under control. Monitoring of the circular performance.	LCA is performed as common practice on all the production processes and products developed internally.	Exploitation of synergies among forward and reverse logistics and among local value chains by sharing a mutual vision leading to the co-creation of new value circles within manufacturing networks.
Information sharing		Experimentation goals and results are shared within the company boundaries across different hierarchical levels - engage employees in the transition.	Initial attempt to share results with value chain partners. Initial adoption of ICT to optimize material management and make operations more sustainable.	ICT used in a more integrated manner.	ICT are highly integrated into operations to support interaction. Strategic, tactical and operational levels of the company are aligned with a systematic and proactive follow-up of the circular transition.

STEP 2 Product-Service System Draft

The second step of the method consists of creating a draft Product-Service System to create the value chain around. The interview section highlighted that the current organizational understanding of the Circular Economy is highly product dependent. Therefore, in order for organizations to be able to conduct the following steps, it is relevant to define a product. In this case, following the principles of circularity, the product needs to come within a Product-Service System, since it ensures a more defined ownership scheme. The PSS defined in this step should show the goals and motivations established in step 1, fall within the boundaries defined in the previous step and consider the role defined for the initiating OEM within the system. This step, combined with step 1, is based in the first step of the process model by Brown et al. (2021) called 'formulate an initial circular proposition'.

A diagram that shows the design factors of a PSS together with a PSS blueprint template can be used to guide the design actions of this stage (see next page). Both of these tools were designed by Moon et al. (2013) and tested by analysing an already existing PSS from the smartphone industry. Using these tools, an initial PSS can be devised and drafted in order to guide the next steps of the method. Here, the design factors are divided in 6 main sections that can be used as guiding factors to draft the product: 1) aesthetics, 2) durability, 3) functionality, 4) controllability, 5) user experience, and 6) objective.

The blueprint can be filled by following the steps established by Moon et al. (2013). First, product functions and service processes need to be determined. Then, the components of the blueprint need to be established based on customer actions. Thirdly, the interactions in the product section need to be drawn, followed by the internal interaction and support workflow. Lastly, the boundary of visibility and the PS platform area have to be determined (Moon et al., 2013).

In this stage of the process, the constraints that might come from other collaborators are not defined. Therefore, and as the title of the step says, the defined Product-Service System is a draft and susceptible to changes. It must be taken as a guiding principle for the rest of the steps.

TEAMS TO BE INCLUDED

- Research and Development
- Design
- Sustainability Management

It is advised to make this draft as ambitious as possible so that it sparks creativity and challenges all collaborators to strive to get out of their comfort zone.

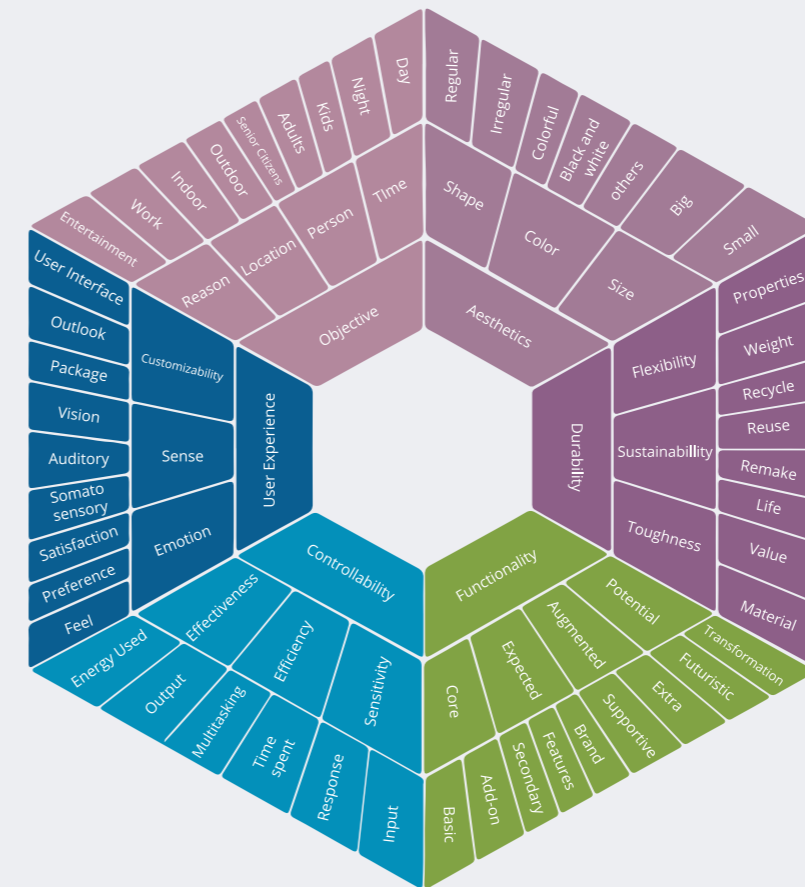
Figure 30. Design factors diagram (obtained from Moon et al., 2013)

Figure 31. PSS blueprint template (obtained from Moon et al., 2013)

OUTCOME

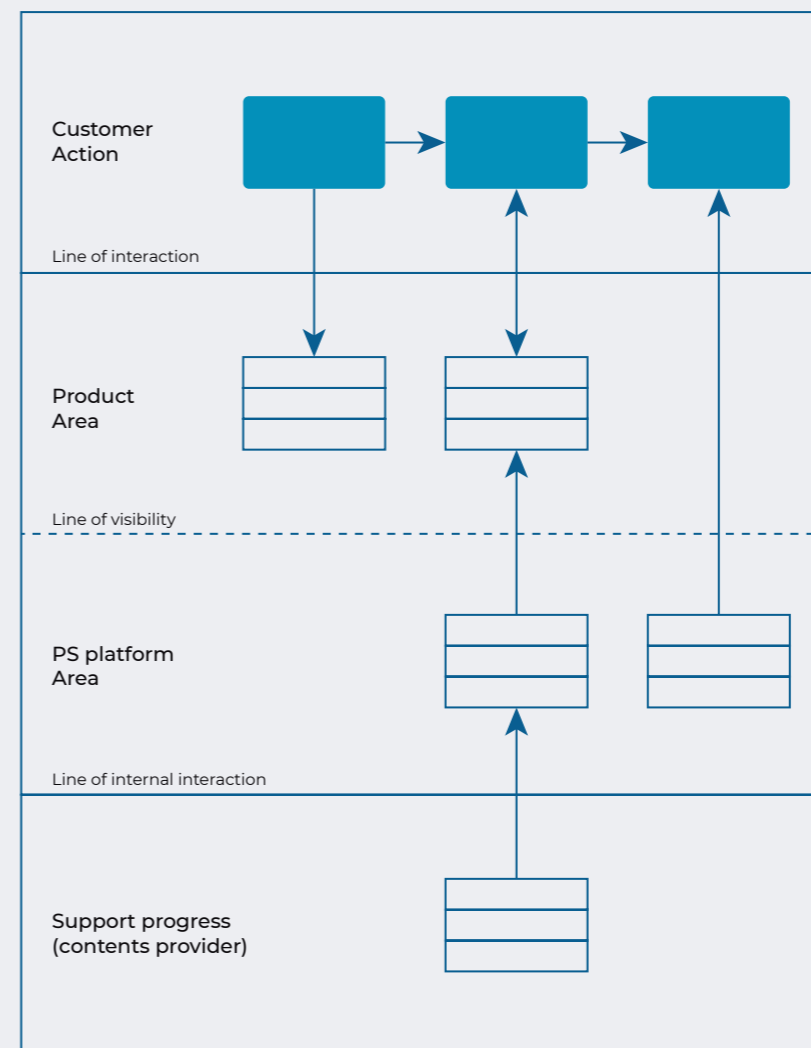
Ambitious Product-Service System Draft establishing the type of product and initial characteristics

STEP 2 - Tools



DESIGN FACTORS DIAGRAM

An initial PSS can be devised and drafted in order to guide the next steps of the method. Here, the design factors are divided in 6 main sections that can be used as guiding factors to draft the product: 1) aesthetics, 2) durability, 3) functionality, 4) controllability, 5) user experience, and 6) objective.



