Master Thesis

A Foundation for Decision Support for Logistics Challenges in the transition to Circular Business Models in the Manufacturing Industry

Mara Mooij
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Ministerie van Economische Zaken en Klimaat
Directoraat-Generaal Bedrijfsleven en Innovatie TOP (DGBI-TOP)
Uitvoeringsprogramma Circulaire Economie (UPCM)

Jeannette Levels-Vermeer
Matthéüs van de Pol

University of Twente
Faculty of Behavioural Management and Social Sciences (BMS)
Industrial Engineering and Business Information Systems (IEBIS)

Dr. D.M. (Devrim) Yazan
Dr. L. (Luca) Fraccascia

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Dear reader,

With this thesis, I finish my master Industrial Engineering and Management and with that my time as a student at the University of Twente comes to an end. My life as a student in Enschede was wonderful thanks to the unforgettable moments I got to experience. I am really grateful for the great friends that I have met, and I am very proud of the personal and professional development that I have achieved.

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Summary

The Dutch government set the goal of an entirely circular economy (CE) by 2050. National goals do not provide sufficient guidance for firms due to the differences between industries. Five transition agendas represent the main industries with a differentiated set of goals. This research concentrates on the transition agenda of the manufacturing industry with a focus on the metal industry. Companies in this industry have a high potential for CE. One of the promising concepts is urban mining, which offers a contribution to exploiting the potential of companies transitioning to circular business models.

However, companies struggle to make the transition. CE is a concept which has been around since the 1960s. Research on CE and business models is widely present, but the transition is very complex as it requires new logistics strategies. Logistics concepts that are essential to CE exist such as the closed loop supply chain and reverse logistics. Nevertheless, they are not widely discussed in academic literature in combination with CE. There is still a considerable gap between the theory and the implementation process. As a result, companies that intended to or started to implement CE lack knowledge and capabilities that support decision making in the execution of circular busines model strategies. This resulted in the main research question:

What logistics concepts that are applicable to companies in the metal industry can be incorporated in a tool in order to support decision making in the execution of circular business model strategies?

The goal is to establish the foundation for a tool, which consists of logistics concepts that provide solutions for the challenges that companies face. To achieve this goal, this research was conducted in an iterative way. First, the current situation is analysed to create an overview of the existing challenges that retain for companies in the metal industry. Then, literature on logistics concepts and circular strategies is used as a starting point for a literature review on circular logistics networks. This helped identify opportunities to overcome logistics challenges. Subsequently, literature on decision support methods is reviewed to build the foundation of a decision support tool for this specific problem. Data of interviews, held amongst eleven employees of companies in the metal industry, is used to determine the content of the tool. Then, a conceptual version of the tool is made in Excel. Finally, the tool is evaluated by ten of the companies that rated 26 statements on a five-point Likert scale.

The format of the decision support tool is based on an ‘if-then’-construct, which provides the user with a direction for a circular approach: given the input that the user provides, a certain output represents the advice for a circular approach. The input consists of 19 questions divided into the four topics: general, company characteristics, product characteristics, and logistics and reverse logistics. The output consists of five strategy factors that form the advice: recovery strategies, product level, product category, place of recovery and method of collection. The companies evaluated the tool on format, content, logic, and use. The overall average rating given by the users is a 3.3 out of 5, which means they have a positive attitude towards the tool. According to the respondents it takes minimum effort to use the tool as it was easy to understand and use. However, based on the results improvements can be made regarding the presentation of the advice and the format of the tool.

A foundation for the tool is proposed in this research. It can be used to further develop the tool by considering three points of improvement. First, the content of the tool is too general and should be designed for a specific target group within the metal industry. Mechanical engineering could provide as a suitable starting point. Second, the format and application of the tool should be reconsidered. It is suggested to transform the tool into a MCDA method. Third, the user should be provided with advice that contains context and guidelines. This enhances the user experience and acceptance of the tool. In order to complete the foundation of the tool, an addition of three topics is recommended: costs, legislation and environment. The findings of this research indicate a foundation for decision support for logistics challenges in the transition to circular business models in the manufacturing industry.

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Abbreviations and Terminology

Terms

Circular strategies R-strategies or Recovery strategies

Abbreviations - General

CE	Circular Economy
CLSC	Closed Loop Supply Chain
EOL	End-of-Life
DSS	Decision Support Systems
MCDA	Multi-Criteria Decision Analysis
MinEZK	Ministerie van Economische Zaken en Klimaat
OLSC	Open Loop Supply Chain
PBL	Planbureau voor de Leefomgeving
RL	Reverse Logistics
UPCM	Uitvoeringsprogramma Circulaire Maakindustrie

Abbreviations - Survey and Tool

CM	Critical Materials
EOLH	End-of-Life Harm
EOLV	End-of-Life Value
HM	Hazardous Materials
MV	Market Value
PC	Pace of Change
PL	Product Level
R	Returns
Qly	Quality
Qty	Quantity
S	State
TV	Technical Value
U	Users

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1. Introduction

This research is conducted at the request of the Ministry of Economic Affairs and Climate Policy (Dutch*: Ministerie van Economische Zaken en Klimaat, MinEZK*). The ministry aims to create and provide an excellent entrepreneurial business climate in order to promote the Netherlands as a country of enterprise with a strong international competitive position and an eye for sustainability (Ministry of Economic Affairs and Climate Policy, 2020). Considering that the ministry encourages the cooperation between research institutes and businesses, it is a convenient organisation to conduct this research into the facilitation of companies transitioning towards circular economy (CE). The assignment for this research is commissioned by a program within MinEZK, which is called Uitvoeringsprogramma Circulaire Maakindustrie (UPCM). It is a program that is developed to work on the goals of the government to achieve a circular economy in the Netherlands by 2050. The goals are translated into transition agendas (Dutch: *Transitieagenda's*), which represent five priority chains: biomass and food, plastics, construction, consumer goods, and the manufacturing industry. UPCM works on projects that are focused on and conducted within the manufacturing industry.

In this chapter, an introduction to this research is given. The background of the problem is covered in Section 1.1. The problem statement is described in Section 1.2. This leads to the research objective which is described in Section 1.3. The outline of the research is explained in Section 1.4. To conclude this chapter, the academic and practical contributions of this research are discussed in Section 1.5.

1.1 Problem Background

The implementation of circular business models requires new logistics strategies. While a lot of information on this topic is available, the use of this information is limited. Currently, many logistics concepts exist that can be applied to CE. Examples of these concepts are closed loop supply chain (CLSC) and reverse logistics (RL). These are used when applying specific R-strategies (Potting, Hekkert, Worrell, & Hanemaaijer, 2016). A more general term for R-strategies is circular strategies or recovery strategies. Authors and researchers use many different sets of R-strategies and define the strategies differently. Potting et al. (2016) identified the following ten strategies: refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, and recover. The first three strategies are used to produce and use a product in a more efficient way. Strategies four to eight aim at elongating the life cycle of the product and components. The remaining two strategies contribute to efficient use of materials.

These circular strategies, except for refuse, rethink, and reduce, demand new and different approaches regarding logistics. Besides the traditional forward supply chain activities, additional activities of the reverse supply chain must be included. This inclusion of logistics of the return process, is what CLSC entails. An example of an additional activity is product acquisition to collect the products from the end-users (Guide, Harrison, & Van Wassenhove, 2003). Reverse logistics move products from the point of use to a point or multiple points of disposition (Guide et al., 2003). A lot of research regarding these topics has been conducted but the times it has been applied is few. Moreover, the application of these topics cannot be done one on one.

This research consists of finding and bundling all relevant information on reverse logistics that contribute to enabling CE in the manufacturing industry. This information is being transformed into a tool that helps companies to progress towards being circular. UPCM mentions that there is a lot of information, but there is a lack of practical advice and tools for companies to make the step towards a circular business process. The team uses this research as an opportunity to contribute to the goals of the government to achieve a circular economy in the Netherlands by 2050.

1.2 Problem Statement

Companies indicate that the concept of CE is useful, but reverse logistics are time consuming and complex to organise. Companies are organised to distribute products to the market, not to retrieve them. Operational excellence is often arranged in such a way that a product is manufactured and exported, and when it breaks down it will be replaced by a new product. Therefore, it is often easier to purchase a new product because it is cheap and reliable. Furthermore, it is possible that retrieving a product and redistributing a product is less environmentally friendly than sending a new product. Therefore, reverse logistics are considered a limitation in achieving CE in the manufacturing industry.

Another problem is that companies do not know where to start. The logistics of retrieving products (upstream the supply chain) is not necessarily the same as the reverse of distributing products (downstream the supply chain). Moreover, the act of retrieving products leads to a change of business's their set of operational processes, like maintenance and reparations. The scope of this project is limited to the reverse logistics that are a result of the operational process. This means that there is no focus on the manufacturing process: neither production nor maintenance. The part of the supply chain, that is included in the scope of this project, is the moment when the product is distributed to the market and all activities hereafter. Companies have trouble to redesign their operational processes and supply chain as well since their products might not fit in such a strategy. It is difficult to find a strategy that fits the circular concept when products are still linear. On the other hand, when the products have circular features, the supply chain must be suitable for these products.

To achieve circularity in the supply chain, companies and industries must be linked to each other. This means that knowledge of the demand and supply of companies and industries must be present and used. However, in general, companies are lacking this knowledge as obtaining this type of knowledge is not the core activity of companies. When these challenges of knowledge can be overcome, there are still financial and logistics issues for which a solution must be found.

In summary, the core problem is that business lack knowledge to identify opportunities in circular strategies and organise reverse logistics such that these strategies can be successfully implemented. A lot of information is available, but it is not processed and used in a way that it can support companies in renewing their business models. Currently, there is gap between the existing knowledge and the practical implications of this knowledge.

1.3 Research Objective

The research problem reflects the knowledge needed to solve the core problem. The problem is formulated as a question as well as a goal and reflects what is addressed in this research.

The main research question is:
What logistics concepts that are applicable to companies in the metal industry can be incorporated in a tool in order to support decision making in the execution of circular business model strategies?

The main research question consists of two sub research questions:
What logistics concepts are applicable to companies in the metal industry that aim to execute circular business model strategies?

How to design a decision support tool for logistics challenges of companies in the metal industry that aim to execute circular business model strategies?

The research goal is as follows:
Establish a foundation for a tool consisting of logistics concepts and circular strategies that are applicable to companies in the metal industry in order to support decision making in the execution of circular business model strategies.

To actually build the tool, many iterative steps are necessary. As the research goal is to establish a foundation for the actual tool, the first steps are conducted within the scope of this research. The nature of this research is incremental as to achieve this goal. The first step is to find relevant knowledge and logistics concepts in literature that can be applied to the organisation of circular logistics in the manufacturing industry.

This way opportunities can be identified for the manufacturing industry and incorporated in a tool. As a result, knowledge becomes available in a way that can be used by companies. The tool should help companies to transition towards CE by executing a circular business strategy. To successfully develop a tool, it is necessary to select a target group in the manufacturing industry and identify their needs. This cluster represents a relevant group of companies in the metal industry and defines the scope of the research.

The next step is to establish the foundation for developing an actual tool. For this purpose, the format, the content and logic will be defined. This research objective is divided into three stages. First, insight must be obtained in the companies and their products. This way information about the organisation, the challenges and the opportunities of a specific supply chain can be determined. The second stage consists of using this information to develop the tool and use it in a business case kind of setting. During the third stage, the tool will be evaluated.

1.4 Research Framework

In this section, five research questions are formulated that need to be answered to provide an answer to the main research question and the two sub research questions. The research questions are used as the outline of this research: each chapter corresponds with a research question.

Chapter 2: Problem Context

This chapter covers the context of the problem regarding companies in the metal industry. It describes the current situation of companies that are shifting to CE. The research question is as follows:

How does the current situation retain barriers for implementing logistics that facilitate the transition of companies to CE?

The objective is to identify problems and limitations that companies experience in the current situation. It provides insight in the logistics issues of the current situation. Furthermore, it contributes to the knowledge of what companies need in order to implement circular business models and make the transition to circular strategies. Given the current situation, this knowledge provides input of how companies cope with the current situation. From this, it can be derived what is holding back companies to make the transition and implement CE strategies.

The method that is used to find an answer to this question is partly desk research. This method aims to collect factual information and existing data to find answers to explanatory research questions. Reports published by the government and the Netherlands Environmental Assessment Agency (Dutch: *Planbureau voor de Leefomgeving, PBL*) are used. In addition, literature research is used to obtain a complete overview.

Chapter 3: Literature Study

This chapter provides in depth knowledge of relevant concepts concerning this research. It creates an overview of the current research topics. The research question is as follows:

What logistics concepts and circular strategies exist that support companies in implementing a circular business model in order to facilitate the transition to CE?

The objective is to build a foundation of theoretical knowledge of the topics covered in this research. It allows to achieve consensus on ambiguous definitions. Furthermore, by operationalising the topics these can be used as input in a later stage of this research. This creates a better understanding of these concepts and provides a state-of-the-art knowledge of the field of research.

The method that is used is a literature study in the form of a semi-systematic literature review. This method is designed for topics that have been conceptualised in different ways and it provides insight in how the topic evolved over time. This contributes to identifying and understanding the topics necessary for this research (Snyder, 2019).

Chapter 4: Decision Support Methods

This chapter explores relevant decision methods that are present in literature. This creates an overview of the different types of methods that already exist and expands the knowledge of the different types regarding the design process and features of methods. The research question for this chapter comprises two sub research questions:

What type of methods exist that provide decision support?
What type of method should be used?
What features should be included in the tool?

The objective is to discover possible methods that could contribute to solving the core problem. The decision support tool should include the right features to reach this goal. Knowledge of different methods should provide a basis to build a new suitable tool for this specific research. This contributes to defining the format, content and logic of the tool.

The method that is used is an integrative literature review. This method assesses literature and enables new frameworks and perspectives to emerge. As the topic of this research is rather new, this type of review can create preliminary conceptualisations. The result is an advancement of knowledge and frameworks rather than simply an overview (Snyder, 2019). The outcome is a framework on how to develop a tool for this specific research.

Chapter 5: Tool Development and Assessment
This chapter gathers information from companies that have made a transition from a linear to a circular business model. This data provides additional information that is valuable to include in the tool. The research question is as follows:

What content and logic should be incorporated in the tool based on business cases of companies in the metal industry that made a transition from a linear to circular business model?

The objective is to obtain knowledge from practice via business cases. Companies that recently have made a transition from a linear to circular business model provide information, so that the content and logic of the tool can be determined. It fills the knowledge gap that is left after reviewing the literature.

The method that will be used is a survey with open and closed questions. Closed questions allow for easy comparison, while open questions leave room for additional information and feedback. The surveys will be conducted as a structured interview. This approach guarantees a similar interpretation of questions and answer possibilities. Moreover, it retains an interactive character to allow for questions and feedback.

Chapter 6: Tool Evaluation
This chapter collects data on the experience and evaluation from users who used the tool. As a new tool is being developed, it is useful to include the intended users. The research question is as follows:

How do companies in the metal industry perceive the use of the designed tool regarding the format, content and logic?

The objective is to find out whether the tool is considered useful by the user and how the tool can be improved. The data should provide insight in the willingness of companies to use the tool and to what extent it helped companies to decide on logistics issues in implementing a circular business model strategy. To gain this insight, questions will be asked regarding the format, the content, the logic and use of the tool. Companies will be given the opportunity to provide feedback and additional information.

The method that will be used is a quantitative approach. It is a survey with statements that have to be rated on a five-point Likert scale. Besides, open questions in the survey allow respondents to provide additional feedback.

Chapter 7: Discussion and Conclusion
Together, the answers to the aforementioned research questions provide an answer to the main research question and the two sub research questions. This is covered in Chapter 7, which provides the discussion and conclusion of this research.

1.5 Academic and Practical Contributions

It is relevant to research the connection between the concepts of CE and logistics, and determine the foundation for a decision support tool for both academic and practical reasons.

From an academic perspective, several reasons exist to conduct this research. First, the concept of CE has been around for a while and poses numerous benefits. However, it is evident there is still a considerable gap between its theory and the implementation process (Kumar et al., 2019). While companies intended to or started to implement CE, they face several barriers in the implementation process of CE and often struggle to mitigate their effects. Many companies are also not well aware of the potential opportunities that CE presents (Ellen MacArthur Foundation, 2013; Kumar et al., 2019). Second, a lot of research on reverse logistics and the resulting CLSC is done. These are essential to CE, but they are not widely discussed in academic literature in combination with CE. Only a very limited scope of sustainable supply chain network design is present (Werning & Spinler, 2020). Third, Kumar et al. (2019) state that implementing CE successfully and effectively can be achieved by horizontally and vertically implementing CE. Horizontal implementation includes industries, urban infrastructure, cultural environment, and social consumption systems. Vertical implementation of CE consists of enterprises on a micro level, industrial parks on a meso level, and cities and regions on macro level. To successfully implement CE, the process should start from a micro level with enterprises. Each level forms a basis for the following level. Eventually, the macro level should be embedded such that sustainable economic growth and development is made possible (Kumar et al., 2019). This is supported by Werning and Spinler (2020), who express the need for further research on firm-level as this is needed to foster the transition to CE. Since CE was developed using a primarily system-oriented perspective, most publications are relatively closely linked to this perspective. Fourth, a change in the design of business models is necessary as most current business models focus on the volume of sold products. A different approach is necessary for circular business models. Whereas research on business models and CE is widely present, the transition to CE is very complex. There is not one simple approach for overcoming barriers to its implementation (Werning & Spinler, 2020).

From a practical perspective, the following reasons are important to conduct this research. First, existing literature and business cases are combined to build the foundation of the tool. The format, the content, and the logic of the tool can be determined. The tool is designed specifically for this research and such a tool did not exist before. Second, as such a tool did not exist and a conceptual version will be made, the outcome of this research offers a basic product for UPCM to adapt and include in their program. Third, the foundation of the tool helps companies to overcome barriers and create a tailored circular business strategy that fits their product group and supply chain. This also contributes to the goals of UPCM to offer support for companies that are eager to transition towards CE. Fourth, the contribution to UPCM's goals are contributing to the set goals by MinEZK and the government of helping the Netherlands become circular in 2050.

2. Problem Context

This section provides an answer to the first research question:

How does the current situation retain barriers for implementing logistics that facilitate the transition of companies to CE?

In Section 2.1 an introduction to the current situation and the need for CE is described. A definition of CE as well as the opportunities and applications of CE are covered. In Section 2.2 the scope of this project is demarcated by the focus of UPCM and its transition agenda, which is the manufacturing industry. An explanation of this industry and its opportunities are described. In Section 2.3, the barriers known to the manufacturing industry are elaborated upon. Based on the literature found and the focus of UPCM a further demarcation to the metal industry is chosen, which is explained in Section 2.4. It elaborates on the potential of urban mining in this industry as the focus of this research.

2.1 Current Situation and CE

The amount of resources that is used worldwide, has increased eightfold in the past century. It is estimated that this trend will continue the coming decades. The result is an ever-rising impact on the environment and on the supply uncertainty. Examples of environmental impact are CO2 emissions, waste, and negative effects on quality of air, soil and water (Kishna, Rood, & Prins, 2019). Furthermore, the increase in use of resources leads to risks in supply uncertainty (Dutch: *leveringszekerheidrisico's*). This is mainly a matter of concern regarding resources that are critical. Critical resources are characterised by two factors: high risk in supply and high economic value. However, the scarcity of these types of resources is often not a result of physical extraction. Common causes are serious price fluctuations and the locations of the critical resources, which are often either very few in number or hard to reach. The dependency on resources and the uncertainty it entails, especially when imported from a foreign country, results in risks for a country's economy (Kishna, Hanemaaijer, et al., 2019; Kishna, Rood, et al., 2019).

The current situation is a result of today's linear economy that is the engine of the world's industrial development. It is an economic model that follows a 'take, make, dispose'-mechanism, which relies on large quantities of cheap, easily accessible materials and energy. The increased price volatility, growing pressures on resources, and supply chain risks are reasons to rethink the current system. In contrast to a linear economy, CE is restorative and regenerative by design. The aim is to keep products, components, and materials at their highest utility and value at all times (Ellen MacArthur Foundation, 2015).

Whereas CE is considered as a new concept in economic development, it has already been around since the 1960s. The idea of CE was based on the fact that the earth is a cyclical ecological system and that circularity is necessary to facilitate constant reproduction (Kumar, Sezersan, Garza-Reyes, Gonzalez, & Al-Shboul, 2019). In general, CE aims at increasing resource utilisation while fostering sustainability. However, over the past decades many different explanations of CE have been proposed, which means CE is not yet well defined (Werning & Spinler, 2020). A comprehensive definition of CE is provided by Kirchherr, Reike, and Hekkert (2017, pp. 224-225): *"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."* From this definition, it can be derived that circular activities have possible advantages concerning the environmental, economic, and social perspective.

All actions that lead to an increase in efficient use of resources and materials can be perceived as circular activities (Kishna, Rood, et al., 2019). The most common triggers for circular activities are regulations and legal demands, customer demands, response to stakeholders, and competitive advantage. Two other triggers might be environmental and social pressure groups, and reputation loss (Seuring & Müller, 2008). Implementing CE leads to opportunities for economies, companies and users (Ellen

MacArthur Foundation, 2015). Economies will gain net savings on material and energy costs, improved mitigation of volatility and supply risks, higher multipliers due to sectoral shifts and reduced externalities. Companies have the opportunity to create new profit pools and competitive advantage, build resilience against some of today's most strategic challenges, and expand from their respective starting situations. Consumers gain more choice, enjoy the extended lifespan of purchased goods, and benefit from improved service quality (Ellen MacArthur Foundation, 2015).

Implementation of CE can happen in various ways. Value Hill, CIRCO and LogiCE describe applications of CE and business models that foster CE (Achterberg, Hinfelaar, & Bocken, 2016; CIRCO, 2015; LogiCE, 2019). A common important factor in implementing these business models successfully is logistics. The applications and implementation of CE business models are mainly based on R-strategies (Kishna, Rood, et al., 2019; Potting et al., 2016). Most of these strategies require a change in the organisation of a firm's logistics. Concepts as CLSC and reverse logistics provide solutions in organising the reverse supply chain.

2.2 The Transition Agenda of UPCM

The goal set by the Dutch government is an entirely circular economy by 2050. The goal of a circular economy consists of three main targets. The first target focuses on decreasing the input of resources. The second target concerns the life cycle expansion. The third target is aimed at decreasing the amount of resources that leave the chain. These targets should contribute to decreasing the environmental impact and the risks in supply security (Kishna, Hanemaaijer, et al., 2019). The government has set an intermediate target by 2030. The use of minerals, metals and fossil resources (e.g. primary abiotic materials) should be reduced by 50 per cent (Kishna, Rood, et al., 2019).

The national goals require a differentiation into transition agendas and product groups. National goals do not provide sufficient guidance for firms. The differences between specific domains or product groups or both are of such relevance that a bottom up approach is needed. For example, relevant negative effects of plastics are mainly litter and CO2 emissions, while in the manufacturing industry a wide range of other effects is present as well. Besides effects on health and environment, the industry also copes with risks in supply uncertainty. Different effects call for different approaches and goals that are relevant for a specific domain (Kishna, Hanemaaijer, et al., 2019). The general approach of transitioning towards CE has a focus on the input, use and output of resources and products. In this respect, not only the volume is considered but also the value of the materials. Moreover, there is a focus on the effects that the implementation of CE can yield. In conclusion, there is a multi-faceted approach on a national level as well on transition agenda and product group level. The national goals are used to identify differentiated goal sets for the specific transition agendas and product groups (Kishna, Hanemaaijer, et al., 2019).

The transition agenda of UCPM concerns the manufacturing industry. This industry is responsible for the production of various commodities. For example, transforming materials into machines, electronics and means of transport (Transitieteam Maakindustrie, 2018). Moreover, the manufacturing industry also consists of sectors in food, beverage and luxury foods, furniture, paper, leather and metal (Kishna, Rood, et al., 2019). Transitieteam Maakindustrie created a model to classify products of supply chain links within the Manufacturing Industry. The products are categorised in five target groups or clusters: capital goods, consumer goods, products, consumables, and construction materials (Transitieteam Maakindustrie, 2018).

Kumar et al. (2019) state that the implementation of CE in the manufacturing industry can yield promising results. In the EU alone, the estimated result in net material cost savings is around \$340–630 billion per year for complex durable goods with medium lifespans. This is roughly 12-23 per cent of current material input costs in these sectors. A global potential is estimated at \$700 billion per year in material savings for consumer goods, which is about 20 per cent of the material input costs in these sectors. As a result of recycling, waste prevention and eco-design policies, 6-12 per cent of all material consumption in the EU, including fossil fuels, was being avoided in 2016. Besides material and cost savings, it is estimated that CE activities will result in 178,000 new direct jobs by 2030 (Kumar et al., 2019).

In 2019 PBL conducted a study to map circular activities in the Netherlands (Kishna, Rood, et al., 2019). The findings show that circular activities and jobs cover 5 and 4 percent of the Dutch economy, respectively. While non-governmental organisations contribute by creating awareness and citizens by focusing on local activities, most activities are carried out by firms. Circular activities in the manufacturing industry are aimed at semi-manufactured products or manufacturing processes. However, the transition to CE is in an early stage and this makes it hard for firms to shift towards circular business strategies (Kishna, Rood, et al., 2019).

2.3 Logistics Challenges in the Manufacturing Industry

The number of logistics types and the logistics' complexity increases when organisations transition from a linear to circular business model. This increase leads to an increase in the barriers and challenges that companies encounter (Polet, Van Aspert, & Huitema, 2020). Researchers have identified a variety of barriers in the manufacturing industry. The worldwide classifications of barriers on firm and system level are discussed in this section, while narrowing it down to national barriers that concern supply chain and logistics challenges.

On firm level Seuring and Müller (2008) found three categories of barriers: higher costs, coordination complexity, and insufficient or missing communication in the supply chain. These categories all concern the company's operations.

Another approach is taken by Kumar et al. (2019). They included the system level and categorised barriers according to either a socio political, economic or environmental perspective. The main socio political barriers are low level of awareness, lack of knowledge, and lack of understanding of CE. These exist on consumer, company and governmental level. Regarding the content of this research, the three most important barriers in this category are the lack of knowledge and skills of companies, the poor accountability of local governments, and an inadequate legal system. The main economic barriers are high investments, lack of financial suport mechanisms, available incentives to promote sustainable activities, and lack of appropriate partners in the supply chain. Environmental barriers concern insufficient technology and capacity to perform circular strategies (Kumar et al., 2019). According to the results of the survey of Kumar et al. (2019), which they have conducted amongst 63 companies in the EU and the UK, the lack of governmental incentives is the greatest external barrier (29%) followed by lack of customer interest (26%), inadequate policies and regulations (26%), and unavailability of appropriate partners (23%).

In the Netherlands, PBL identified five barriers that hamper the transition to CE. First, consumers prefer new products over used products, because they are considered to be better. Second, people tend to throw products away instead of reparing them, since this is a habit. Third, no charges for negative environmental impact are reprimanded: environmental impact is not entirely included in the price of raw materials and products. The cheap price causes a lack of incentive for manufacturing companies to invest in efficiency. Fourth, as the setup of current rules and regulations are focused on linear business strategies, they can hinder companies that carry out circular business strategies. The fifth and last barrier, stems from the fact that investors are not keen on investing in circular activities of companies because they are lacking awareness of circularity and questioning the returns of an investment in circular activities (Rood & Kishna, 2019).

Versnellingshuis Nederland highlighted the company perspective, by listing the five most frequently posed problems by companies. First, companies indicate that they have trouble creating and adapting their business models for circular strategies. Second, positive effects of implementing circular strategies are only visible at other actors of the supply chain. Third, despite their circularity, companies do not experience a competitive advantage in tender procedures. Fourth, the down-stream and consumer demand are too low. The last problem is that regulations and financial subsidies are still too focused on linear strategies (Versnellingshuis, 2020).

Barriers should be described rather on firm level than on system level according to Werning and Spinler (2020). They believe this is necessary to foster and accelerate transition to circular economy business models. They identified three broad-sub areas as possible sources of barriers: shifting towards CLSC, network design, and uncertainty of returns. A CLSC requires reverse logistics, which potentially entails high costs and management attention. The network design consists of decisions regarding the integration of the reverse logistics network into the existing forward supply chain or the set-up of two separate supply chains. Another decision regards the organisation of direct or indirect reverse logistics. Direct reverse logistics refer to taking back products directly from customers. Indirect reverse logistics refer to the collection of used products via third parties. The uncertainty of returns concerns both the quality as well as the quantity of returned products (Werning & Spinler, 2020).

Polet et al. (2020) describe barriers as logistics challenges in four distinguished flows. The first flow is distribution logistics, which concerns activities as warehousing, inventory management, and transportation. One example of a challenge is the need for reviewed transportation methods due to changes in products like adjusted shape, size, weight or materials. Another example is that a change in product and service, like rent or pay-per-use, leads to different needs for logistics. The second flow is service logistics, which relates to maintenance activities and recovery strategies. This flow increases as a result of increasing circular strategies. An increase in service logistics results in higher complexity and higher costs. The third flow is reverse logistics, which relates to End-of-Life (EOL) handling of products. The organisation of reverse logistics can be complicated by current (inter)national laws and regulations regarding presence, transport and handling used products. Another example is the allocation of reverse logistics. Also, reintegrating products into the manufacturing process is difficult due to the uncertainty and complexity of returned products. The fourth flow is third party and reverse logistics, which refers to logistics that are not taking place in the initial supply chain. A challenge is to decide whether to keep products in its original value chain or not. It might be better to keep a product in its original value chain, although a lower level of circularity is established. Another challenge is to connect supply and demand. The final challenge that is mentioned concerns the need for marketplaces where companies can exchange new and used materials, components and products (Polet et al., 2020).

2.4 The Metal Industry and Urban Mining

Based on the assignment of MinEZK this research focuses on the metal industry. UPCM has business cases available that are suitable to generate input data for the content and logic of the tool concerning logistics challenges in implementing circular business strategies. Furthermore, this industry is suitable for the goals of this research for several reasons.

The metal industry is the fourth biggest industry in the Netherlands. The size of this industry has been slowly increasing over the past two decades. Sectors within this industry are the metal construction products industry, the metal working sector, and other metal products, tools, forges and rolling mills (Van Gessel-Dabekaussen, 2018). Metals are one of the major materials upon which economies are built. Both mass applications of metals and specific applications of metals for innovation led to a rapid grow of the use of metal during the twentieth century. A lot of metals will be needed in the future, but it is not easy to provide them. In the Netherlands hundred per cent of the metals are imported, which means the supply risk is high (CBS, 2020; Van der Voet, 2020). Furthermore, Statistics Netherlands (Dutch: *Centraal Bureau voor de Statistiek, CBS*) mentions that metals are scarce and it costs a lot of energy to extract metals, which leads to high CO2 emissions. Options to reach CE include keeping metals in use for a long time, to avoid having to mine new ones (Van der Voet, 2020). Almost every kind of metal can be recycled infinitely without degradation of properties, which makes it a suitable product for circular strategies. However, there are some challenges. Due to these properties the products do not break down: they are functional and reliable. As a result, they are not presented to be recycled. Limits are imposed as well by social behaviour, product design, recycling technologies, and the thermodynamics of separation (Reck & Graedel, 2012). While the industry is large and the potential is high, the number of companies focusing on CE is low.

The concept of urban mining offers a contribution to exploiting the potential of companies transitioning to CE in the metal industry. EOL products, buildings and infrastructure consist of much material that can be reused. This is considered as the ‘urban mine’. The purpose of urban mining is to cover the demand of raw materials by using the products of waste flows. Ghosh (2020) describes that this provides a considerate potential to shift from extraction to reuse and recycling of raw materials. Urban mining is a new approach towards recycling, which is necessary due to high volatility of resource prices, heavy pollution of primary production, resource productivity and sustainable use of natural resources. Materials within the urban mine might contain a significant source of resources, with concentrations of elements often comparable to or exceeding natural stocks. Electrical and electronic wastes contain relatively high concentrations of expensive metals and rare earth elements. Urban mining focuses on these material stocks as they are considered as potential assets instead of waste. The need for this vision appears from the fact that material stocks containing elements like, for example, copper are now globally comparable in size to the amount of natural resources. Another fact is that half of the amounts extracted to date of base metals such as iron and copper are no longer in use. Urban mining should contribute to resource conservation, environmental protection, and economic benefit generation. The large stocks of materials that cities hold are to be found in buildings, infrastructure, landfills and households (Ghosh, 2020). Urban mining generates many opportunities to seize and many challenges to overcome in executing new circular business models.

2.5 Conclusions

Today's industrial development is still thriving on a linear economy. Companies try to make the transition to CE to increase resource utilisation while fostering sustainability. The implementation of CE into business models requires a change in the organisation of a firm's logistics. The shift from a linear to circular business model is hard as the transition is at an early stage and the number of logistics types and the logistics' complexity increases. Companies face challenges on both system and firm level. The first category concerns socio political, economic, and environmental barriers. The second category concerns challenges such as higher costs, coordination complexity, communication in the supply chain, but also challenges that concern distribution, service, reverse and third-party logistics. Barriers should be tackled on a firm level rather than on a system level in order to accelerate the transition to CE. This way, challenges in shifting towards CLSC, network design and uncertainty of returns can be addressed.

3. Literature Study

This section presents an overview of logistics networks and circular strategies to answer the research question:

What logistics concepts and circular strategies exist that support companies in implementing a circular business model in order to facilitate the transition to CE?

CE can be established when all phases of an electronic product's lifecycle are connected and directed to a return system for e-waste. The application of CE in e-waste management considers the concepts of circular strategies, reverse logistics and urban mining in supply chain management (Ottoni, Dias, & Xavier, 2020). These three concepts are covered in Section 3.1, Section 3.2 and Section 3.3, respectively. This provides insight in the relevant concepts of logistics involved in the reverse supply chain and the execution of circular strategies within the field of urban mining. Section 3.4 consists of a literature review on the relation between these topics and a synthesis of these findings. Based on these findings, a comprehensive model of common logistics scenarios in the field of urban mining has been created. Section 3.5 concludes this chapter.

3.1 Circular Strategies

Circular strategies are ways to make the pre-use, use and post-use phase of a product more sustainable according to the CE principle. The main principle of CE considers cyclical logistics, which means that products must return to the productive chain by their EOL phase (Ottoni et al., 2020). However, for all three phases one must consider the alternative strategies as each phase represents a different value retention. It is argued that conservation of resources closest to their original state yields the most value (Ottoni et al., 2020). Circular strategies is a general term which can be referred to as recovery strategies or R-strategies. In research, authors use different sets of R-strategies as well as different definitions. In the remainder of this section, a concise overview of four sets of R-strategies is given. Finally, the definitions used in this research are introduced.