TEMPLATE FOR PSS BLUEPRINT

Then the blueprint can be filled by following the steps established by Moon et al. (2013). First, product functions and service processes need to be determined. Then, all the components of the blueprint need to be established based on customer actions. Thirdly, the interactions in the product section need to be drawn, followed by the internal interaction and support workflow. Lastly, the boundary of visibility and the PS platform area have to be determined (Moon et al., 2013).

STEP 3 Envisioning a Value Chain

This step consists of defining all the roles that will be needed to be taken up in order to form the value chain that enables the draft product-service system. This step is also where the method loops back to after successfully reaching the value proposition of each defined horizon in step 5. In the process model by Brown et al. (2021) an additional step is needed to translate a vision into a value chain. Research outcomes show how role definition is a crucial part of the process of setting up a value chain. Without role definition evaluating organizations that could become partners would become an even more complex task, since no starting point for the assessment would be in place.

However, in order to envision this ideal value chain, and facilitate the future thinking exercise the drafted PSS needs to be brought to the current value chain(s) and analyse all the possible problems that might emerge with the existing constraints. The exemplary value chains created for this step can be used to imagine the current value chain and the possible constraints that there might be between the relationships among the different roles. This step follows the future thinking steps suggested by Sanders & Stappers (2012), that highlight the need for thinking of the present before imagining the future.

Once this exercise is done, the organizations can envision an ideal value chain and the pertaining roles if those restrictions would not exist.

The partners in the collaboration need to be aware of all the necessary roles that are needed, specially of those that are outside of the system boundaries defined by their direct activities (Cimprich et al., 2022), the ones that they are not in direct contact with.

In order to help the complexity of this step, a set of archetypical value chain structures have been developed based on the Product-service systems defined by Tukker (2004; see tools for this step). These examples serve as inspiration for those method users that might not think of certain roles as part of the necessary ones for the value chain of their product-service system.

TEAMS TO BE INCLUDED

- Research and development
- Logistics
- Procurement

OUTCOME

Current Value Chain and its restrictions
Ideal Value Chain Depiction with necessary roles within

STEP 3 - Tools

VALUE CHAIN ARCHETYPES

These archetypical value chains were generated based on the descriptions by Tukker (2004) for Product Service Systems. These descriptions were taken as a reference, and a value chain example was designed for each one of them using the roles that emerged from interviews as well as from the strategies defined by Blomsma et al. (2019).

7 different value chain archetypes were generated following a cascading structure as defined by the Ellen MacArthur Foundation (2013). Here, apart from the roles mentioned by Tukker, recycling, refurbishing, and repairing roles were included in order to close the loops. These roles were obtained from the report analysing the circularity in the consumer electronics industry by Meloni et al. (2018), as well as from the roles that emerged from the interviews.

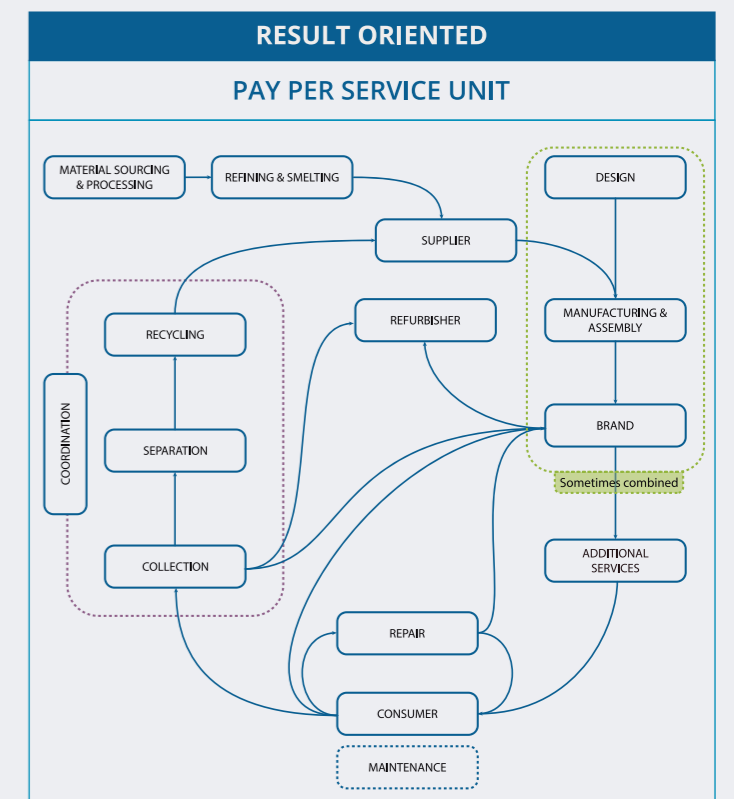
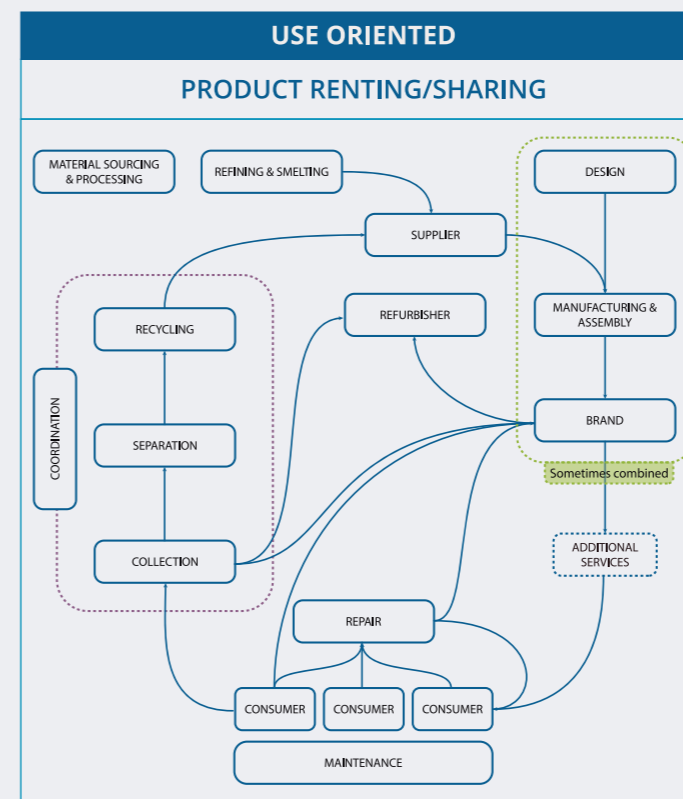
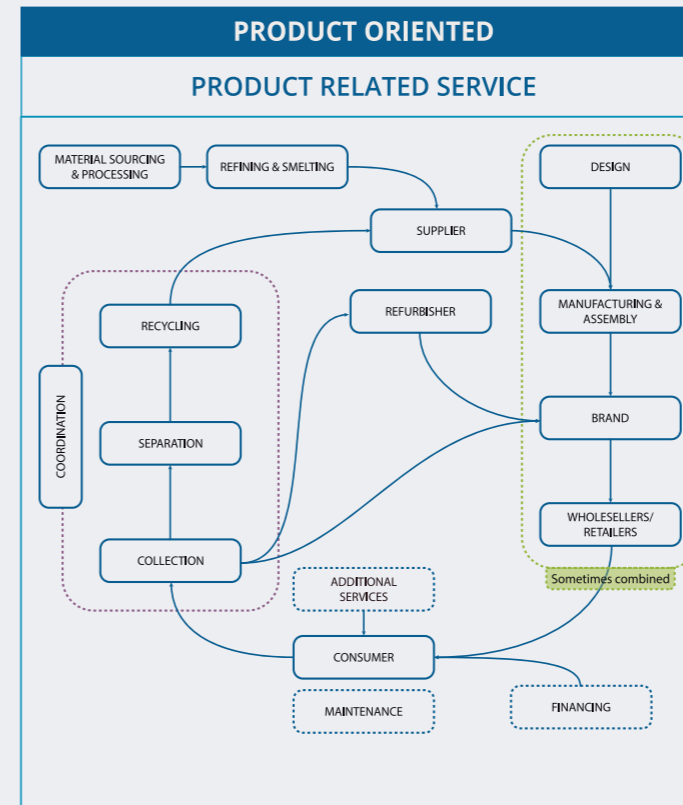


Figure 32. Examples of value chain archetypes

STEP 4 Assessment of potential partners

Step 4 is about assessing potential partners that could fulfil the roles defined in step 3. This step is based in step 2 of the process model established by Brown et al. (2021) called 'involve the right people - focus on circular vision and motivations'. It answers the question posed by the aforementioned authors, that suggest creating a way to assess the right people for circular collaborative innovation.

The assessment is done by following two steps.

Fill the card

A card has to be filled with information relevant for the process of selecting and aligning partners within a collaboration that follows principles of the Circular Economy. This cards provides a common set of information to analyse organizations, enabling an easy way of comparing the differences between them. It answers to the barriers found both in literature and interviews that companies lack a common set of guidelines and information, as well as a common language (in this case structure). The card contains information relevant to the 3 alignment dimensions and the 4 types of organizational boundaries mentioned in section 3.3, enabling this way well-informed decision-making.

The card comes with a set of instructions that explain how to fill it. This set of instructions, as well as the card, can be found on the next page.

Difficulty when filling the card can vary depending on the availability of information. 2 options have been devised:

Organizations already in contact with: the availability of information is higher, and therefore, the difficulty is reduced.

Pre-collaboration/unknown organizations: The tool is used as an initial evaluation of an organization to know their characteristics, guide an initial approach, and start conversation with useful information. However, obtaining the information might become more complicated and assumptions might be necessary.

TEAMS TO BE INCLUDED

- Logistics
- Procurement
- Sustainability Management

Simplify the information of the card in a spider diagram

Once card is filled, the information contained there can be simplified in a spider diagram that contains 5 levels. A matrix has been designed that explains the 5 different levels of all the elements present in the card in order to fill the spiderweb graph. This way, comparison between different potential partners is simplified. The matrix to fill the spider diagram can be found in Appendix J.

Figure 33. Assessment card

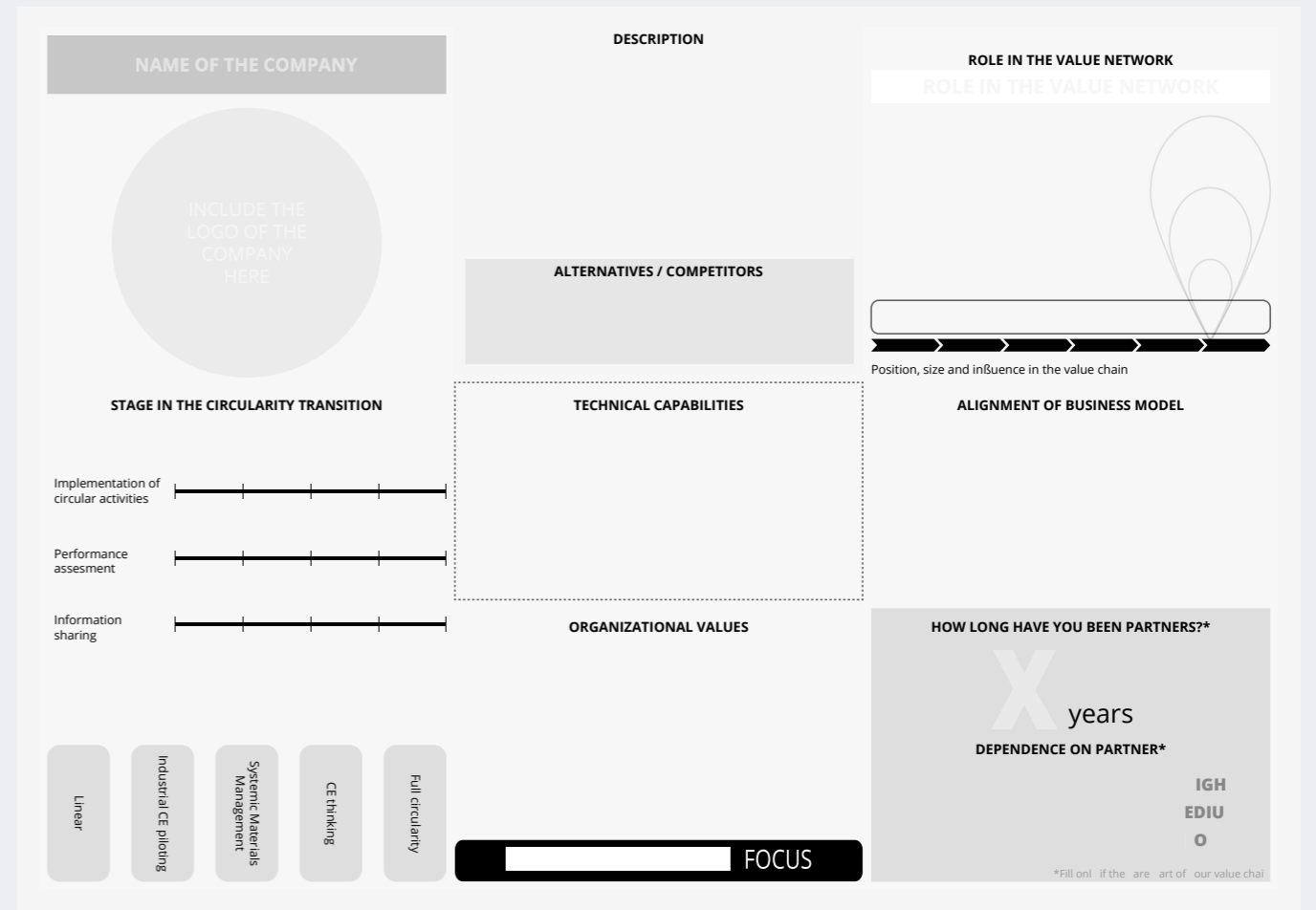
Figure 34. Spider diagram

OUTCOME

A set of cards containing the assessment of potential partners that could fit the roles established within the value chain.