Potting et al. (2016) identified ten R-strategies: refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, and recover. The first three strategies are used to produce and use a product in a more efficient way. Strategies four to eight aim at elongating the life cycle of the product and components. The remaining two strategies contribute to efficient use of materials (Potting et al., 2016).

Ottoni et al. (2020) identified ten slightly different R-strategies. The strategies, which are referred to as retention options in their paper, are the following: refuse, reduce, reuse or resell, repair, refurbish, remanufacture, repropose/rethink, recycle, recover, and remine.

PBL identified which strategies are commonly used and proposed to use the following six R-strategies: refuse and rethink, reduce, reuse, repair and remanufacture, recycle, and recover. These strategies form the R-ladder (Kishna, Rood, et al., 2019).

A set of circular strategies is included in a tool called the Value Hill (Achterberg et al., 2016), which is presented in Figure 1. The five R-strategies that are distinguished to create this tool are: repair/maintain, reuse/redistribute, refurbish, remanufacture, and recycle. It provides companies with an understanding of how to position their business in a circular context and to develop future strategies for CE. Furthermore, it gives insight in the importance and levels of the different strategies.

Figure 1. The Value Hill (Achterberg et al., 2016)

The two sets with ten strategies (Ottoni et al., 2020; Potting et al., 2016) cover all possible strategies including the strategies that are suitable for the pre-use phase. This explains that these sets contain more strategies than the other two sets. However, Kishna, Rood, et al. (2019) included refuse and rethink as one strategy to cover the pre-use phase. Achterberg et al. (2016) only considers the use and post-use in the Value Hill. Another difference is that Kishna, Rood, et al. (2019) do not distinguish between remanufacturing and refurbishing but only mention remanufacturing. Finally, as opposed to the other two references, both Potting et al. (2016) and Ottoni et al. (2020) propose the strategy of repurposing and reproposing.

Ottoni et al. (2020) provided the most comprehensive set of R-strategies and their definitions. These are mainly used in this research. However, their definitions are slightly adapted to reach consensus on all strategies accordingly with the definitions of other researchers. Some strategies will not be used at all throughout this research as they are out of scope. In order of decreasing value retention, the following definitions are used for each R-strategy:

- Refuse: Refrain from buying (Ottoni et al., 2020).
- Reduce: Use less, use longer (Ottoni et al., 2020).
- Repair: Making the product work again by preparing of replacing deteriorated parts (Ottoni et al., 2020).
- Reuse/resell: Buy second hand or sell your non-used products (Ottoni et al., 2020).
- Reuse: Reuse of materials or products to produce other products.
- Refurbish: restore an old product and bring it up to date (Ottoni et al., 2020). The refurbished product might be of lesser quality than a new product.
- Remanufacture: use parts of discarded product in a new product with the same function (Ottoni et al., 2020). Moreover, the quality is high as if it was a new product.
- Repropose/rethink: use parts of discarded product in a new product with another function Again, the quality is high as if it was a new product.
- Recycle: Process materials to obtain the same or lower quality (Ottoni et al., 2020).
- Recover: Energy production as by-product of waste treatment (Ottoni et al., 2020).
- Remine: Buy and use secondary materials from landfills (Ottoni et al., 2020).

These strategies, except for refusing and reducing, demand new and different approaches regarding logistics. Besides the traditional forward supply chain activities, additional activities of the reverse supply chain must be included (Kishna, Rood, et al., 2019). This, and the role and definition of logistics and reverse logistics in supply chain management are elaborated upon in the next section.

3.2 Reverse Logistics

Currently, supply chain management is mainly focused on forward supply chain logistics. The organisation of logistics and the possibilities to change or expand logistics determine the feasibility of transitioning to CE. The organisation of logistics concerns a wide variety of topics, which includes managing information flows, resources, production, inventory, warehousing, and transportation. Not all companies can execute all these activities inhouse as this requires capabilities and resources to manage them (Polet et al., 2020). Therefore, companies must decide on what activities to perform inhouse and which to outsource. The organisation of logistics includes decision making on return policy as well.
Despite the main focus on forward supply chain logistics, a strong relationship between CE and reverse logistics exists (Isernia, Passaro, Quinto, & Thomas, 2019). This calls for the need to include reverse logistics in supply chain management. Both concepts, CE and reverse logistics, have similar characteristics concerning the cyclical nature of the supply chain. Nevertheless, CE principles are considered to be broader than to reverse logistics activities (Isernia et al., 2019).

A simple description of reverse logistics is given by O'Farrell and Wright (2019) as the backward flow of used products from consumers to producers. Though, they state that it encompasses activities such as the movement of returned products, facilities to accommodate returned items and overall management process for returned items. The series of operations are initiated at consumer level with the collection of products and terminated with the re-processing of these products at remanufacturing facilities.

Not taking CE principles into account, Quesada (2003) defines reverse logistics as the management of any type of items, which are sent by one member of the supply chain to any other previous member of the same chain, regardless of the reason. This means reverse logistics move products from any point of use to any point of disposition.

The definition of reverse logistics is often used for the role of logistics in recycling, waste disposal and management of hazardous materials. As a broader perspective, it can also refer to all issues relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal (Islam & Huda, 2018).

Isernia et al. (2019) distinguish between definitions of reverse logistics that are limited to the logistics of returning the product, and the ones that go beyond the logistics of returning the product. Definitions of the latter include activities such as R-strategies in which case it is appropriate to adopt a reverse supply chain framework. This is the efficient and effective management of a series of necessary activities to recuperate a product from the consumer to dispose it or to recover the residual value. The reverse supply chain consists of five activities, which are collection or acquisition, reverse logistics, inspection and arrangement, reconditioning, and distribution and sale (Isernia et al., 2019). The forward supply chain is a system consisting of material suppliers, production facilities, distribution services, and customers. These are linked via the downstream flow of materials and upstream feedback flow information, which are deliveries and orders, respectively. When the reverse and forward supply chains are integrated, a CLSC evolves (Islam & Huda, 2018).

The supply chain concerns either an open loop or a closed loop. The reverse logistics network establishes the relationship between the market that releases used products and the market for new products. In case of a closed loop network, these two markets coincide. Otherwise the network is referred to as an open loop (Islam & Huda, 2018). Reverse supply chain management and reverse logistics have emerged to adapt CE principles to both the Open Loop Supply Chain (OLSC) as well as CLSC. In case of an OLSC, recovered materials are returned to external parties and in case of a SLSC to the original manufacturers (Garrido-Hidalgo, Ramirez, Olivares, & Roda-Sanchez, 2020).

In an OLSC there is a focus on the activities and flows of the reverse channel. Reverse logistics activities are composed of: collection, inspection, sorting, disassembly, reprocessing/recycling, and disposal operations (Islam & Huda, 2018).

In a CLSC there is a direct and coordinated relationship between forward logistics activities and task associated with the reverse supply chain (Islam & Huda, 2018). CLSCs usually include R-strategies applied to EOL products in order to improve environmental performance in the context of waste management (Luiz et al., 2018). CLSC management is the design, control, and operation of a system to maximise value creation over the entire life cycle of a product with dynamic recovery of value from different types of volumes and returns overtime (Islam & Huda, 2018).

According to Islam and Huda (2018) reverse logistics and CLSC are integral parts of the holistic waste management process. This process is an important aspect of urban mining which is discussed in the next section.

3.3 Urban Mining

Urban mining is the recovery of secondary raw materials from waste by reducing, reusing and recycling. This happens in a way that is analogous to mining (Xavier, Giese, Ribeiro-Duthie, & Lins, 2019). Valuable materials are recovered from stocks of materials that have been incorporated into cities or landfills (Ottoni et al., 2020). According to their definition, urban mining consists of a set of operations, such as the recovery, analysis, processing, and recycling, amongst other R-strategies, of products and materials. Recycling is the primary waste treatment strategy, while urban mining could benefit from using other R-strategies as well (Garrido-Hidalgo et al., 2020). The activity of urban mining is a necessity in e-waste treatment. First, it addresses the shortage of mineral resources for the electronics industry. Second, it helps decline the environmental pollution and human health risk (O'Farrell & Wright, 2019).

E-waste are electrical and electronic products at their EOL phase. This means the products are either post-consumed, post-industrialised or post-sold. Hence, most technological products become e-waste (Ottoni et al., 2020). Examples of e-waste are computers, hard copy devices, televisions, mobile phones, computers, IT equipment and household appliances (O'Farrell & Wright, 2019). Other examples are temperature exchange equipment, lamps, medical devices, screens and monitors, automatic dispensers, toys and sports equipment, and monitoring and control instruments (Islam & Huda, 2018). A categorisation of e-waste is made by WeCycle. The six categories represent most types of e-waste and are widely used in the Netherlands (WeCycle, 2020). E-waste can be referred to as cores, which stands for used products that can be restored to expected quality (Vogt Duberg, Johansson, Sundin, & Kurilova-Palisaitiene, 2020). Another term for e-waste is WEEE (Waste Electrical or Electronic Equipment).

The importance of handling e-waste properly is caused by four main reasons. First, there are critical, valuable, and hazardous substances which need to be handled correctly to avoid environmental and health problems. E-waste is a difficult type of waste to handle. O'Farrell and Wright (2019) state that the composition of WEEE is highly toxic and a threat to the environment. It also poses a threat to human health as it contains several toxic additives, hazardous substances and critical metals (Forti, Baldé, Kuehr, & Bel, 2020). Moreover, reverse logistics and the CLSC processes are complex due to multiple factors like quality, quantity and timing of the returned products (Islam & Huda, 2018).

Second, there is an opportunity to reduce greenhouse gas emissions and environmental impact. There are precious materials that can be recovered from WEEE, which can be used in the production of other goods. In 2010 only 27 per cent of disposed technology was recycled while electronic waste is responsible for 70 per cent of the heavy metals found in landfills (O'Farrell & Wright, 2019). In 2015 only four European Union Member States recycled over half of the electronic products put on the market. In general, e-waste has the lowest recycling rate which is 32 per cent (Garrido-Hidalgo, Olivares, Ramirez, & Roda-Sanchez, 2019). The Global E-waste Monitor shows that the amount of recycled e-waste was 20 per cent in 2016 and 17 per cent in 2019 (Baldé, Forti, Gray, Kuehr, & Stegmann, 2017; Forti et al., 2020). This means that there is a huge opportunity to decrease environmental impact when e-waste management is improved.

Third, e-waste is one of the biggest waste streams and the fastest growing streams in the world. The amount of e-waste is increasing as more electronic equipment is used and new types of equipment are discovered. WEEE has become one of the fastest-increasing waste streams. At the end of 2016, an amount of 44.7 million metric tonnes (Mt) of WEEE were generated worldwide. This amount is expected to reach 52.2 Mt in 2021 (Baldé et al., 2017). They state that the annual growth rate, based on weight, is 5 per cent. However, a similar report by Forti et al. (2020) shows that approximately 53.6 Mt of e-waste (excluding solar panels) was generated in 2019 already. Furthermore, they estimate that the amount of e-waste generated will exceed 74 Mt in 2030. This means that the growth rate is almost 2 Mt per year. An explanation for the waste stream growing fast is the short life cycle of products and the stock being landfilled or stockpiled in households (Garrido-Hidalgo et al., 2020). Islam and Huda (2018) adds the changing customer attitude towards disposing of products. An explanation for the magnitude of the streams is the increased use of electrical and electronic equipment. For example, the use of electric vehicles is growing. In the coming decades, the number of batteries to be disposed or recycled will drastically increase. Worldwide sales of electric vehicles are expected to increase to 11 million in 2025 and to 30 million in 2030. As a consequence, the quantity of electric vehicle batteries reaching the EOL status is expected to grow exponentially (Garrido-Hidalgo et al., 2020).

Fourth and last, there is an economic opportunity in recovering the large quantity of precious and special metals that e-waste contains (Isernia et al., 2019). While there is already a need to mitigate environmental pollution, the economic value associated with raw materials present in e-waste is estimated at 55-57 billion euros (Garrido-Hidalgo et al., 2019). Forti et al. (2020) estimate this value as approximately 57 billion USD which corresponds to a total of 25 Mt of e-waste. With the current recycling rate of 17%, a potential raw material value of 10 billion USD can be recovered, which leads to 4 Mt of secondary raw materials that would become available for recycling.

These four issues show the importance of handling e-waste as it possibly prevents environmental harm and poses numerous benefits.

While e-waste is suitable for recovery strategies, product characteristics influence the opportunities for CE in a considerate way. The Circular Economy Task Force and TNO determined five characteristics (Circular Economy Task Force, 2013; TNO, 2019). The first characteristic is Product Value (PV): the value of products and materials determines the justification of investment in recovery. This is the case in both a high value and a high EOL value. The second is Control, Collection and Communication (CCC): in case it is possible to control or reliably collect a known quantity of materials or products, circular models are more likely to succeed. The third is Ease of Recycling (ER): circular systems are more likely if the physical characteristics of products or materials make them easy to transform. The fourth is Pace of Change (PC): if a product or material function changes too rapidly, investment in recovery may not occur. This is especially an issue where material substitution, technological development, or fashion changes demand rapidly. The fifth is Concentration and Contamination (CC): where materials are dissipated or contaminated. Recovery is either more expensive or impossible (Circular Economy Task Force, 2013; TNO, 2019). As a sixth category Product Quality (PQ) is introduced: the state and quality of a product determine the feasibility of applying a recovery strategy. The product characteristics should be considered when identifying suitable recovery strategies and selecting the most appropriate strategy.

3.4 Literature Review Circular Logistics Networks

This section presents the literature review on logistics networks. The method and results of the literature are covered in Section 3.4.1. The synthesis of the reviewed literature is written down in Section 3.4.2.

3.4.1 Literature Review

This section covers the literature review on logistics networks in the field of urban mining. The following research string has been applied to title, abstract, and keywords of papers in the database of Scopus:

("reverse flows" OR "closed loop supply chain" OR "reverse supply chain" OR "product recovery" OR "reverse logistics") AND ("circular economy") AND ("Electronic waste" OR WEEE OR "E-Waste" OR "waste electrical and electronic equipment" OR EEE).

The search strategy yielded 27 results. After reading the abstracts, 11 articles were considered as useful and included in the review. Amongst these articles, two cited articles appeared to be useful as well. This lead to a total of 13 articles, which are listed in Table 1.

Table 1. Articles included in the literature review

(Author, Year)	Title	Journal
(Agrawal, Singh, & Murtaza, 2015)	A literature review and perspectives in reverse logistics	Resources, Conservation and Recycling
(Islam & Huda, 2018)	Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: A comprehensive literature review	Resources, Conservation and Recycling
(Ottoni et al., 2020)	A circular approach to the e-waste valorization through urban mining in Rio de Janeiro, Brazil	Journal of Cleaner Production
(Xavier et al., 2019)	Sustainability and the circular economy: A theoretical approach focused on e-waste urban mining	Resources Policy
(Isernia et al., 2019)	The Reverse Supply Chain of the E-Waste Management Processes in a Circular Economy Framework: Evidence from Italy	Sustainability
(O'Farrell & Wright, 2019)	E-Waste & the Circular Economy: An Irish Sme Context	Collaborative European Research Conference
(Vogt Duberg et al., 2020)	Prerequisite factors for original equipment manufacturer remanufacturing	Journal of Cleaner Production
(Mansuy, Verlinde, & Macharis, 2020)	Understanding preferences for EEE collection services: A choice-based conjoint analysis	Resources, Conservation and Recycling
(Garrido-Hidalgo et al., 2019)	An end-to-end Internet of Things solution for Reverse Supply Chain Management in Industry 4.0	Computers in Industry
(Garrido-Hidalgo et al., 2020)	The adoption of internet of things in a circular supply chain framework for the recovery of WEEE: the case of lithium-ion electric vehicle battery packs	Waste Management
(Luiz et al., 2018)	Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal	Journal of Manufacturing Technology Management
(Jin et al., 2020)	Life cycle assessment of emerging technologies on value recovery from hard disk drives	Resources, Conservation and Recycling
(Fleischmann et al., 1997)	Quantitative models for reverse logistics: A review	European Journal of Operational Research

A logistics network consists of several factors that distinguish the organisation of the network, which are actors and flows. Islam and Huda (2018) support this idea as they mention that the performance of a reverse distribution channel mainly depends on three issues. First, the actors who are involved in the reverse distribution channel. Second, the locations and functions carried out in the channel. Third, the relation between the forward and the reverse supply chain. These issues will be referred to as elements. The actors are the first element. The actors as well as the locations and functions determine the flows in the network. Flows is considered as the second element. Both elements can be described by certain characteristics. Fleischmann et al. (1997) describes three factors as dimensions of a logistics network: actors, form of reuse, and type of items. This leads to the introduction of two other elements. Forms of reuse is represented by the element of R-strategies and type of times is adapted to the element product level. This leads to a total of four network elements: actors, flows, R-strategies and product level. An explanation of each element as well as the sub-elements are presented in Table 2. The literature is described by means of these elements to provide a systematic and cohesive overview.

Table 2. Elements of a logistics network design

Network element	**Explanation**	**Sub-Element(s)**
Actors	Links in the forward or reverse supply chain	*Characteristics*
Flows	Activities conducted to set the forward or reverse supply chain in motion	*Characteristics*
R-strategies	Strategies to handle e-waste	Refuse Reduce Reuse/Resell Repair Refurbish Remanufacture Repropose/Rethink Recycle Recover Remine
Product level	State of the e-waste that is being processed	Product Component Material Substance

A basic representation of a circular logistics network design is presented in Figure 2. It entails the key processes of reverse logistics. In this framework, used products are collected after acquisition. The returned products are then inspected and sorted into different categories. They are either disposed for repair, remanufacturing, recycling or reuse. In case these options are not viable, the product is disposed entirely. The flows present in the model are product acquisition, collection, inspection and sorting, and disposition (Agrawal et al., 2015).