A set of spider diagrams visualizing the assessment of the potential partners.

STEP 4 - Tools



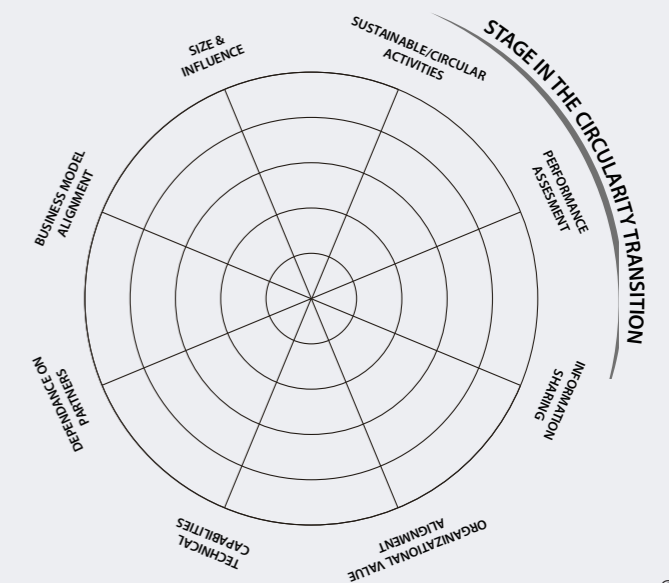
ASSESSMENT CARD

In order to provide organizations with the necessary criteria to assess partners and their adequacy for circular oriented collaboration, the relationships found in literature were leveraged. Since the end goal of the method is creating aligned value chains, the criteria would need to cover all 3 dimensions of alignment defined by Velter et al. (2020). For that, issues from the barrier and driver categories have been used as reference. The included criteria has been selected from the research insights and presents both the product centric approach expressed by the interviewees and the emphasis given to some topics.

SPIDER DIAGRAM

The spider diagram simplifies the measurable elements of the assessment cards and visualizes the information about the assessed organization.

A matrix has been designed that defines the 5 levels of each visualized categories. The characteristics of these 5 levels have been defined as to how adequate the organization would be when collaborating within a circular value chain. This matrix can be found in the complementary tool of this manual.



STEP 5 Selection of Partners

After having conducted the assessment in the previous step it is time to select the most adequate partners to conduct the collaboration. This step is crucial since the selection will define how the collaboration will happen and how successful the vision will be. This step concludes step 2 from Brown et al. (2021), and concludes involving the 'right people'.

In order to aid companies in their selection, a set of guidelines have been defined. These guidelines have been designed based on the work by (Phaal & Muller, 2009), and focus in 3 different horizons for the collaboration to reach an ideal future vision. In this case, the future vision consists of "Having a completely circular value chain where all involved organizations collaborate to have negative environmental impact, eliminate waste, and use all resources efficiently". These guidelines are based on 5 different categories: value proposition of the stage, the circular maturity level that should be reached in this stage, the characteristics of the value alignment between collaborators, the requirements of the stage, and the ideal organizational characteristics of the collaborators (spider diagram).

Each collaboration and value chain around a different consumer electronic PSS might have its own characteristics and limitations. Therefore, the tool that includes the guidelines is meant to be used by implementing the needs of the organizations and the members of the value chain, rather than as a strict rulebook. They answer to the insights derived from literature and interviews that organizations lack a set of guidelines and tools for the circular economy.

TEAMS TO BE INCLUDED

- Research and development
- Logistics
- Procurement
- Management

OUTCOME

A selection of organizations that could potentially fill the roles required for the value chain.

STEP 5 - Tools

GUIDELINES FOR PARTNER SELECTION

In order to select the organizations, a guiding table was designed based on the topics of the card as well as the research outcomes. The table follows the work by Phaal & Muller (2009) establishing 3 horizons and a future vision for the setup of the value chain. The Future Vision follows the selected definition of the circular economy by Kirchherr et al. (2017) and the properties established by the Ellen MacArthur Foundation (2013) in order to define the characteristics of the value chain.

The guidelines consist of 6 information types: time horizons, value proposition of the horizon, the circular maturity of the value chain in that phase, value alignment of the organizations within the value chain, requirements related to the topics of the assessment card, and spider diagrams of the ideal organization to conduct the value proposition of each horizon.

Figure 35. Table of guidelines for partner selection

	SHORT TERM +1 Year from now	MEDIUM TERM +3 Years	LONG TERM +10 Years	FUTURE VISION
VALUE PROPOSITION	Building a success story of a product or part of your value chain by trying to adapt existing resources. Building trust.	Partial circularity. Scale up the success story by incorporating new members and helping them transition if necessary.	Partnerships across the whole life cycle of the product. Loop is almost closed. First fully circular successful product is marketed.	Having a completely circular value chain where all involved organizations collaborate to have negative environmental impact, eliminate waste, and use all resources efficiently.
MATURITY SCALE	2-3	3-4	4-5	5
VALUE ALIGNMENT	Organizational values should be fully aligned since it's a venture that both partners need to embark on.	Alignment in values is necessary, but can be negotiated with some time and to some extent.	Since a whole ecosystem needs to be created, it is preferable that values start aligned. However, the systematic innovation allows for some shared values within partners while other might not be shared. Core values need related to sustainability or innovation in practice need to be aligned and the ones that are not, need to not be opposing.	Negative environmental impact - Remove more CO2 than created - Waste-water is fully treated - Promote environmental quality - 100% renewable energy
REQUIREMENTS	<ul style="list-style-type: none"> - Technical capabilities need to be already there or experiment how to adapt the existing ones - Partners need to be comfortable with risk and uncertainty - Wanting to exploit existing knowledge to generate new insights and opportunities for the future - Both partners need to be able to obtain, implement and showcase the innovations - High adaptability is helpful/necessary - Information sharing is vital. Building a success story requires transparency and collaboration so that both parts grow simultaneously and learn new knowledge. - All actions need to be evaluated to support the information sharing with a common tangible data. - Since it's a success story, it's the best opportunity to try to find out what could and couldn't work. - If you have a high dependence on a partner and you can't let them go, the success story can be used to build circularity together and develop a sustainable relationship. 	<ul style="list-style-type: none"> - Create consumer awareness and exploit opportunities with business models - Once success story gets out, it needs to scale up. Organizations need to be included when they add new value/capabilities to the already existing successful proposition. - Existing collaborations might need to shift or be adjusted - Tech capabilities might need to be innovative. Otherwise, the necessary technologies can be developed collaborating and innovating openly - Information sharing is very important in this phase to communicate all the knowledge built around the success story so that new actors can take the proposition and build on it. - For this, the new actors in the supply chain need to receive and share information openly. For that, information sharing platforms and ICT systems can be incorporated. - R cycles have to become standard practice and partners need to constantly be looking for improvement. Therefore, the collaborators need to have a will and capacity to recirculate resources within the chain. - If you have a high dependence on a partner and you can't let them go, build circularity together and develop a sustainable relationship. 	<ul style="list-style-type: none"> - CBMI to engage aware consumers and create a community. - In this last stage, before reaching the fully circular value chain, a combined value proposition needs to be set up between all partners. - All included organizations need to provide new knowledge and help grow the ecosystem. - At this point, the OEM loses the initiator role since in the previously scaled up solution already involved an equal share of responsibility and benefits. - Organizations in level 5 of value alignment that are outside the industry can be included to help the system grow and inspire a collaborative solution - An ecosystem needs to communicate constantly, but this can be compartmentalized depending on what type of innovation is developed. This will help with management of partnerships and useful knowledge availability. Follow up on the situation of all the actors needs to be constant to see how everyone is acting and if goals are being reached. - In order to create the ecosystem and involve new actors, influence over a number of other organizations is needed. Otherwise, the industry won't move as one and the pressure won't be high enough. - If dependence is high on a company that is already part of the value chain and it has not evolved with the previous stages, it either needs to be let go and look for the same capabilities elsewhere, or it has to adopt the propositions 	<ul style="list-style-type: none"> 0 waste: all resources used by the organization are employed in some way. The organizations in the value chain aid the rest of partners in the resource utilization. Strengthen the loops and maintain the value of products, components, parts and materials throughout the full life cycle. Cascading of products, components, parts and materials by following the R principles.
IDEAL PROFILE OF PARTNERS				



STEP 6 Alignment and definition of actions

Step 6 consists of approaching and aligning with the organization(s) selected in step 5. As highlighted in the visual of the method (figure 11), this step is highly iterative and might require many conversations and trade-offs in order to reach alignment and conduct collaboration, as shown in Figure 11. This sixth step combines steps 3, 4 and 5 from the process model by Brown et al. (2021). This combination of steps is in order to differentiate the stages of the method more easily, by combining all steps from Brown's model that pertain to alignment in the same one. During this stage, partners are required to establish a mutual circular goal, shape the decision-making framework, and outline the model for collectively capturing shared value. As mentioned in the general overview of the method, the negotiation and definition of the parameters for collaboration can be unsuccessful. Therefore, it might be necessary to go back to step 5 in order to select a new organization.

As mentioned in step 4, the assessment card contains useful information for the 3 dimensions of alignment: normative, strategic, and instrumental (Velter et al., 2020). This is also the step in which the assumptions included in the assessment card should be clarified and the information should be specified further.

STEP 7 Conduct collaboration

The last step of each iteration of the method is conducting all the activities decided in step 6 until the value proposition that collaborators have aligned upon has been reached. Once reached, the already collaborating partners should go back to Step 3, *Envisioning a Value Chain*, and conduct another iteration of steps 4,5,6 and 7 together. This way, more and more partners will be included in the process, slowly and collaboratively closing the loop, and reaching a circular value chain.

STEP 6 - Tools

CIRCULAR COLLABORATION CANVAS

Together with the information collected in the assessment card from step 4, tools for circular collaboration are suggested. In order to facilitate the conversations and design a circular value proposition together, the Circular Collaboration Canvas designed by Brown (2020) can be used in a creative setting. This canvas was originally developed to identify partners. However, apart from identifying new partners for the collaboration, the questions contained in it can be used as a guide to trigger the alignment.

TEAMS TO BE INCLUDED

- Research and development
- Design
- Logistics
- Procurement
- Management

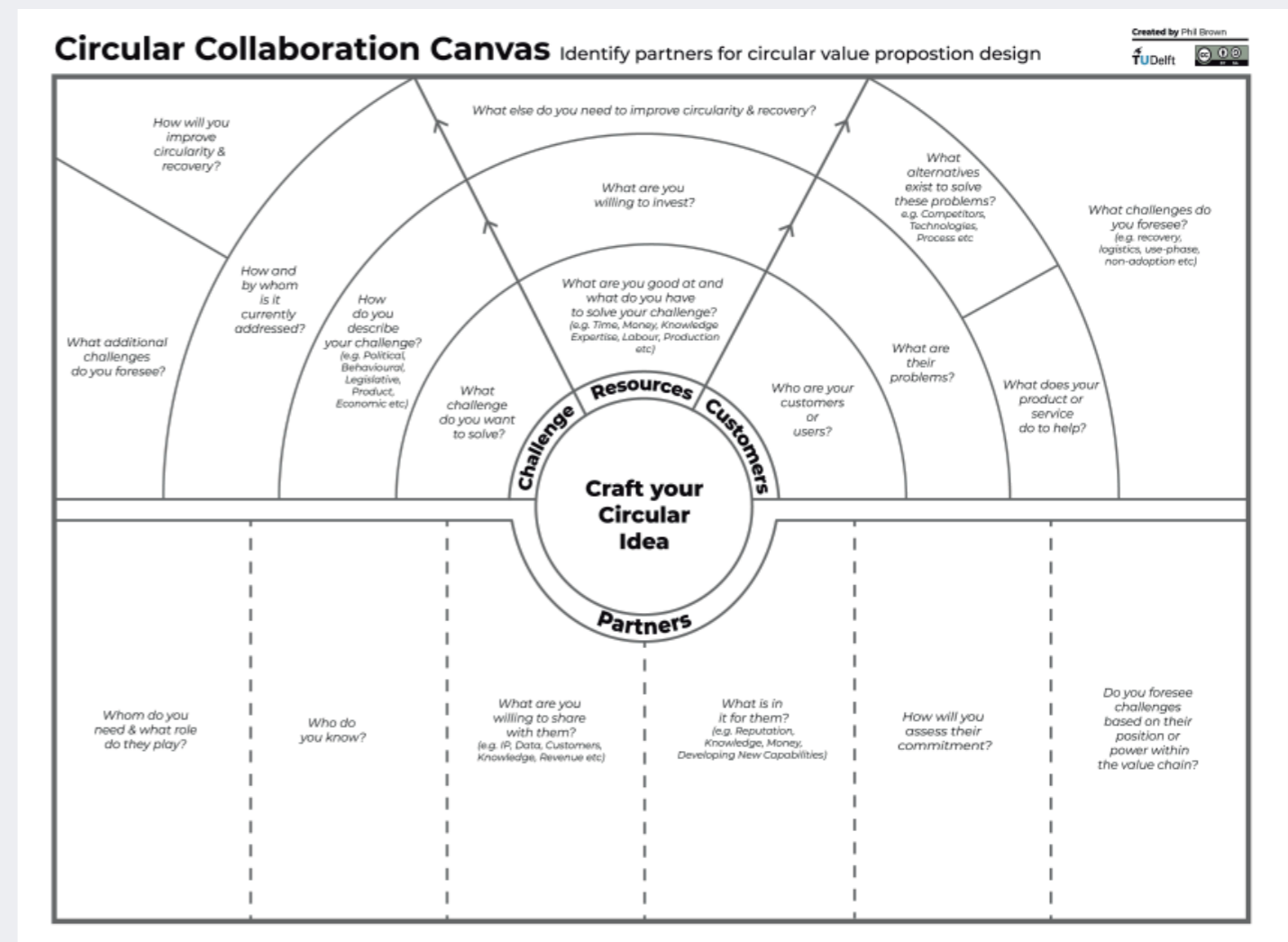
WHAT TO ALIGN ON

- Shared circular vision
- How to collaborate: conditions, limits, meeting frequency, info. exchange...
- What and how the exchange of value will be
- Role of each partner within the Value Chain
- Characteristics of the drafted PSS

Figure 36. Circular collaboration canvas (Obtained from Brown 2020)

OUTCOME

- Circular vision
- Collaboration characteristics
- Exchange of value
- Role
- Defined PSS



7. Discussion

The following section of the report discusses the limitations of the research and the design outcome. Academic and practical contributions are then mentioned, concluding with future research recommendations.