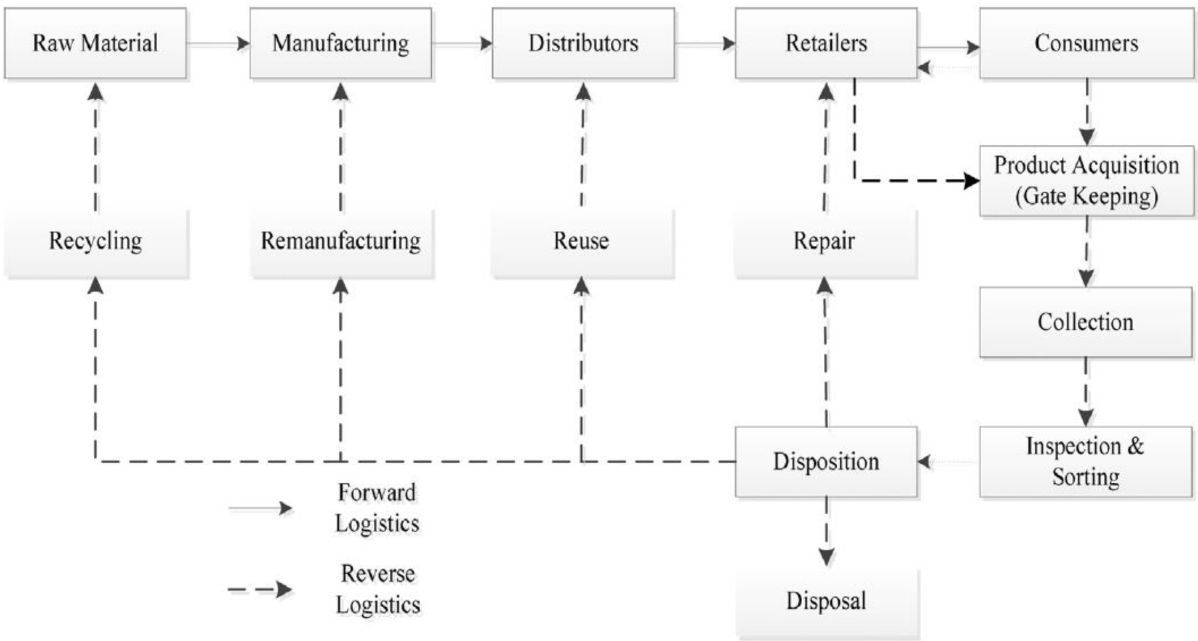

Figure 2. Basic flow of forward and reverse logistics (Agrawal et al., 2015)

Islam and Huda (2018) wrote that the process of reverse logistics and CLSC starts with the disposal of electric equipment. E-waste is coming from households, government and institutions, and businesses. The collection takes place via municipal collection points, kerbsides, drop off at special events, returns to retailers or point of purchase, and returns to manufacturers or recyclers appointed by the manufacturer. Collected cores are transported to treatment facilities where they are tested, inspected, sorted and disassembled. Subsequently, the cores are transferred for processing. As an example, they mention five different alternatives for processing: reuse, repair, remanufacture, and recycling. In order to design the reverse logistics network, one should consider the possibilities of four matters: an open loop network design, a closed loop network design, the third party reverse logistics providers selection, and the vehicle routing problem. The design by Islam and Huda (2018) of a reverse logistics network is shown in Appendix A Figure A1.

Ottoni et al. (2020) showed the relationship between urban mining and reverse logistics in CE. The framework, presented in Figure 3, consists of a production phase, a consumption phase and the activity of urban mining. During the production and consumption phase the four possible R-strategies are: refuse (R0), reduce (R1), reuse/resell (R2) and repair (R3). After the consumption phase, e-waste can either be processed as a product, components, material or substance. Amongst the possible R-strategies on product level, they mention refurbish (R4), repropose/rethink (R6) and recycle (R7). The component level includes the strategies of remanufacturing (R5), recycling (R7) and remining (9). On a material level, recycling (R7), recover (R8) and remine (R9) are indicated. On a substance level recycling (R7) and recovering (R8) are the defined R-strategies. The selection of the best routes for e-waste through reverse logistics and urban mining is supported by four criteria and related indicators. The first criterium is the distance from the places where the most e-waste is generated, hotspots, to the industries that carry out the R-strategies. The second criterium is proximity from hotspot to hotspot. The third criterium is the type of recycling industry. The fourth and last criterium is local context of the hotspots.

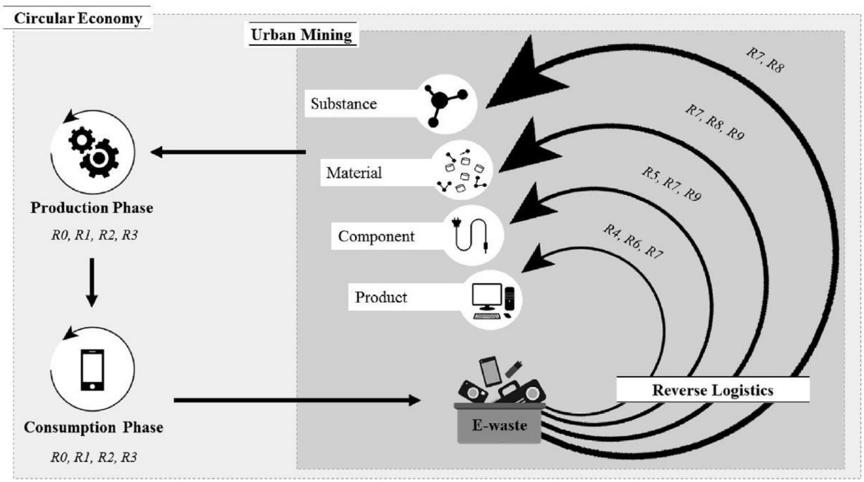

Figure 3. E-waste Framework for urban mining and reverse logistics (Ottoni et al., 2020)

Xavier et al. (2019) distinguish three R-strategies to recover secondary raw material from waste: reduce, reuse and recycle. They refer to these strategies as the 3Rs, which are considered as the most important topic among CE together with reverse logistics and urban mining.

A simple view of a reverse supply chain is described by Isernia et al. (2019) and consists of five stages: collection or acquisitions, reverse logistics, inspection and arrangement, reconditioning, and distribution and sale. The stages represent the flows. As an important actor they mention the collection centre, which is used as a main strategy to collect cores.

Reverse logistics could also encompass activities such as the movement of returned products, facilities to accommodate returned items and the remedy process for these items (O'Farrell & Wright, 2019). As an EOL strategy products are remanufactured. First, products are dismantled and then recovered products are tested. Components that are reusable are re-marketed to approved buyers. Defective or non-usable components are recycled. These activities take place in technology hubs.

According to Vogt Duberg et al. (2020), an important requirement for remanufacturing, besides reverse logistics, is core acquisition. The availability of cores consists of used products that can be restored to expected quality. Cores can be acquired through a product-service system as part of a CLSC. Cores can also be returned by the product owner either by choice or through the use of an incentive. Returns may come from a variety of links in the CLSC. Companies experience problems with acquiring cores for their processes and with the uncertainty of their quality. Core acquisition management can contribute to solving these problems. Retailers of the OEM receive products when customers return the product when service is needed or when customers utilise a service collecting offering where the retailer collects the product directly from the customer. Retailers can vary in size as they have different capacity constraints and capabilities, which requires additions to be made to the existing logistics network. Mansuy et al. (2020) describe home collection, curb side collection, unmanned drop-off and staffed drop-off as four ways to execute core acquisition.

E-waste is identified, inspected and classified after which it either can be repaired, recycled or reused (Garrido-Hidalgo et al., 2019). The actors in the network are suppliers, remanufacturers, manufacturers, distributors, retailers and customers. They made a distinction between products, parts and materials. Both products and parts can be reused. Parts can be also be repaired. Materials can only be recycled. Appendix A Figure A2 shows a visual representation of the relations between these elements.

Garrido-Hidalgo et al. (2020) designed a circular supply chain network designed for EOL management of electric vehicle batteries that includes forward and reverse supply chain management operations. The network is presented in Figure 4. The stages involved are collection, inspection, disassembly, remanufacturing, refurbishing, shipment and recycling of products as well as components. Both material and information flows are present in the visualisation of the network. In case of product reuse the product is returned to the phase after product assembly. In case of module reuse to the phase after module assembly. In case of parts remanufacturing to the phase after manufacture assembly.

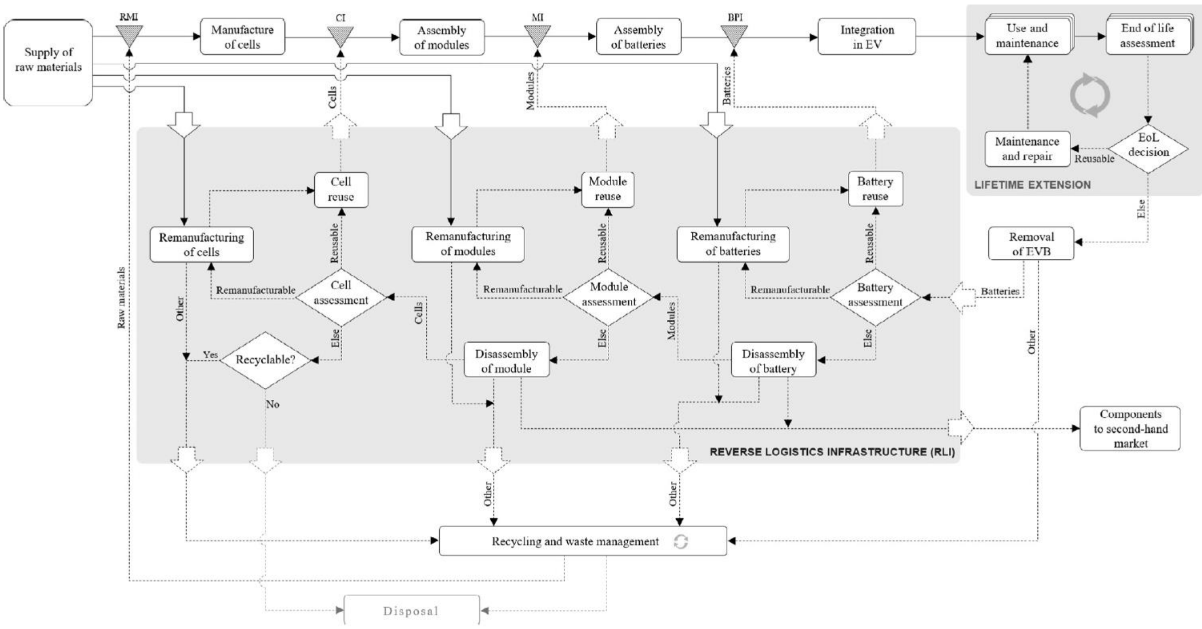

Figure 4. Supply chain and reverse logistics network (Garrido-Hidalgo et al., 2020)

Closed loop production systems usually include recycling, remanufacturing or reuse chains as EOL strategies for products. The chain consists of seven links: product lifecycle, selective waste collection, waste sorting, waste treatment, product recovery, product assembly and product selling Luiz et al. (2018). A visual representation of the chain is shown in the framework of Appendix A Figure A3. They state that waste collection involves two essential elements: management of data regarding waste types, amounts of waste and collection sites, and a logistic-transport model. As an efficient model they propose the concept of milk run. This is a logistics system in which the delivery of one product and the collection of another is carried out by the same transport.

Jin et al. (2020) decided to map a logistics network for different strategies. They proposed to generate a process flow of the logistics as the baseline option. This is the organisation of business as usual in a linear economy. Alternative business models are then created and modelled into a process flow as well. This way, they modelled the differences between the baseline and the following alternatives: product reuse, component reuse, component recycling and material recycling. In case of product reuse, the product returns into the cycle after the assembly phase. The process flow of the baseline and this alternative is set out in Appendix A Figure A4. When components are reused, the products are sent to a facility of an after-market service provider. Component recycling takes place at the recycler and material recycling at the metal recycler.

Together, the articles provide important insights into the actors, flows, R-strategies and product levels that shape the logistics network.

3.4.2 Synthesis of Literature Review

This section provides a synthesis of the four elements reviewed in Section 3.4.1. The results for the actors are shown in Table 3, for the flows in Table 4, for the R-strategies in Table 5, and for the product levels in Table 6. Every table consists of three columns. In the first column, the selected overarching term for the various elements is displayed. The second column represents the terms used for various elements as used in the paper. The third column shows the authors of the paper. The most important findings per element are elaborated upon. This section is concluded with the proposed logistics network.

Actors

An overview of the results of the reviewed papers regarding the element actors are included in Table 3. In total, ten overarching actors are identified, which represent the first column of the table. These actors should be included in the logistics network model: manufacturer, supplier, user, assembly, retailer, distributor, sales point, collection point, place of treatment, and place of disposal. Depending on the data of the business model and the needs of the firm that is using the tool, the actor's level of detail can be determined. For example, in case of a component manufacturer different strategies apply compared to a material manufacturer. However, in case there is no need to specify the type of manufacturer, general strategies regarding this actor can be applied.

Table 3. Literature review results: Actors

Main Actor	Term in paper	Authors of paper
Manufacturer	Original Equipment Manufacturer	(Vogt Duberg et al., 2020)
	Material Manufacturer	(Jin et al., 2020)
	Component Manufacturer	(Jin et al., 2020)
	Manufacturer	(Garrido-Hidalgo et al., 2019) (Garrido-Hidalgo et al., 2020) (Islam & Huda, 2018) (Agrawal et al., 2015)
Supplier	Supplier	(Garrido-Hidalgo et al., 2019)
	Supply of raw materials	(Garrido-Hidalgo et al., 2020)
	Raw material	(Agrawal et al., 2015)
User	Consumer	(Vogt Duberg et al., 2020) (Ottoni et al., 2020) (Mansuy et al., 2020) (Agrawal et al., 2015)

	Customer	(Garrido-Hidalgo et al., 2019)
	User	(Garrido-Hidalgo et al., 2020) (Luiz et al., 2018)
	Households	(Islam & Huda, 2018)
	Governments and institutions	(Islam & Huda, 2018)
	Businesses	(Islam & Huda, 2018)
Assembly	Assembly	(Garrido-Hidalgo et al., 2020)
	Assembly modules	(Garrido-Hidalgo et al., 2020)
	Assembly product	(Garrido-Hidalgo et al., 2020)
	Assembly centre	(Luiz et al., 2018)
Retailer	Retailer	(Vogt Duberg et al., 2020) (Garrido-Hidalgo et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015)
Distributor	Distributor	(Garrido-Hidalgo et al., 2019) (Agrawal et al., 2015)
Sales	Store	(Luiz et al., 2018)
	Point of purchase	(Islam & Huda, 2018)
Collection	Collection centre	(Isernia et al., 2019)
	Municipal collection points	(Islam & Huda, 2018)
	Kerbsides	(Islam & Huda, 2018)
	Drop off events	(Islam & Huda, 2018)
Recovery	Remanufacturer	(Garrido-Hidalgo et al., 2019)
	Subsequent recycling centre	(Luiz et al., 2018)
	Recycling centre	(Luiz et al., 2018)
	Recycler	(Islam & Huda, 2018)
	Technology hub	(O'Farrell & Wright, 2019)
	Facilities to accommodate returned items	(O'Farrell & Wright, 2019)
Disposal	Disposal	(Garrido-Hidalgo et al., 2020)
Excluded for categorisation	Data wipe & transportation	(Garrido-Hidalgo et al., 2020)
	Shredding & recovery	(Garrido-Hidalgo et al., 2020)
	Integration in end product	(Garrido-Hidalgo et al., 2020)
	Industrial sector	(Luiz et al., 2018)
	Producer	(Ottoni et al., 2020)
	Production centre	(Luiz et al., 2018)

Some of the actors require some further clarification. A main actor can refer to either a term with a similar meaning or to a term that is a specific type of actor. For example, user is synonym to consumer and customer. While households, governments and institutions, and businesses are types of users. The term place of recovery will be used for any place where any type of R-strategy is executed. The term disposal is regarded to as the activity of getting rid of a product. While Agrawal et al. (2015) refer to disposal as done by the place of recovery as it is no longer suitable for any kind of R-strategy, Islam and Huda (2018) refer it as done by the users that throw away products. The former description will be used in this research for two reasons. First, this research considers a firm level perspective of the supply chain. Second, this definition means that a product leaves the supply chain instead of having the chance of re-entering the supply chain. The last row of Table 3 shows the remaining terms that were mentioned in the papers, but are not included. The first three terms are considered as too specific and the other two as too broad.

Flows

In Table 4, the results of the element flows are presented. Eight main flows are determined: production, distribution, consumption, collection, inspection, recovery, redistribution, and disposal. These flows take place when actors interact, which means they connect the actors in the logistics network.