7.1. Limitations of research

In this section the limitations of the present research will be discussed. These limitations will be divided in theoretical background, empirical research, and limitations of the tools and methods.

Theoretical background

The current graduation project presented time and scope constraints which limited the amount of consulted literature. This affected the understanding of the complexity of the topic. The diverse understandings of the circular economy amongst researchers also affected the review, creating a fuzzy scenario where sources had to be differentiated on the basis of how they considered the circular economy and subsequent sustainable development. The majority of consulted literature was focused on sustainability, organizational design, and production, to follow the underlying motivations of the project and ease the translation of the outcomes to the project scope. The main focus being sustainable development in terms of a positive environmental impact rather than economic prosperity resulted in not enough coverage of economic or management issues.

This focus has also constrained the understanding of the existing frameworks to set up value chains. Analysing what other frameworks and methods have been developed without an explicit environmental focus would have benefited the project. The test also made evident that the defined criteria set was not complete enough for organizations. Similarly to the methods, researching selection criteria from other domains and adapting it to the context of this project would have been positive.

Furthermore, the characteristics of the consumer electronics industry created a paradoxical situation where sources for the specific context of the Netherlands had to be combined with the characteristics of a global value chain. On the combination of these two different contexts, some nuance might have been lost.

The research that has been done around the adoption of the circular economy has taken an approach of generating insights from diverse use cases and then generalizing them to overarching barriers and drivers. This made the differentiation between what issues were relevant to the

context of this project and which lacked importance more complex. Additionally, the limited number of publications offering context specific information resulted in some parts of literature review being high-level. These parts were interpreted with previous knowledge and the most context-relevant information was then selected.

Lastly, even though the supervisory team and fellow graduate students helped during the interpretation and reflection of the outcomes, the project was mainly conducted individually. Involving additional people in the process would have increased researcher triangulation, reducing potential bias and improving the reliability of the findings.

Empirical research

In order to make the findings of the literature review more context specific, this project included organizations that are part of the Circular Circuits consortium. The contacted organizations were present throughout the whole value chain of electronic products. However, some organizations were not part of the consumer electronics industry and take a business-to-business approach. Even though the findings were enriching and relevant to the project, the inclusion of more organizations present in the consumer electronics value chain would have provided more context specific insights.

The study also included actors throughout the whole value chain, with an uneven share of representants from different positions. A larger share of organizations in all positions would have benefited the insights, increasing the generalizability of the outcomes. Although a lot of positions were involved, the empirical research lacked 2 crucial members of the value chain: consumers and legislators. Even though the project scope was focused on organizational dimensions, it is undeniable that consumers and legislators play a crucial role in the setup of value chains and adoption of circular strategies. Involving them would have contextualized the insights even more by giving the user-centrism that characterizes consumer products, as well as more overarching conditions that legislation poses.

Lastly, the project included information obtained mostly from organizations that are part of the consortium and organizations that have already focused on circular practices. Involving actors from the consumer electronics industry that do not have a focus on sustainability or circularity would have enriched the insights and provide a method suited for a wider set of organizations.

7.2. Limitations of the outcome

Since the method and tool were designed based on the outcomes of the research phase, the limitations from were also translated to the solution. Overall, similarly to the theoretical background and the empirical research, due to the reduced information around consumer electronics, the context specificity of the solution can still be further improved. However, the current abstraction level of the method allows for organizations to adapt it to different contexts and their own needs. Furthermore, the designed method is subjected to the time, scope, and available resource limitations. Therefore it results in the first version of a method that needs further development. Next, the gaps and limitations of each step and potential improvements are elaborated on.

The first step, self-evaluation and goal definition, presents some limitations. On the one hand, the tool offered to evaluate the circular maturity was directly taken from Acerbi et al. (2021) without adapting it to the current context, since the scope did not include developing criteria to establish the circular maturity of an organization. Therefore, the information offered in each part of the tool is very high level and generic, posing an opportunity to further detail it by including easily measurable elements. Next to this, establishing motivations and goals might require knowledge on the CE that organizations might not possess. Even though a future vision is explained in the fifth step, when organizations lack the aforementioned knowledge, as seen in the barriers, the method could include guidelines to help establish circular goals. Regarding role definition, the method includes the ideal evolution of the role of an OEM within the transition, this is strictly theoretical. Practical implications should be studied and included in order to give more clear guidance.

When drafting a PSS in the second step, coming up with a PSS draft might feel daunting to organizations within a highly product-centric context like the one this project has looked into. In order to improve this, service and PSS related

knowledge might be necessary to offer to organizations. In some cases however, the possibility of drafting just the product part and including the service system parts further down the method should be contemplated. This issue is directly translated to the tools offered in this part, where only templates to fill are offered, without information on the elements that should be in each part.

Even if facilitation is necessary throughout the whole method, it gains critical relevance in step 3 when envisioning a future value chain. This step requires future visioning skills that need to be either trained or facilitated. Without proper guidance, the resulting value chain and involved roles might be inadequate and affect the rest of the steps downstream. This guidance is facilitated by the offered value archetypes, that in turn are based in theory and the conducted interviews. They have not been tested for their effectiveness in providing circular benefits and sustainable development, which creates a need to further develop and test them.

Step 4, assessment of potential partners, has some gaps as well. The step proposes 2 possible scenarios to conduct the assessment. However, the test conducted with an OEM showed that the temptation to only assess organizations that they are already in contact with is very high. This results from the prerogative that they have already contemplated multiple options and that no more exploration is needed. The facilitator and method need to encourage exploring new organizations. As mentioned in the test section, the tool also presents shortcomings in the information it contains. Further tests should be conducted to see if the contained information is enough to provide grounding for the alignment in upcoming steps or if it's not, to find what other information should be included. It is also worth mentioning that the assessment is highly dependent on the transparency of organizations and relies on available information, hampering the assessment if the available information is not of enough quality or quantity.

Regarding the selection of partners in the fifth step, the project lacked testing the selection guidelines in the context of the dutch consumer electronics industry, making them purely theoretical. Only a quick test was conducted with the selected OEM, where the profile of an already existing success story was compared to the ideal organizational profile offered in the first horizon. Even though the partner fit within the ideal profile, further testing needs to be done for all the guidelines. They offer a high-level view of the selection criteria based on the assessment card of step 4. Therefore, it can be extrapolated that similarly to the assessment card, the guidelines require more information.

The alignment step presents the most abstract content of the overall method. Even though information pertinent to the alignment is obtained throughout the method, and the topics that the alignment process should cover are offered, specific guidance as to how to translate and use the information in the alignment dimensions and topics is missing. Moreover, these guidelines should cover scenarios where the selected partners fit all the necessary categories, fit some of the categories or do not fit any category. Furthermore, the tool offered in this step was originally not designed to fit the purpose, but due to its content and questions it was considered that it could serve as a conversation guide. However, this is yet to be tested and new tools for the alignment need to be developed.