Table 4. Literature review results: Flows

Main Flow	Term in paper	Author
Producing	Production	(Ottoni et al., 2020)
Distributing	Distribution	(Ottoni et al., 2020) (Jin et al., 2020)
	Transportation	(Islam & Huda, 2018)
	Transferring	(Islam & Huda, 2018)
Consuming	Consumption	(Ottoni et al., 2020)
Collecting	Distribution and sale	(Isernia et al., 2019)
	Collection service	(Vogt Duberg et al., 2020)
	Home collection	(Mansuy et al., 2020)
	Curb side collection	(Mansuy et al., 2020)
	Unmanned drop off	(Mansuy et al., 2020)
	Staffed drop off	(Mansuy et al., 2020)
	Collection	(Ottoni et al., 2020) (Jin et al., 2020) (Luiz et al., 2018) (Isernia et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015)
	Returning	(Islam & Huda, 2018)
	Product acquisition	(Agrawal et al., 2015)
Inspecting	Inspection	(Garrido-Hidalgo et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015)
	Inspection and arrangement	(Isernia et al., 2019)
	Classification	(Garrido-Hidalgo et al., 2019) (Xavier et al., 2019)
	Identification	(Garrido-Hidalgo et al., 2019)
	Sorting	(Luiz et al., 2018) (Islam & Huda, 2018) (Agrawal et al., 2015)
Recovering	Treatment	(Luiz et al., 2018)
	Recovering	(O'Farrell & Wright, 2019)
	Remedy processes	(O'Farrell & Wright, 2019)

	Processing	(Islam & Huda, 2018)
	Reconditioning	(Isernia et al., 2019)
	Testing	(Islam & Huda, 2018)
	Disassembling	(Islam & Huda, 2018)
	Remarketing	(O'Farrell & Wright, 2019)
	Dismantling	(O'Farrell & Wright, 2019)
Redistributing	Reverse Logistics	(Isernia et al., 2019)
	Redistribution	(Ottoni et al., 2020)
Disposing	Disposal	(Ottoni et al., 2020) (Islam & Huda, 2018) (Agrawal et al., 2015)
Excluded for categorisation	-	-

Producing refers to all flows concerned with the pre-use phase of the product, including for example manufacturing and assembly. Whereas distributing represents the forward flows in the network, redistributing covers all reverse flows. Recovering is the activity of performing any kind of treatment similar to R-strategies, i.e. recovery strategies. Inspecting is used as an umbrella term for the terms inspection, sorting, identification and classification. The first reason is that only a few papers mentioned them separately and the second reason is that only a few papers mentioned them at all. No terms had to be excluded for the categorisation.

R-strategies

The third element concerns the R-strategies that were mentioned in the papers and are listed in Table 5. The categorisation enabled defining the meaning of the R-strategies and the inclusion of R-strategies.

Table 5. Literature review results: R-Strategies

Main R-Strategy	Term	Author
Remanufacture	Remanufacture	(Vogt Duberg et al., 2020) (O'Farrell & Wright, 2019) (Islam & Huda, 2018) (Agrawal et al., 2015) (Ottoni et al., 2020)
Reuse	Reuse	(Jin et al., 2020) (Garrido-Hidalgo et al., 2020) (Garrido-Hidalgo et al., 2019) (Xavier et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015)
Recycle	Recycle	(Jin et al., 2020) (Garrido-Hidalgo et al., 2020) (Garrido-Hidalgo et al., 2019) (Luiz et al., 2018) (O'Farrell & Wright, 2019) (Xavier et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015) (Ottoni et al., 2020)
Dispose	Dispose	(Garrido-Hidalgo et al., 2020)
Repair	Repair	(Garrido-Hidalgo et al., 2019) (Islam & Huda, 2018) (Agrawal et al., 2015) (Ottoni et al., 2020)

Refurbish	Refurbish	(Ottoni et al., 2020)
Repropose/rethink	Repropose/Rethink	(Ottoni et al., 2020)
Excluded for categorisation	Remine	(Ottoni et al., 2020)
	Refuse	(Ottoni et al., 2020)
	Reduce	(Xavier et al., 2019) (Ottoni et al., 2020)
	Reuse/Resell	(Ottoni et al., 2020)
	Recover (energy)	(Ottoni et al., 2020)
	Recover (back into cycle)	(Luiz et al., 2018) (Islam & Huda, 2018)

For this element, some terms are excluded for categorisation. Remine is not used because buying and using secondary materials from landfills is out of the scope of this research. Refuse, reduce, reuse/resell, reuse and recover (energy) are R-strategies that belong to the pre-use or use phase, which is out of scope as well. Recover (back into cycle) is excluded as in this research this term is referred to as any kind of R-strategy in this research and thus too general.

Product Level

The fourth and final element, product level, is presented in Table 6. Only the level of component was referred to by different terms in the reviewed papers. A distinction could be made between components consisting of one part and consisting of multiple parts. For the sake of simplicity, a component can be either one of the two. Substance was only mentioned in the paper of Ottoni et al. (2020). No terms had to be excluded for categorisation. However, the level of substance will probably hardly used as this level is not as suitable for recovery strategies as the other three levels.

Table 6. Literature review results: Product Levels

Main Product Level	Term	Author
Product	Product	(Vogt Duberg et al., 2020) (Ottoni et al., 2020) (Jin et al., 2020) (Garrido-Hidalgo et al., 2020) (Garrido-Hidalgo et al., 2019) (O'Farrell & Wright, 2019)
Component	Module	(Garrido-Hidalgo et al., 2020)
	Component	(Ottoni et al., 2020) (Jin et al., 2020) (O'Farrell & Wright, 2019)
	Part	(Garrido-Hidalgo et al., 2020) (Garrido-Hidalgo et al., 2019)
Material	Material	(Ottoni et al., 2020) (Jin et al., 2020) (Garrido-Hidalgo et al., 2019)
Substance	Substance	(Ottoni et al., 2020)
Excluded for categorisation	-	-

Circular Logistics network

In view of all that has been mentioned so far, a circular logistics network is proposed that includes the most important features. It covers a major part of possible logistics scenarios in the field of urban mining. As presenting all elements in a single network might be hard to read, the results are dedicated to two figures. The result of the actors and flows is shown in Figure 5. The boxes represent the actors and the type of actor is written in the box. The flows are represented by arrows. The boxes with the dotted line demarcate the types of flows. The type of flow is mentioned outside these boxes. For example, the flow of producing concerns the suppliers, manufacturers and assemblers. Redistributing concerns all flows from recovery back to the forward supply chain from supplier to sales.

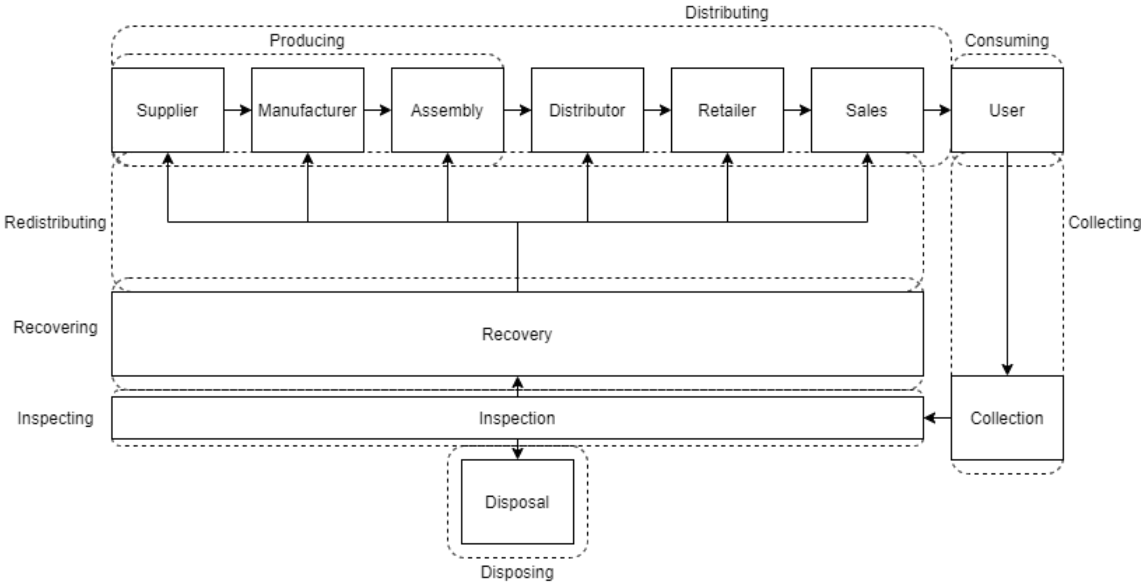

Figure 5. Circular Logistics Network: Actors and Flows

The type of recovery is referred to as the R-strategy. This and the product level, determine the various pathways from recovery to the actors in the original supply chain. In Figure 6 the recovery strategies, represented by the circles, are linked to the actors in the supply chain. For example, refurbishing might happen at the manufacturer or at assembly. Most R-strategies take place after collection, but repair can take place directly when the user chooses to do so. Recycling is regarded as the last option as it has the lowest value retention and it is likely that parts of the product have to be disposed. This is the reason an arrow from recycle to both supplier and disposal are drawn.

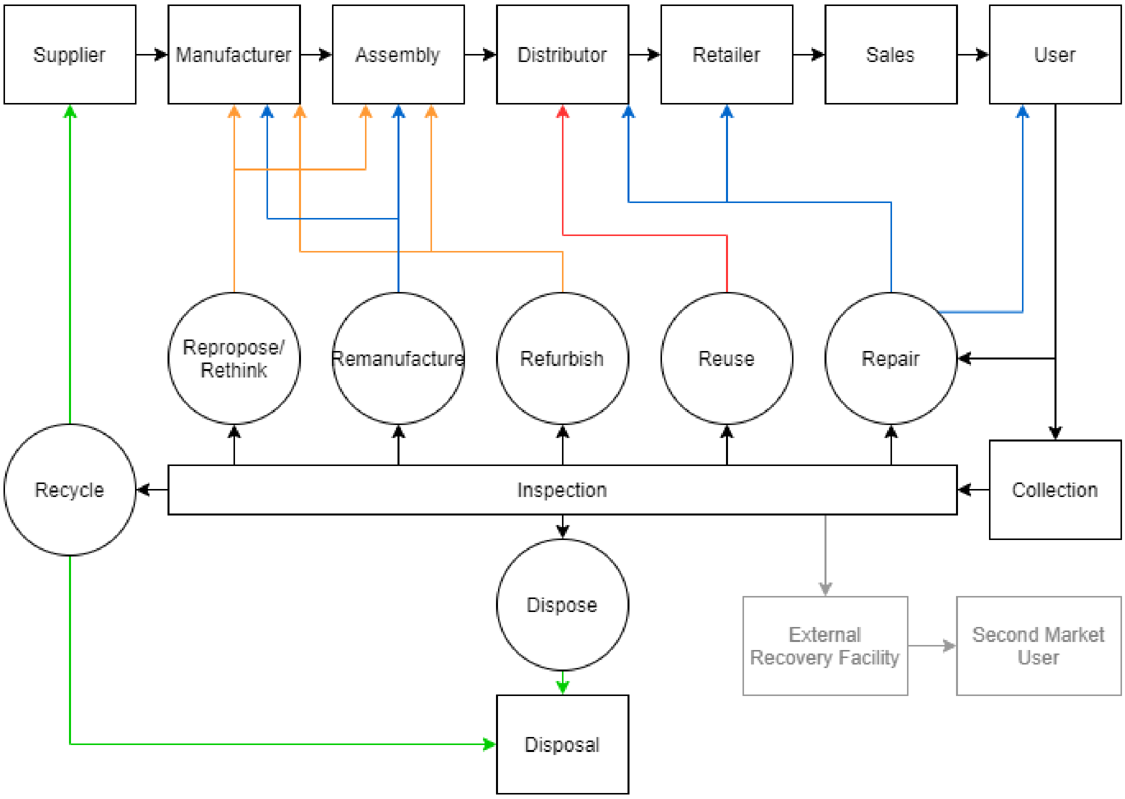

Figure 6. Circular Logistics Network: Actors and R-strategies

An important feature of the logistics network of Figure 6 is the grey coloured area. Products that are being recovered enter the supply chain again. However, not all products are recovered by an actor of its original supply chain: an external recovery facility might perform this task. This product will most likely not end up at its original user, which means it ends up in another market. The product has left the original supply chain and ends up at a second market user.

Another feature concerns the coloured arrows. The reviewed papers indicate what R-strategies could be used for which product level. A product could be used to recycle, repropose/rethink, remanufacture, refurbish, reuse and repair. On the level of components of a product, it is possible to recycle, remanufacture, reuse and repair. The material level allows for reuse and recycle. On a substance level, only recycling is possible. This means that four streams can be distinguished, which are either dedicated to: all four levels; to product, component and material level; to product and component level; and product level only. The first stream is green, the second stream is red, the third stream is blue and the fourth stream is orange.

3.5 Conclusions

The reviewed papers show that there is much ambiguity amongst the definition of logistics and R-strategies. Researchers use different definitions and different sets to determine logistics networks. This section provided a comprehensive overview and a circular logistics network suitable for handling e-waste in the execution of urban mining.

Ten strategies are identified that establish circularity: refusing, reducing, repairing, reusing/reselling, refurbishing, remanufacturing, reproposing/rethinking, recycling, recovering, and remining. Except for the first two strategies, the strategies demand new and different approaches regarding logistics. Besides the traditional forward supply chain activities, additional activities of the reverse supply chain must be included (Kishna, Rood, et al., 2019). The adoption of CE practices is necessary to support sustainable supply chains.

Supply chain management must be combined with circular strategies to achieve circularity. This way R-strategies can be performed successfully and make the pre-use, use and post-use phase more sustainable (Luiz et al., 2018). However, the supply chain is a complex system and the inclusion of reverse logistics operations adds uncertainties that are difficult for companies to deal with (Garrido-Hidalgo et al., 2020). According to Islam and Huda (2018) reverse logistics and CLSC are integral parts of the holistic waste management process.

This process is an important aspect of urban mining and an essential management strategy for EOL products to adhere to the principles of CE. In order to successfully implement this strategy, supply chain management should pay attention to reverse logistics and CLSC networks. Islam and Huda (2018) question to what extent the reverse logistics and CLSC systems of generic waste and e-waste are different as they mention that previously published papers have not clearly specified the difference. However, e-waste possesses some special characteristics and features which make their systems unique. Considering the hazardous potential of electronic products, a special logistics system is necessary for this type of waste. This means reverse logistics and CLSC systems are different for e-waste compared to other waste (Islam & Huda, 2018; Ottoni et al., 2020). Islam and Huda (2018) state that an optimised network design plays a crucial role in an efficient and successful reverse logistics process. Subsequently, circular strategies can bring benefits to the system. Whereas reuse of products is the most cost effective strategy, followed by refurbishing, remanufacturing and recycling, disposal is the least beneficial option (Garrido-Hidalgo et al., 2020).

The logistics network of a company is a result of the company's characteristics, ambition and goals, and the product characteristics. The sector in which the company operates and its core business define the characteristics. The ambition is often aimed at less use of critical or hazardous materials, and life cycle extension. Product characteristics are defined by the value of the product, the ability to control, collect and communicate, the ease of recycling, the pace of change, the concentration and contamination of the product, and the product quality. The network presented at the end of this chapter covers all possible scenarios according to the reviewed literature. The network consists of actors and flows while using R-strategies and product levels to determine the activities and paths in the network.

4. Decision Support Methods
This chapter presents an overview of relevant decision support methods to answer the following research question and two sub research questions:

What type of methods exist that provide decision support?
What type of method should be used?
What features should be included in the tool?

Section 4.1 provides insight into the requirements of a decision support method and four decision support methods. Section 4.2 presents the conceptual framework to design the support tool based on relevant features of each method. Section 4.3 concludes this chapter.

4.1 Decision Support Methods
Many different methods exist to support decision making. Tools have been defined as *"techniques, tools, methods, models, frameworks, approaches, and methodologies"* (Köseoglu, Tetteh, & King, 2019). Terms are used interchangeably when referring to a concept with the same goal. The systematic literature review that Köseoglu et al. (2019) conducted, shows that only four percent of the analysed papers was focused on conceptualising and defining tools. In order to design a decision support method, it is important to review existing methods. This way it can be determined what type of method should be used and which features it should include.

Before looking into decision methods, three requirements have been determined upfront. These are based on the aim of this research to limit the scope of the decision methods to review: the decision tool should provide companies with decision support regarding logistics challenges in executing a circular business model. The first requirement is choosing a format which is easy to design, implement and understand as only a foundation for a conceptual tool will be build. The second requirement is that the format of the tool encompasses conditionalities and constraints. As described in Chapter 3 new circular business models demand adjustments in the current logistics network of companies. The company's current situation and the possible strategies for a circular business model determine the opportunities for such a network. The third requirement is that the format should allow flexibility in scenarios. A scenario is the outcome of a set of decisions. Due to the high variety in company's current situations and possible strategies for circular strategies it would be hard to define all feasible scenarios upfront.

Four decision support methods are selected that fulfil these requirements: Decision Support Systems in Section 4.1.1, Multi-Criteria Decision Analysis in Section 4.1.2, Decision Trees and Flow Charts in Section 4.1.3, and Business rules in Section 4.1.4. The review of each method considers its approach, its applications and its design process.

4.1.1 Decision Support Systems (DSS)
The use of information technology to support business activities is more and more important (Teniwut & Hasyim, 2020). With help of Decision Support System (DSS) decision makers are supported to make decisions regarding these activities. It provides them a form of a guidance to select the best sets of option to increase the efficiency, profit and customer satisfaction (Teniwut & Hasyim, 2020). The use of DSS is proposed in the field of sustainable supply with a greater emphasis on economic, environmental and social dimensions. The most widely used form of DSS is numerical simulation. An example of this form is linear programming. This is followed by multi objective decision making and multi criteria decision making. The latter is discussed in the next section. Other forms of DSS are web based approaches, artificial intelligence, spatial and big data (Teniwut & Hasyim, 2020).

DSS cover various parts of supply chain in decision making. The approach is most often used for problems that regard selecting, evaluating and organising suppliers. The problem that is second most often addressed by DSS concerns deliveries, distribution and transportation.