Lastly, due to the time and network constraints, the test of the method was conducted with an OEM that is not part of the consumer electronics industry, but fulfils the role established for a user of the method. Hence, even though the insights have helped to improve the method, context relevant testing is lacking. Testing the method with OEMs from the intended context would highly benefit the outcome, both for iterating on it and to validate the outcomes.

7.3. Academic relevance

The current project does not only show relevance in practice but also for academia in multiple ways. On the one hand, it offers an answer to the gap found in literature about how to align partners that want to collaborate within a circularity framework using a value chain perspective. The relationship found within alignment dimensions, categories of drivers and barriers, and organizational boundaries provides a theoretical framework for alignment and collaboration that can be leveraged to research these processes more thoroughly.

Related to the organizational drivers and barriers for the adoption of circular practices, present in sub-question 3 – **what are the barriers and drivers for circularity experienced by organizations in consumer electronic value chains?** – the present project has found an extensive list of 194 issues (Appendix A). This summary of multiple research insights provides researchers with a list of actionable points that can be leveraged for future research regarding the implementation of circular practices.

The designed method as well as the tools do not only cover the need for new methods and tools expressed by Velter et al. (2020) but also combine already existing research using a new perspective. The method extends the process model designed by Brown et al. (2021) to adapt it to a value chain perspective, making its adoption in the industry easier. Within the method, the designed value chain archetypes extend the work by Tukker (2004) making it visual and tangible from a value chain perspective. This does not only help in translating the PSS options described by Tukker into value chain structures, but also poses an opportunity for future scholars to elaborate them further and explore their sustainable properties. Therefore, leveraging existing frameworks, a new method closely focused on the needs of the end user has been developed.

Moreover, the insights used to build the tool included in step 4 of the method has given an answer to the questions posed by Brown et al. (2021): -1) *How can companies assess who are the 'right' people to maximize collaborative COI potential and effectiveness?* 2) *How can companies scope the range of potential partners for COI projects across sectors and value-networks?* The answer is provided by a tool that includes a set of criteria to assess other organizations (Question 1) and focusing on the role of the organization, without any specific sector or value-network focus (Question 2).

7.4. Practical relevance

As this project has highlighted, the implementation of circular practices requires a systemic approach that organizations do not currently have. Collaboration is a vital aspect in this systemic transition, and therefore, value chains based in aligned collaboration between multiple stakeholders present an opportunity for further advancing the implementation of a circular economy to obtain sustainable development.

Research has shown that organizations lack concrete guidelines as well as methods for the implementation of the aforementioned approaches. As shown in the testing with an OEM section, the CVC method has been able to answer some of the needs expressed by actors within the context. By designing a method with a well-defined set of steps and complementary tools, organizations are offered guidelines to set up value chains based in circularity principles.

The method applies language and concepts that are already used by both OEMs and the rest of the actors to facilitate the adoption. It also covers the needs expressed by the organizations by focusing on role definition, as well as establishing criteria that follows the needs that emerge from an alignment process in circular value chains. All this allows initiators and potential partners having well informed conversations and decisions with a set of common criteria. It also offers tools that serve as conversation starters or inspiration, such as the value chain examples or the circular collaboration canvas, and that help to think of possible roles or issues that usually would not come up in a conversation.

As mentioned in the testing with an OEM section, the method was evaluated as having high potential and usefulness for setting up new circular value chains, as well as implementing it in organizational structures, with training and guidance. All the tools that were tested worked as conversation starters, proving their potential to use in practice. However, as mentioned in the limitations, the practicality of the tools still needs to be increased by conducting more tests to define the most adequate information to include.

7.5. Recommendation for future research

While the present project has provided some answers to the landscape of circular value chain setup and alignment, it has also unraveled new research opportunities and potential improvement paths of the current outcome:

ADOPTING A CIRCULAR MINDSET WITHIN THE ORGANIZATION.

The interviews showcased the relevance of an adequate mindset within the organization as well as the value chain to adopt circular practices. Since this is key to the first step of the CVC method, future research should focus in finding ways to help organizations adopt a new mindset as well as the necessary internal structures and dynamics to promote circularity. This track could also be complemented by including how the role of an organization can change to adapt to the new paradigm while leveraging existing capabilities and knowledge.

HOW TO DEVISE A PRODUCT-SERVICE SYSTEM DRAFT ANSWERING MOTIVATIONS.

The second step of the method consists of designing a product-service system draft that will guide the rest of the steps of the method. However, tools that will help organizations translate their motivations and goals into draft propositions that will follow circularity principles are still to become widely adopted. So adding to the already ongoing circular design method research, scholars could investigate the integration in organizations.

COMPARATIVE ANALYSIS OF VALUE CHAIN EXAMPLES AND THEIR EFFECTIVENESS ON REACHING A SUSTAINABLE DEVELOPMENT.

As said in the limitations of the tool, the exemplary circular value chains have not been tested for their effectiveness in long term sustainable development. Further research could conduct a comparative analysis across industries and value chain types in order to assess the impact on the sustainable development through the adoption of circular practices. Ultimately the archetype or example classification could be refined, and more context-specific recommendations provided.

ROLE MAPPING IN CIRCULAR VALUE CHAINS.

To assist OEMs in identifying the roles within evolving value chains, future research could delve in developing more tools to map those roles. The tool offered in this thesis includes a set of exemplary value chains with included roles that help as inspiration, but further research needs to be done in the included roles. The existing tool could also be adapted to service contexts, addressing other potential roles and flows.

VALIDATION AND GENERALIZATION IN THE CONSUMER ELECTRONICS INDUSTRY.

To validate the circular value chain alignment method in consumer-centric industries like consumer electronics, future research should engage in empirical studies. By collaborating with consumer electronics companies and assessing the practical applicability of the method and associated tools, researchers can refine and expand the framework to address the specific challenges and opportunities of this sector.

DEVELOPMENT OF COMPREHENSIVE CIRCULAR ALIGNMENT ACTIONS.

To provide practical guidance for organizations of varying degrees of circular fit, future research can focus on developing comprehensive alignment guidelines. In order to complement the assessment table of step 5, researchers can design a set of actions for alignment based on the company assessment tool and considering scenarios of organizations that present no fit, partial fit, and full fit to the ideal profile for each stage of the 3 horizons.

SCALING AND LONG-TERM IMPACT ASSESSMENT.

To ensure the long-term effectiveness and scalability of circular value chains developed using this method, future research could investigate the long-term impact of the proposed strategies and tools. This could involve comparative studies of value chain that have adopted circular practices and assessing their ecological, economic, and social outcomes over time.