As an approach to develop DSS, the design science framework is proposed (Hevner, March, Park, & Ram, 2004; Yan & Hu, 2014). The framework is shown Figure 7. Within the framework, a distinction is made between environment, research and knowledge. Environment concerns the people, organisations and technology as input for research: the business needs. The knowledge base concerns foundations and methodologies, which serves as a second source of input: applicable knowledge. The research consists of developing and building theories or artifacts like, for example, a tool. Then, this tool must be assessed and refined by justifying and evaluating it by means of research methods. Lastly, the tool can be applied in the appropriate environment and the obtained knowledge could be added to the knowledge base.

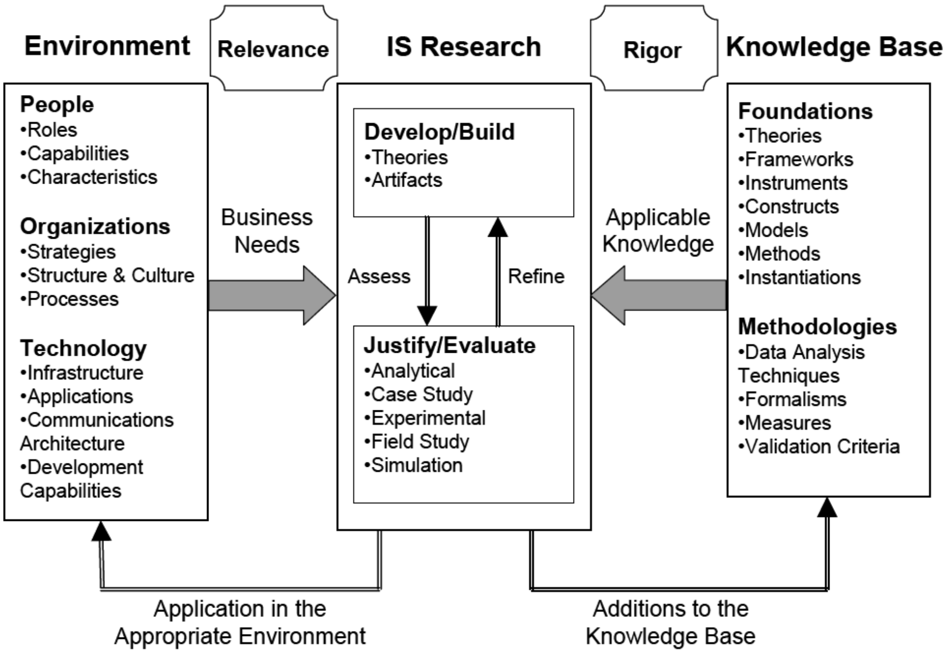

Figure 7. Design Science Framework (Teniwut & Hasyim, 2020)

4.1.2 Multi-Criteria Decision Analysis (MCDA)

MCDA involves making decisions about conflicting criteria or objectives. For example, efficiency and quality are conflicting criteria, because higher quality often results in higher costs (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2005). MCDA methods differ in the type of questions asked and the type of results given as output. There are universal methods and methods created particularly for one specific problem. Choosing the right method is important, because each method might result in a different type of outcome. First, the method should measure what is supposed to be measured to reach validity. Second, appropriateness should be achieved by finding a method that provides the decision maker with all information they need and that is compatible with the data available. Third and last, the method should be easy to use and understand to build trust.

MCDA methods are originally used in the field of operations research, but it has been widely used as well in fields like environmental management, agriculture, transportation and urban planning, and even public health (Hongoh et al., 2011).

The general procedure for these methods consists of eight consecutive steps, which are shown in Figure 8 (Bystrzanowska & Tobiszewski, 2018).

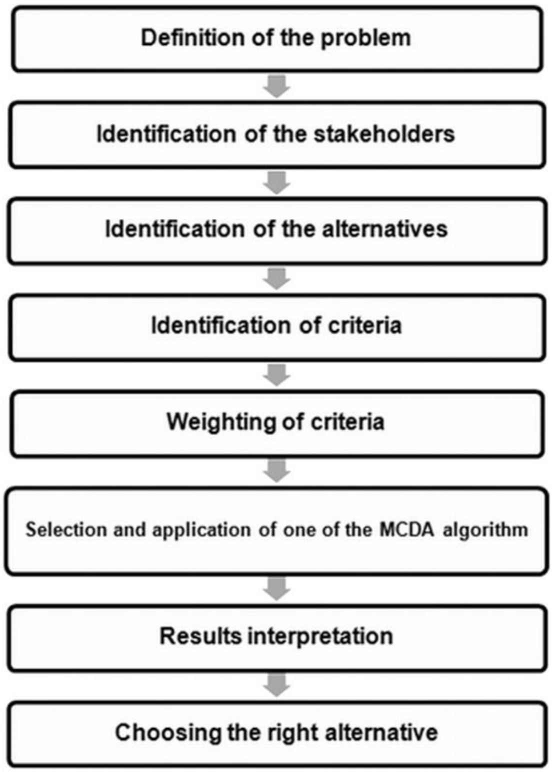

Figure 8. General steps for MCDA methods (Bystrzanowska & Tobiszewski, 2018)

4.1.3 Decision Trees (DT) and Flow Charts (FC)

A decision tree is a method, which uses a tree-like graph or model. A decision tree consists of a finite number of nodes, split into three disjoint sets: decision, chance and terminal nodes. The various types of nodes represent different stages of a sequential decision problem. Each node is connected to another via an edge: the first node represents the parent node and the second node the child node. In a decision node, an action is selected via an adjacent edge. In a chance node, an adjacent edge is randomly selected. A terminal node represents the end of a sequence of actions and chances (Kamiński, Jakubczyk, & Szufel, 2018). A flow chart is a visualisation of sequential steps. Following these steps helps to identify the best strategy to reach a goal or solve a problem. A combination of a decision tree and a flow chart (DT/FC) can be used to guide through the process of choosing an appropriate strategy. This method summarises the main considerations for setting up the best possible strategy. This allows for flexibility in starting point and size. The method illustrates the hierarchical, consecutive decisions, without weighting alternative approaches (Potthoff, Weil, Meißner, & Kühnel, 2015).

Decision trees and flow charts are applied across all fields of research. It is used in decision making on strategic and operational levels in business. Besides, decision trees are used in classification systems and other algorithms as well. Flowcharts are also used to describe programming features or pseudocode.

The general procedure for this method can be described by the following steps. First, identify the points of decision and alternatives at each point. Then, identify points of uncertainty and type of range of alternative outcomes at each point. Subsequently, estimate the values needed to make the analysis. This entails the probabilities of different events or results or action, and costs and gains of various events and actions. Finally, analyse the alternative values to choose a path (Magee, 2010).

4.1.4 Business rules

Business rules are used for describing the decision-making process. This method is used as decision support, not just to describe technical fixed conditions. By using historical data or known trends, opportunities can be identified by using business rules. However, the involvement of human interaction is necessary. By using constraints or decision blocks, business rules manage the flow of business processes (Zámečníková & Kreslíková, 2016). The rules are defined as statements about guidelines and restrictions regarding the state and processes of companies (Knolmayer, Endl, & Pfahrer, 2000).

The application of business rules concerns business processes and workflows. Furthermore, this method is used to document organisational policies and procedures (Knolmayer et al., 2000). The area of application is very broad as business rules can be applied to any company in any field or industry.

An approach to set up business rules is to first extract rules from data in sentences of natural language. Then, these sentences are associated with specific parts of business processes. Subsequently, the rules can be translated into more structured and detailed statements. These are the condition-action statements. Finally, the rules are transformed into structured executable rules. Any relation between data is considered as a business rule (Zámečníková & Kreslíková, 2016). This is similar to the use of conditional statements in programming language, which is a common feature in the field. Algorithms use these 'if-then'-constructs as a rule to determine what input should lead to a specific output.

4.2 Synthesis of Decision Support Methods

This section provides a synthesis of the methods reviewed in Section 4.1 and highlights the useful features of each method. The MCDA method and the DSS are too complex to develop in this stage of the research because of two reasons. First, not all relevant data is available, and second due to time constraints of this research. The Decision Tree and Business rules do not provide a sufficient framework for the design process. Therefore, different features from the four reviewed methods are used to create a framework for the design process and usage of a new decision support tool in this research. The steps of the new framework are derived from the general steps of the MCDA method and listed in Figure 9. The first two steps are identical to the first and second step of the MCDA method. The three next steps concern the choice for the format, content and logic of the tool. Then during the last three steps, again similar to the MCDA method, the decision maker implements the tool, interprets the results and selects the best alternative.

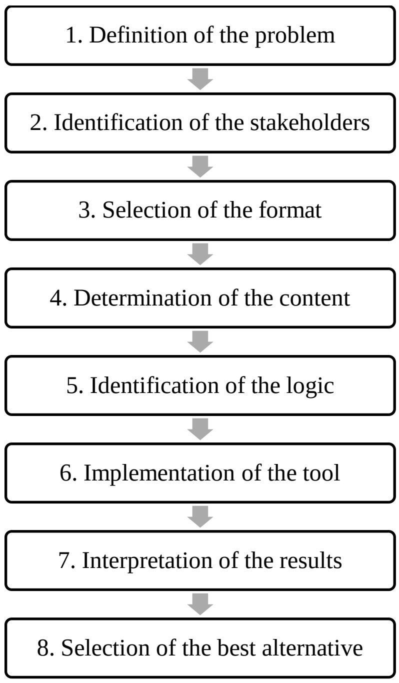

Figure 9. General steps for the conceptual decision support tool

The first two steps of the process, the definition of the problem and identification of the stakeholders, are performed in Chapter 1 and Chapter 2 of this research.

In order to conduct step 3-5, features of the design science framework are used. Both the environment and knowledge base serve as a starting point in choosing the format, content and logic of the tool.

To select a proper format for the tool, step 3, the knowledge base is explored and reviewed. This knowledge consists of literature on decision support methods and provides sufficient information regarding the theoretical foundation and methodology. The knowledge and requirements elaborated upon in Section 4.1 provide the foundation that contributed to selecting the format of the tool. The format has similar features as the DT/FC method and business rules. Both these methods depend on an 'if-then' or 'action-consequence' type of construct. This means that input and output must be defined: a certain input leads to a specific output. In this research, the input will be defined by business and product characteristics as these influence the possibilities of executing circular strategies. The input can be obtained through a questionnaire with predefined answers. The output consists of the advice regarding the execution of circular strategies.

Step 4 concerns the determination of the content of the tool. During this step, the environment is explored such that information is gained about the people, organisation and technology. Based on this information, the business needs can be identified. In this research, this information is gathered through conducting surveys or interviews amongst the people or stakeholders. This method is mainly used to gather content regarding the people and the organisation but also the technology. Before conducting the interviews, literature must be reviewed to serve as a knowledge base. The content is used to define the input and output of the tool. The required content to include in the tool is limited to the scope of this research, which was already defined during step 1 and 2 of the process.

Step 5 is the identification of the logic that will be included in the tool. It refers to the mechanism that defines the 'if-then' or 'action-consequence' constructs such that the input is connected to the output of the tool. The logic can be identified by analysing the collected information from the knowledge base and the environment, which is already done in step 3 and 4. The process of analysing this information is derived from the steps of the process of business rules. First, the rules are extracted from the real world. Both the interviews and literature provide insight in the real world. Second, these rules are connected to actual business processes and theory about business processes. Third, the rules are translated into formulas that are executable.

The development of the conceptual tool is finalised when steps 3-5 are combined. Then, the implementation of the tool, step 6, can be conducted. As it is a first concept of the tool, research features of the design science framework are included in this step. After building the tool, it can be assessed by the user. In this research, the tool will be evaluated by letting decision makers use the tool and fill in an evaluation form. The evaluation results allow for refinement of the tool such that it can be improved.

When the final version of the decision support tool is implemented, the decision makers can use the tool in practice. Then, in step 7, the decision maker interprets the results of the tool and selects the best alternative in step 8. In these two steps of the decision-making process, the human factor is involved. This is similar to the features of DSS and MCDA. This allows the decision maker to take into account multiple objectives or consider conflicting criteria.

Within these eight steps, the constant engagement of the user is described. It is relevant to include the user's psychological and physiological characteristics in the design process for three reasons. First, the tool is more efficient to use. Second, use of the tool is easier to learn. Third, the tool will be more satisfying to use (Nielsen, 1993). The research regarding the user engagement is divided into three stages: the development (Section 5.1), the assessment (Section 5.2), and the evaluation (Chapter 6).

4.3 Conclusions

Regarding the decision support tool that is desired for this research, it is important to choose a proper format. It should be easy to design, to implement, and to understand. Furthermore, the tool should take into account conditionalities and constraints. Additionally, the tool should allow flexibility. None of the four reviewed decision support methods fits the requirements entirely but they pose advantageous features. DSS and MCDA are too complex to develop in this stage of the research because of two reasons. First, not all relevant data is available, and second, the time constraints of this research. However, the steps of the design process of both methods are used as a guideline for the newly developed framework. Moreover, both methods include the human factor as an important feature. This is adopted in the framework as well. The other two methods were used to define the format and logic of the conceptual tool. The features of DT/FC and business rules are not sufficient to design the entire tool, but the 'if-then'-construct provided the basis for the input-output format of the conceptual tool. Based on the relevant features of all four methods, the design process as well as the outline of the tool could be determined. Not only the steps are described, but also the method on how to conduct each step is elaborated upon.

5. Tool Development and Assessment

This chapter provides an overview of the steps taken to develop and assess the tool. The research question is as follows:

What content and logic should be incorporated in the tool based on business cases of companies in the metal industry that made a transition from a linear to circular business model?

The outline of the design process of the tool is visualised in Figure 10. Building the foundation of the tool happens in three stages. The first stage, the development, is elaborated upon in Section 5.1. The second stage, the assessment, is discussed in Section 5.2. The tool evaluation is the third stage and is discussed in Chapter 6. The final section of this chapter is Section 5.3 which concludes this chapter.

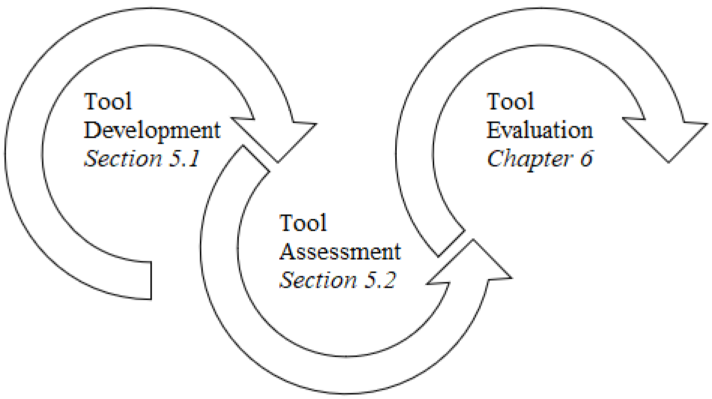

Figure 10. Decision support tool design process

5.1 Stage 1: Development

The first stage consists of collecting data from companies to determine the content of the conceptual tool, which corresponds with step 4 and 5 of the framework proposed in Chapter 4. The data is collected via interviews, of which the method and design is elaborated upon in Section 5.1.1. The results of the interviews are presented in Section 5.1.2. Section 5.1.3 provides a synthesis of the results as a stepping stone to the second stage.

5.1.1 Interviews

The purpose of the first stage is to develop the tool by including companies. This stage helps to obtain insight in the companies and their products. This way information about a specific supply chain's organisation and their challenges and opportunities can be determined. Furthermore, it helps to demarcate the scope of the research and the tool. Lastly, companies can express the needs that should be fulfilled by the tool.

The information should be obtained in a concise and structured manner, while being able to explore any topics that are not predefined. Quantitative data collection methods seek to confirm hypotheses about phenomena. An example of such a method is a survey. The aim of this method is quantifying variation in data and predicting causal relationships. The design often consists of closed-ended questions and the design is stable throughout the execution of the research. Qualitative methods seek to explore phenomena by conducting, for example, semi-structured interviews. The aim is to describe variation, and describe and explain relationships between variables. The design often includes open-ended questions and is flexible. During the research, questions might be added when additional information is obtained (Mack, Woodsong, Macqueen, Guest, & Namey, 2005).

As mentioned in the introduction, Section 1.3, the nature of this research is incremental and follows an iterative process. Since the objective is to explore, describe and explain variation on the research topic, a qualitative approach is chosen. However, in order to compare results and perform the research in a structured and concise way, quantitative aspects are included as well. As a data collection method, a survey was designed. The majority of the questions concerned closed-ended questions. The surveys were conducted as an interview in a semi-structured way. Therefore, in the remainder of this research report, the surveys will be referred to as interviews. The interview setting provided that questions and topics could be explored that were not yet included in the survey. Moreover, a part of the survey consisted of open questions to permit an unlimited number of possible answers. This was required due to the variety of respondents regarding their position in the supply chain and the diversity in their products. Furthermore, the possibility of getting stuck on predefined answers was avoided and it helped to collect more detailed answers. It allows the researcher to receive additional information which was not initially included. This complies with the incremental nature of the research set up.

The survey was made in Qualtrics, which is an online survey tool. The respondents received a PDF version of the survey via email in advance. During the interview, the respondents could read along with this version, while the researcher asked questions and filled out the survey online in Qualtrics. This way, the respondent could ask questions during the survey. Besides, the researcher could make sure the respondents had a good understanding of the concepts and interpreted the questions and answer possibilities similarly.

The sample of respondents consisted of employees from companies that have made the transition from a linear to circular business model. Because of the qualitative approach there is no fixed or predetermined minimum number of respondents. However, the number of respondents should ensure that a saturation is reached in the data that is collected during the interviews. The inclusion criteria for respondents in this first stage of the research were as follows:

- The company operates in the manufacturing industry
- The company operates in the metal industry
- The company is part of a supply chain in which, at some point, urban mining takes place
- The company shifted from a linear towards a circular business model
- The company operates in the Netherlands

The survey can be found in Appendix B, and the informed consent that was given to the respondents prior to the interview can be found in Appendix C. The survey contains many concepts and terms, which are subject to interpretation. A list with definitions is used to ensure consensus and is included as Appendix D. The survey consisted of four substantial categories: General, Supply Chain Characteristics, Logistics and Reverse logistics, and Product Characteristics. The fifth and last category concerned Feedback and Questions. The content of each category is elaborated upon in the remainder of this section.

The general questions regard business characteristics that provide a basic understanding of the company. This includes the company's work field, the product that the company sells and the supplies that determine the input flow. In Section 3.3 these topics are elaborated upon.

The questions about supply chain characteristics are meant to create an image of the supply chain of the company by identifying the present actors and flows. Both characteristics are explained in Section 3.4.2.

The category of logistics and reverse logistics concern questions about the organisation of these topics. On the one hand, questions include topics of return policy, in- or outsourced logistics, and availability of logistics resources. These topics are based on the findings in Section 3.2. On the other hand, questions regard circular strategies and core collection, which are described in Section 3.1 and Section 3.4.2, respectively.

Questions about product characteristics are used to obtain an overview of the product that the company sells. The six types of product characteristics are derived from the ones described in Section 3.3. Furthermore, the product level is included in this category as a result of the findings in Section 3.4.2.

The last category concerned feedback and questions and gives respondents the opportunity to share any feedback or to ask questions.

Considering the qualitative approach, the following steps are conducted to analyse the results of the interviews. First, the answers to the survey questions are collected in Excel. Relevant combinations of questions are determined that are analysed simultaneously such that patterns in answers could be identified. Closed-ended questions could be analysed one on one. The open questions are analysed to explore the differences and similarities in given answers. Second, the recordings and the notes of the interviews are summarised as answers to the open questions or feedback section of the survey. This data is used to support the analysis of the survey data. Third and last, the results of both approaches are combined to construct a complete overview of the results.

5.1.2 Interview Results

In this section the results of the interviews are presented. The section displays the answers to the general questions first to provide insight in the companies. The remainder of this section shows the results per survey category as follows: first, the answers to the closed-ended questions are presented as the descriptive statistics provide a general overview of the companies; second, the answers to the open-ended questions are discussed as an addition to the closed-ended answers.

General

In total, eleven companies (n=11) were interviewed. All of the companies were operating in the manufacturing and metal industry, and included both producers and service providers. The companies' activities vary from remining metals to selling lighting solutions, ICT and telecom products. Other activities are collecting, transporting and recovering ferro and non-ferro metals, batteries, mechanical equipment and electromechanics, and other types of electronic waste. One company provides headphones as a service.

Seven companies indicated that their product assortment includes products that fit in either one of the e-waste categories. The six categories of e-waste are mentioned in Section 3.3. The product assortment of the other four companies consisted of metals, electronics and hardware. Considering the interviewed companies, product categories 5 and 6 are most common as five companies processed these types of products. Category 4 was processed by three companies, and category 1, 2 and 3 by two companies. Nine companies mentioned a category of products which was not listed in the survey but are relevant to this research. The results of the product categories are shown in Table 7.

Table 7. Interview results: General – Product Categories

Company	Category	Category other
1	-	Metal powder (.9999 purity)
2	3 and 5	-
3	-	Metals, electronics and sensors
4	6	IT and telecom devices larger than 50 cm
5	2, 4, 5 and 6	-
6	6	IT and telecom devices larger than 50 cm
7	1, 2, 3, 4, 5 and 6	Metals
8	-	Batteries larger and smaller than 50 cm and automotive batteries
9	-	Lithium-Ion batteries
10	5 and 6	Headphones
11	1, 4 and 5	Components of category 1, 4 and 5

The type of customers that the companies deliver to varies amongst the companies. Companies 1, 6, 8 and 9 only deliver their product to producers, while companies 3, 4, 5 and 10 only deliver to end-users. The three remaining companies, 2, 7 and 11, deliver to both producers and end-users.

The type of materials that companies purchase are mainly products (9 companies), components (8 companies), and parts and semi-manufactured products (7 companies). Only three companies purchase raw materials and resources. These materials consist mainly of metals, batteries, circuit boards, electronics, plastics, and products like laptops, phones, and printers.

Supply Chain

The actors of the supply chain provided insight in the position of the company in the supply chain. Figure 11 visualises the position of each company with a coloured dot. The lines reach from the preceding to the succeeding actors of the company. One finding is that due to the circularity of a company, one actor might be a predecessor and a successor of the company at the same time. For example, the company represented by the light purple dot. This company receives supplies from the client, which will be recovered by the company and delivered back to this client. In this case, the client is both supplier and the user.

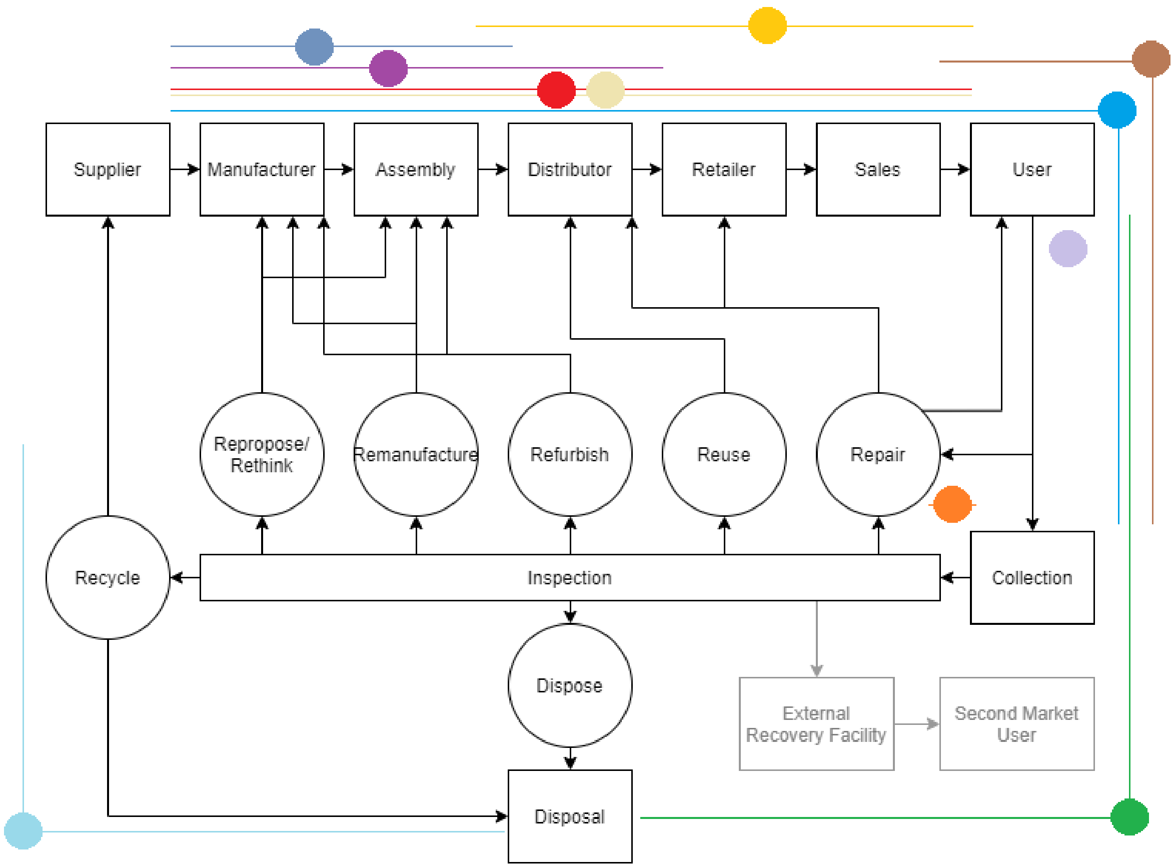

Figure 11. Interview results: Supply Chain – Position of companies

The flows in the survey referred to the processes within the company, not to the flows of the entire supply chain. As a result, the answer possibility consumption has been removed. Nine companies inspect the products and eight of them also collect the products. Five companies redistribute the products after recovery.

Logistics and Reverse Logistics

The answers given to the closed-ended questions in the category of logistics and reverse logistics are shown in Table 8.

Table 8. Interview results: Logistics and Reverse Logistics

Company	Return Policy	Logistics in- (In) and/or outsourced (Out)	Logistics Resources	Warehouse	Inhouse R-strategies	Legislation
1	No	Out	No	Yes	Yes	Yes
2	Yes	Out	No	No	Yes	No
3	Yes	In	Yes	Yes	Yes	No
4	Yes	Out	No	Yes	Yes	Yes
5	Yes	In and Out	Yes	No	No	Yes
6	Yes	In and Out	Yes	Yes	Yes	Yes
7	No	In and Out	Yes	Yes	Yes	Yes
8	Yes	Out	Yes	Yes	Yes	Yes
9	Yes	Out	No	Yes	Yes	Yes
10	Yes	In	No	Yes	Yes	Yes
11	No	Out	No	Yes	Yes	Yes

The organisation of logistics is defined by the variables: return policy, in- or outsourced logistics, logistics resources, and warehouse. Three companies mention that there is no return policy. Company 1 and 7 are recycling companies who state not needing a return policy. The third company, company 11, mentions it is not necessary as the products they recover are products from a client who brings and picks the products up. Company 6 says it is creating a return policy. The six companies that do have a return policy mention that an additional infrastructure was created. In cases of B2B, agreements and contracts can be made. Either products are sent to a predetermined location or back to the factory. In case of B2C, the return policy is to have product returns from customers arranged via call centres or return forms at their websites. Companies state that product returns in case of B2B are easier than B2C as these are more predictable and reliable. Five companies have their logistics outsourced: company 1, 2, 8, 9 and 11. Only company 3 and 10 have their logistics completely insourced. The other three companies have their logistics partially outsourced and partially insourced. Companies 3, 5, 6, 7 and 8 have their own logistics resources. Company 2 and 5 are the only companies that do not own a warehouse.

Ten companies perform recovery strategies inhouse. Company 5, that does not perform R-strategies inhouse, indicated to have a direct link with the recovery facility. The most common R-strategies are refurbishing and repairing (6 companies), followed by remanufacturing and recycling (5). The other R-strategies are performed by 4 companies. In Table 9 an overview of the companies and the strategies they perform is shown. Two R-strategies were mentioned that were not included in the survey. Company 1 mentioned upcycling as the remining of raw materials from components. It was described as a form of recycling, which is only performed as a final recovery strategy. However, the difference is that upcycling ensures that the quality is as high as newly mined raw material. Company 4 mentioned recollection, as a different form of regular collection in reverse logistics. The reason was that certain types of products need cautious transportation due to their characteristics. For example, products that contain hazardous materials or fragile products of which the state and quality must remain intact.

Table 9. Interview results: Logistics and Reverse Logistics – R-strategies

Company	Reproposing/ Rethinking	Remanufacturing	Refurbishing	Repairing	Reusing	Recycling
1						Yes
2	Yes					
3		Yes	Yes	Yes		
4		Yes	Yes	Yes	Yes	
5						
6						Yes
7						Yes
8	Yes		Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes	Yes	
11		Yes	Yes	Yes		

In Table 10, the answers given by the companies to the question about their input flow are presented. Three companies indicated that new products from suppliers and returned products were not the only two sources to obtain supplies: clients and disposed products were mentioned as other categories.

Table 10. Interview results: Input flow

Company	Category	Category other
1	Suppliers	
2	Suppliers	
3	Suppliers	
4	Returned products	
5	Suppliers	
6	Returned products and Suppliers	
7	Suppliers	Clients who may or may not remain owner of the product
8	-	Disposed products
9	Returned products	Clients who remain owner of the product
10	Returned products and Suppliers	
11	Returned products	

Five companies indicate that they use methods for collecting products. Table 11 shows the number of companies that used each collection method. One company mentioned an additional method: products can be brought to the company by the client.

Table 11. Interview results: Methods of Collection

Method of collection	Number of companies
Products can be returned for a fee.	5
Products can be returned for free.	3
Products can be brought to designated locations, like shops.	3
Products can be collected by the company.	3
Products can be collected by the municipality.	1
Products can be brought to a recycling centre *(Dutch: milieustraat)*.	1
Products are collected via promotions.	0

Companies mention that they face legislations that might hinder their activities. Only two companies, company 2 and 3, mention that they do not encounter legislation that constitutes any barriers. The other nine companies experience hinder from national legislation, of which three also from international legislation. These companies, 8, 9 and 11, mention that it is difficult to export and import products due to international regulations.

Moreover, company 8 and 9 stress the difficulties on a national level. One reason for this is the ADR: the treaty that governs transnational transport of hazardous materials. Another reason is that the products companies are transporting are considered as waste, hence need to be transported like this, while the companies do not consider and have no intention to treat the products as waste. Another barrier comes from storage legislations of waste. Company 8 mentions that their storage needs to be relocated because of these regulations.

Company 5 and 6 mention that privacy regulations are strict when it comes to wiping data off of products. Company 10 mentions that they experience difficulties in performing R-strategies as it is prohibited to replace components in some products due to safety regulations and certifications. Company 1 mentions that legislation concerning emissions and environment create barriers for business.

Company 7 mentions that it is a problem that once products are considered waste, it is not possible to reverse this. Companies support this statement as they need to pay electronic waste disposal fees, even when the company does not process the product as waste.

The companies name various types of challenges. Company 8 and 9 mention that transportation legislation is a logistics challenge. The fact that products are seen as waste causes difficulties in transporting products, due to the ADR. However, company 9 states that this is part of the job.

Company 10 mentions that the dependence on third party logistic companies is a logistics challenge. This company aims to insource logistics when the company will grow.

Two companies face logistics challenges in storing products. Company 11 argues that there is no alignment between supply and demand. There is a need to store products in case they are needed later on, while it is undesirable to unnecessarily store products. Company 5 states that storage of products is a challenge as products can only be sent for recovery in a big batch size. This means the company has to wait and store the products until a minimum number of products is reached. All the while, products become outdated.

Company 2 only performs the strategy reproposing/rethinking inhouse and outsources other recovery strategies. This company indicated that not being able to monitor these products is a disadvantage. They do not know exactly what happens with products that are sent to a recovery facility. Similarly, the company is not aware of how the user uses the product. This means they have no idea what the state nor the quality of the product is, and how to improve the product. As a solution, the company mentions the use of Internet of Things (IoT).

Company 7 states that they do not face any challenges as they are experienced in carrying out logistics for many years.

Product Characteristics

The majority of this category concerns closed-ended questions among the subcategories Product Value (PV), Pace of Change (PC) and Product Quality (PQ). The category Control, Collection and Communication (CCC) contains one closed-ended question. The answers to these questions are displayed in Table 12 and will be discussed first. At the end of the section, the open questions of the subcategories CCC, Ease of Recycling (ER) and Concentration and Contamination (CC) are discussed.

Table 12. Interview results: Product Characteristics

	PV				PC	PQ		CCC
Company	**MV**	**TV**	**EOLV**	**EOLH**	**PC**	**Qly**	**State**	**Users**
1	High	High	Low	High	Low	High	B	>2
2	Low	Medium	Low	Low	Medium	High	B	1
3	High	Medium	Low	Low	Medium	High	BW	2
4	High	High	Medium	Low	Medium	Medium	BW	1
5	Medium	Low	High	Medium	Low	High	BW	1
6	High	High	Medium	High	Medium	Low	BW	2
7	High	Medium	Medium	High	Low	High	BW	2
8	Medium	Low	Medium	High	High	Medium	BW	2
9	High	High	High	Medium	Medium	High	BW	2
10	High	Medium	High	Medium	Medium	High	BW	2
11	High	Medium	High	High	Low	High	BW	>2

Concerning the PV several results from Table 12 are highlighted. The majority, eight of the companies, considers the market value of their product high. One company indicates that the technical value is higher than the market value of their product and four of the companies consider the values to be similar. Only four companies think the EOL value of the product is high, while four companies consider it medium and three companies even low. Five companies consider the EOL harm of their product to be high. Three companies think the EOL harm of their product is low.

The PC is considered high by only one company. Six companies think the pace of change is medium and four of them think it is low.

The PQ is high according to eight of the companies. Two of the companies recover broken products, while the other nine companies recover either broken or working products.

Regarding the CCC, three companies estimate that a product has only one user before it reaches the EOL state. Six companies estimate this number to be two, and two of the companies think it is more than two. Concerning the quantity of the sales, company 8 is the only company that was not able to give an estimation or exact number of the sales. Companies mention it is hard to give an exact number, or even an estimation, as they have different type of products. For example, a part of the products is sold in large quantities and another part in small quantities. The percentage of returns of these products is 0-10% for seven of the companies: 1, 2, 3, 5, 7, 8 and 9. The percentage is 10-20% for company 4, 60-70% for company 6, 70-80% for company 11 and for company 10 even 90-100%.

Concerning the CC, Company 8 indicates that products contain 90-100% hazardous materials and company 6 indicates this percentage as 70-80. Company 1 says 10-20%, while all other companies state the percentage is between 0 and 10. Company 11 mentions explicitly that the products they recover hardly contain any hazardous materials, and company 2 and 9 mention their products do contain any hazardous materials at all.