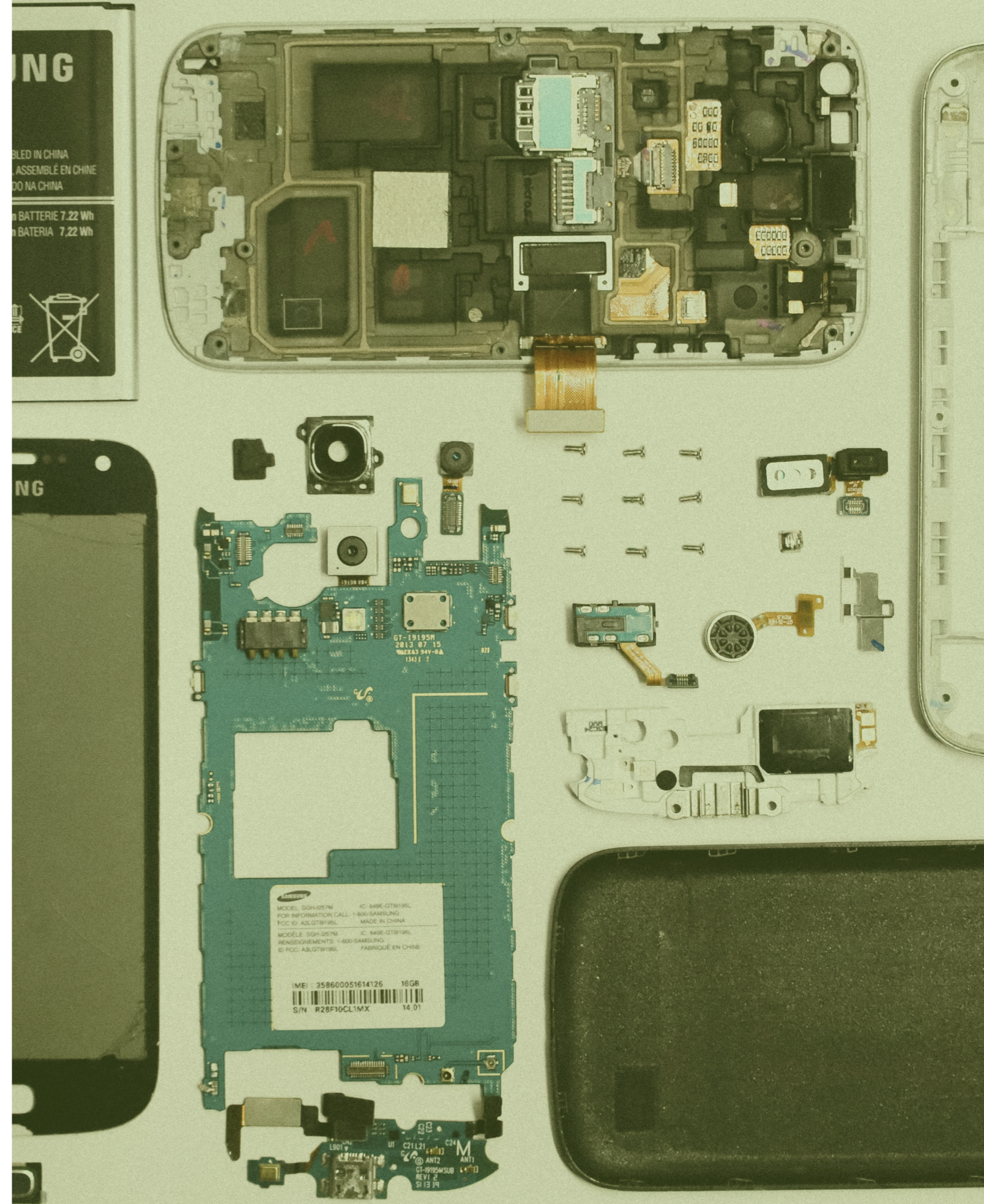


Figure 37. Disassembled smartphone (Obtained from splash)

8. Closing

The present chapter closes the thesis report by offering a conclusion on the overall project and finalising with a personal reflection.

8.1. Conclusion

The present project looked to answer the following research question - How can organizations set up an aligned circular value chain for consumer electronics? - It was addressed by creating a method to set up aligned value chains. The method assumes OEMs to take the initiator role when setting up a value chain and offers concrete steps and tools to make well informed partner selection as well as alignment actions. The value chain perspective of the method involves a more systemic approach than the one taken by organizations currently, offering guidance to adopt a more adequate mindset for the implementation of circular practices. It also aids in considering collaborations that might have not been considered previously throughout the different phases of setting up a circular value chain.

An extensive literature review was initially done. This review covered the current situation of circularity principles and strategies in the consumer electronics industry, as well as in the Netherlands, barriers and drivers for the adoption of said strategies within different categories of value chains, and the different dimensions of alignment within organizational boundary work. These topics were used to generate a framework to guide the alignment of collaborating partners that was used to structure the next stage.

A set of interviews were then conducted helped by the framework from literature. 10 representatives from 7 different organizations from the Circular Circuits consortium were interviewed. These organizations represented different positions of an electronics value chain, as well as organizations from other electronics industries. The gathered insights covered the roles organizations adopt within a value chain, the understanding of Circular Economy, awareness around the organization's environmental impact, barriers and drivers they experience for the adoption of circularity principles and strategies, and the characteristics of collaboration between organizations.

Lastly, a method and subsequent tools was designed to help OEMs set up aligned circular value chains. The method was developed by adapting existing processes and models, such as the one by Brown et al. (2021), to the context of this project and including a value chain perspective that is not common in already existing methods. Tools that guide or help the different steps were either adapted from literature (Brown, 2020; Moon et al., 2013) or developed from research insights. This way, the end user of the method has guidance along all the different steps of the method. The method and tools were then tested in a Dutch OEM, and the insights from the session were used to further improve the method.

Overall, the project concluded with the first version of a method and helping tools that help OEMs when setting up an aligned circular value chain. This outcome sets the starting point to further develop a method that will offer concrete guidelines to OEMs and promote the creation and adoption of circular value chains that promote a sustainable development.

8.2. Personal reflection

Since the beginning of the thesis I realized that I embarked in no simple task. Even though the project started with a different framing, the complexity of the topic was clear since the beginning. The multiple understandings of circularity depending on who you ask made me realize that I had to be really mindful of my own understanding as well as the sustainability approach I wanted the project to have. Keeping these principles as a guiding star throughout the project really helped me in being critical when analyzing the insights and deciding what approaches to follow.

Approaching a project with circularity as means to obtain sustainable development goal in the context of consumer electronics felt scary or even impossible at times. During the research phase, as well as the design phase I became even more aware of how complex the context is. Perceiving the tensions within the industry and amongst different actors made the challenge somehow discouraging at times, but also exciting when thinking of the set of opportunities it offers.

One of the biggest struggles I encountered during the thesis was being weary to move from the research phase to the design phase. The research phase ended with so many actionable insights that moving forward with just a few was a hard step. I usually struggle with leaving the comfort that objective data analysis offers and moving into the uncertainty of following a path that includes personal preference on top of objective data. The lack of knowledge as to what the outcome of the design phase would be was also what was making me wearier on taking the steps, since this involved managing the discomfort caused by ambiguity. However, this project has helped me in believing in my designer skills and finding my place within the ambiguity.

When it comes to writing, I have usually been quite the extensive writer. I tend to offer a lot of information so that the reader also has the option to analyse the content and compare their conclusions with the insights I offer. However, throughout this thesis, I have realized that being concise and offering the right amount of information for the reader to understand the project is one of the most crucial actions. Letting go of the extensive literature review I wrote during the research phase was not easy, but it helped me in making a coherent project, both for the readers as well as for myself.

Reflecting on how my process has looked like, I have been reassured of my time management skills. I have been able to balance my personal time and hobbies with the structure I needed to finalize the project and be satisfied with the outcome.

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Appendix overview

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