Company 4 mentions that materials can either be hazardous, because of the risks involved in mining, or due to the toxic characteristics of the materials. The following hazardous materials are named during the interviews: lithium, plastics, bromine, fiberglass, phosphorus, chlorine, gels, lithium, copper, silicon, halogens, flame retardants, chemical substances, asbestos, chromium, lead, mercury, radioactive substances, acids, and toxic metals. The following products were named to contain hazardous materials: batteries, printers, toners, laptops, and telephones.

Only companies 5 to 11 were asked about critical materials as this question was added to the survey after interviewing companies 1 to 4. Company 7 and 8 state that the products contain 80-90% critical materials. Company 11 states this is 20-30% for their products, and the other companies state it below 10%.

Company 7 mentions that every material is critical and listed the following materials: copper, aluminium, steel, zinc, lead, palladium and rhodium, as these are all mined from ore. The other companies brought up the following materials: cobalt, metals and precious metals, copper, rhodium, lithium, and nickel.

Companies and their products respond different to the ER as the suitable strategies vary for each company. Three companies already perform all strategies that they consider to be suitable strategies. While one company does not perform strategies inhouse, seven out of ten companies perform the strategy that they consider to be the best possible strategy for their product. The three companies that do not perform the best possible strategy are the companies that only perform recycling and all three consider the strategy reproposing/rethinking as the best strategy. This is considered to be the best strategy by four companies in total. Followed by remanufacturing, refurbishing, and recycling by two companies each. Repairing is considered as the best strategy by only one company.

Two companies introduced an R-strategy that was not listed in the survey. Company 1, that previously mentioned upcycling, also mentions the possibility of downcycling. This is also a form of recycling. However, this method does not ensure a quality as high as the original raw material. The other company, Company 5, mentions the act of bring your own device. The company asks employees to use their own telephones or laptops instead of handing out these types of devices to them.

The most used PL by companies to recover products is the level of components, namely ten companies. Followed by parts and semi-manufactured products, and products: both PL are used by six of the companies. The use of substance and materials happens at two of the companies.

Feedback and Questions

Company 1 argues that the Netherlands offers a poor environment to perform their R-strategies. Due to a lack of knowledge of the technologies they use, the technologies are not really accepted and valued the way they should. Moreover, they feel pushed into scaling their company, while the company stresses the fact that this is not necessary because of this technology.

Company 3 states that for companies to become circular, employees need to change the way they think and operate. Company 6 says that this is a duty of the government: it must not only think in terms of circularity, but it must also act in this way.

There is no market for reuse as the market is focused on recycling. Company 5 mentions this is caused by products that are not built in a modular manner: components are glued or melted together. Company 4 mentions that legislation should focus on reuse instead of disposal, because the market for reuse is different than the recycling or disposal market. Company 4 and 6 mention that they do not benefit from a waste disposal fee, like the recycling organisation WeCycle, while they state to not only dispose and recycle but also recover waste. As a result, recycling is rewarded and other strategies are not.

Regarding the survey, one remark was made by company 4. The company indicates that it might be useful to cluster companies. Currently, a wide range of companies is interviewed, while a manufacturer provides different answers than a supplier.

5.1.3 Interview Synthesis

This section presents a synthesis of the interview results. This contributes to the foundation for stage 2: the assessment of the tool. Per category the results are discussed as to explain the results and to determine the relevance for the content of the tool.

General

Based on the results, it can be concluded that a high variety in companies was included regarding their position in the supply chain, their core business, and the products and services they offer. There is a great variation as well in the type of customers they serve. Both these findings result in difficulties generalising the results of the remainder of the survey.

Supply Chain Characteristics

The companies have been positioned in the general logistics network of Section 3.4.2. Due to the variety and complexity of the supply chains it is not easy to define all actors and their positions to visualise each supply chain. However, information about actors each company is collaborating with provides useful insights. The formulation of a new circular logistics network is facilitated by the actors already in the network and the actors yet to include. For example, the only company that does not perform recovery strategies inhouse does have a direct link with the recovery facility. Besides, it is important to know the role of the company itself and its processes.

The flows within the company add knowledge to what processes can be performed inhouse and for which processes a third party should be hired. The results showed that out of the eleven companies: nine of the companies inspect; eight of them collect; five of them redistribute products. This means that the processes that are necessary for a circular approach are performed inhouse.

Logistics and Reverse Logistics

The organisation of logistics is defined in this research as having logistics in- or outsourced, and having logistics resources, a return policy and a warehouse. Only company 3, has its logistics insourced and has all aforementioned elements of their own. Company 10 organises this completely on its own but does not own logistics resources. As the companies their core business is not concerned with logistics resources except for company 3, it makes sense that the companies outsource logistics. Nevertheless, eight of the companies have a return policy, which is an important facilitator in executing circular strategies.

The organisation of logistics and the return policy are influenced by whether companies work B2B or B2C or both. This is relevant knowledge, because of the impact it has on the volume, the quality and the collection methods of returned products. High volume, high quality and the ability to collect products determine the feasibility of circular strategies.

Upcycling and downcycling were mentioned as an addition to the list of strategies in the survey. As recycling already comprises these two strategies, the list of R-strategies will not be extended. The other proposed strategy is recollection. However, this is rather a process or flow than a strategy.

In case the input flow was established by suppliers, the quality of the delivered products was always high. Three cases where the quality was medium or low it was either a combination of returned products and suppliers or returned products only. This might indicate that it is a higher risk to use returned products for the recovery strategies as a lower quality means that it is harder to perform recovery strategies.

Legislation constitutes an important challenge mainly due to transportation regulations. This topic is important to include when formulating and executing circular business models. Companies need to get familiar with this legislation and comply with the regulations.

Product Characteristics

In cases companies indicate that the market value is high, all recovery strategies are performed and most of the companies perform three or more strategies. The one company that considers the market value to be medium, performs five strategies. The one company that has a low market value product, performs only one strategy. It would be expected that a higher market value allows more suitable recovery strategies.

In case the EOL value is high, all strategies are performed. Every company performs three to six different strategies. This is mainly remanufacturing, refurbishing and repairing. In case of a medium EOL value, companies perform two, four or five strategies, representing all strategies. Three companies indicate that the EOL value is low. One of them recycles, another reproposes or rethinks, and the third does remanufacturing, refurbishing and repairing. This might indicate that a higher EOL value allows for more recovery strategies.

There might be an indication that the EOL value and EOL harm are related. In case the value is considered higher by companies, the harm is considered to be higher as well. It could be the case that a product that contains a fair amount of critical and hazardous materials is considered valuable, but harmful at the same time.

The pace of change does not seem to influence the choice for circular strategies. Despite the rating of pace of change, at least four different strategies were performed by the companies. Pace of change might influence the ability to perform a strategy, but not which strategy.

In case the quality of the product is high, all strategies are performed. There are only two companies who considered the quality of the product as medium and they perform all strategies as well. The only company with low quality, performs recycling only. It is suggested that the higher the quality of the product, the easier to perform an R-strategy. As a result, more strategies are suitable in case of a product with a higher quality.

The state of a product does not influence the choice of strategies. Depending on the strategy and the product, it might matter or not whether the product is broken or working. Anyhow, nine out of eleven companies recover products that are either broken or working. There are no indications that the quality depends on the state of the product

The number of users does not seem to have an impact on the quality of the products. During the survey, the number of users was defined as number of owners. While a consumer might be the only person who uses a product, a company might have multiple users who use the product. This again highlights the importance of making a distinction between B2B and B2C. This determines the type of user, which would potentially reveal more relevant information than the number of users.

The volume of processed and recovered products plays an important role. In case the EOL value is low or the market value is low, a high volume of products might justify the investment and execution of recovery strategies. It is justified when it is beneficial in terms of money and sustainable factors.

The cases where companies indicated to return more than 60 per cent of the products, were cases where the EOL harm was considered medium or high. The reasons for product returns are various but returning higher EOL harm products is even more important than returning lower EOL harm products.

Concerning hazardous and critical materials, the results show that products of all interviewed companies either contain hazardous or critical materials. This makes sense given that the companies are all operating in the metal industry. Quantification of the hazardous and critical materials is difficult due to the variety of products and the variety of hazardous and critical materials. Furthermore, the measurement of the materials should be decided upon. For example, whether to measure the weight or the number of materials. Only when this is quantifiable in ways that it can be compared amongst companies, it is a useful topic. As all of the companies deal with these types of materials, it is no decisive factor.

The ranking of circular strategies by the companies differs amongst the companies. Besides the differences in their opinion, one explanation for this would be that the companies process different types of products. The ranking also differs from the Value Hill ranking (Achterberg et al., 2016). While seven out of ten companies perform the best possible strategy according to their own ranking, five companies could perform a strategy that is better according to Value Hill ranking.

5.2 Stage 2: Assessment

The second stage consists of using the information to develop a conceptual tool and use it in a business case setting. This corresponds with step 6, 7 and 8 of the framework proposed in Chapter 4. Based on the reviewed literature, the interviews and assumptions the foundation of the tool is build. The foundation consists of the input, output and logic of the conceptual tool, which all comes together in Section 5.2.1. As an example, the results of a fictive business case are shown in Section 5.2.2.

5.2.1 Tool

As the format of the tool is decided upon, this section describes the input, output and logic of the conceptual tool as a result of the literature, interviews and assumptions. First, the topics for the content of the input of the tool are covered. Then, the content for the output of the tool is described. Lastly, the results for the logic of the tool are elaborated upon.

Input tool

The characteristics that influence the decision for a circular approach are divided over four categories: General, Business Characteristics, Product Characteristics, and Logistics and Reverse Logistics. Per category the important features that serve as input for the tool are briefly described.

The first category concerns general questions, which are meant to draw a basic image of the company. Besides the name of the company, it is relevant to know what products or service they offer. The product categories are extended as a result of the survey. Furthermore, insight must be gained in the sustainable ambition they strive for.

In the second category the business characteristics and the supply chain characteristics from the survey are put together. This category concerns the possibility to perform inhouse strategies and what other processes or flows are present within the company. It also determines what kind of actor the company is and what kind of actors are present in the supply chain.

The third category contains questions about product, like the market value, technical value, quantity, product level, state, and quality. These topics impact the choice for a circular strategy. Furthermore, an additional question about possible circular strategies provides insight suitable strategies for the specific type of product or service that the company offers.

The fourth category includes topics related to logistics. These topics provide insight in the return policy of a company, and the nature of the reverse flows: B2B or B2C, collection methods and transportation possibilities.

For all four of these topics, a list of questions and answers possibilities has been made to serve as input of the conceptual tool. The questions for each category are listed in Appendix E. Besides these topics, there are three more topics that should be included in the resulting tool: legislation, environmental impact and costs. These are important when selecting and executing a circular approach. As the topics are outside the scope of this research, these topics are not developed and included here.

Output tool

Strategies that construct the advice for a circular approach consist of the logistics concepts covered in Chapter 3. These are covered in five strategy factors: Recovery Strategies, Product Level, Product Category, Place of Recovery, and Method of Collection. Per strategy factor the possible strategies that serve as output for the tool are briefly described.

The first strategy factor contains the same seven recovery strategies as in the survey: Repropose/Rethinking, Reusing, Refurbishing, Remanufacturing, Repairing, Disposing, and Recycling.

The second strategy factor consists of the four identified product levels: Raw materials and resources, Parts and semi-manufactured products, Components, and Product.

The third strategy factor is the Product Category. The categories to define the product are not limited anymore to the six e-waste categories only. The following four are added to the list: Metals, Consumer electronics, Batteries, and IT and telecom larger than 50 cm. The eleventh category is Other, in case a product does not fit into the previously mentioned categories.

The fourth strategy factor contains three options for the place of recovery: Inhouse, Outsourced Decentral, and Outsourced Central.

The fifth strategy factor consisted of seven options in the survey and has been extended by one option for the tool: Customer return for free, Customer return for fee, Designated location, Product collection company, Product collection municipality, Production collection facility, Product return via promotions, and Product is brought by client to the company.

Concerning the advice on these topics, it should be kept in mind that it serves as a guideline. The human factor is necessary to make final decisions about the circular approach. For example, about which R-strategy to choose. The ranking of strategies can assist in this choice as well as the knowledge of the decision maker.

Logic

The answer possibilities to all questions and the strategies of the strategy factors are linked by logic based on the literature and the results of the survey. The input draws up a profile of the company, which reveals the logistics challenges on firm level. These challenges were described in Chapter 2 and the challenges to be addressed with the tool are displayed in the first column of Table 13. The output is the advice for a circular approach, which consists of the concepts covered in Chapter 3. These concepts were linked to the challenges in Table 13 such that it provides possible solutions for the decision maker. This logic is incorporated in the conceptual tool.

Table 13. Logistics challenges and contributing concepts

Challenges	Concepts
Firm Level – General	
High costs	Recovery Strategies
Network redesign integration logistics	Place of Recovery
Organisation direct or indirect reverse logistics	Method of Collection
Uncertainty of returns: quality	Product Level
Uncertainty of returns: quantity	Product Level
Firm level – Logistics	
Distribution Logistics	
Transportation methods	Place of Recovery
Inventory management	Place of Recovery
Warehousing	Place of Recovery
Service Logistics	
Increasing service	Place of Recovery
Reverse Logistics	
Reintegrating products into manufacturing process	Place of Recovery
Third Party and Reverse Logistics	
Original value chain or second market	Recovery Strategies
Connection supply and demand	Method of Collection
Marketplaces to exchange new and used commodities	Method of Collection

The conceptual tool

The input, output and logic of the tool is incorporated into a conceptual tool. The tool is built in Excel, version Microsoft 365. The Excel file has four worksheets:

1. [Introduction] This sheet shows the content of the file and provides guidelines on how to use the tool.
2. [Questionnaire] This sheet contains the list of questions and corresponding answer possibilities. The user can provide answers to the questions in this sheet.
3. [Advice] This sheet shows the advice which is comprised of the possible strategies for each strategy factor.
4. [Calculations] This sheet contains the formulas which connect the answers of the questionnaire to the strategies of the strategy factors.

A manual on how to use the tool can be found in Appendix F.

5.2.2 Tool Results

The results are obtained through business cases. The users of the tool are decision makers who own a company that recently has made the transition from a linear to circular business model. The decision makers provided answers to the questionnaire of the tool and interpreted the results. In this section a fictive business case is presented to demonstrate the use of the tool.

The user of the tool is an employee of CircularICT with a core business of selling ICT products. In Table 14, the answers that the employee provided to the questions in the tool are shown.

Table 14. Answers fictive business case CircularICT

General		Q11.	A
Q3.	BF	Q12.	AD
Q4.	A	Q13.	A
Company Characteristics		Q14.	B
Q5.	C	Q15.	BCEG
Q6.	B	**Logistics and Reverse Logistics**	
Q7.	AFH	Q16.	A
Q8.	D	Q17.	C
Product Characteristics		Q18.	A
Q9.	A	Q19.	A
Q10	B		

Advice

	Strategy Factors				
Letter strategy	**Circular Strategy**	**Product level**	**Product category**	**Place of recovery**	**Method of collection**
A		Raw materials and resources			
B	Reuse		E-waste category 2		
C	Refurbish			Outsourced: central	Designated location
D					
E	Repair				Product collection municipality
F			E-waste category 6		Production collection facility
G					
H					
I					
J					
K					

Figure 12. Advice fictive business case CircularICT

As can be seen in Figure 12, the tool provides the user with advice that recommends a strategy for each strategy factor. For example, the first strategy factor, Circular Strategy, contains three possible strategies. The company could choose to reuse, refurbish or repair. The company could also choose to perform two or all three of the strategies. To summarise, the advice for a circular approach would be:

"The circular approach for CircularICT consists of performing **reuse**, **refurbish** and/or **repair** on a product level of **raw materials and resources**. The **E-waste category 2** and **E-waste category 6** products will be recovered at an **outsourced: central** location. The products will be returned via a **designated location**, **product collection municipality** and **production collection facility**."

5.3 Conclusions

The content of the tool is divided into the input of the tool and the output. The literature and the interviews provided the knowledge to define this content. The input consists of 19 topics covered in four categories, which are: General, Company Characteristics, Product Characteristics, and Logistics and Reverse Logistics. The output consists of five strategy factors: Circular Strategies, Product Level, Product Category, Place of Recovery, and Method of Collection. The logic of the tool is implemented in the tool by connecting the input to the output. Specific answers to a question determine the output of the tool as the answers are linked to the strategies of the strategy factors.

6. Tool Evaluation

As mentioned in Chapter 5, this chapter entails the third stage: the evaluation of the tool. This chapter provides an answer to the following research question:

How do companies in the metal industry perceive the use of the designed tool regarding the format, content and logic?

The goal of the third stage is to acquire the experience of the user. The evaluation of the user experience of the tool is measured by means of a survey. This concerns an evaluation criteria form, which is described in Section 6.1. This chapter is concluded in Section 6.2.

6.1 Stage 3: Evaluation

In this section the method and results of the evaluation form are described. Section 6.1.1 elaborates on the method that is used. Section 6.1.2 shows the results of the evaluation criteria form. Section 6.1.3 provides a synthesis of these results.

6.1.1 Evaluation Criteria Form

In order to answer the research question a survey is designed to measure the user experience. The survey consists of mainly closed questions, although open questions are included as well. The closed questions will be posed as statements, to which respondents can respond via a five-point Likert scale. This asymmetric Likert scale contains the following answer possibilities:

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

This scaling method measures an either positive, neutral or negative response to a statement. The Likert scale allows to measure attitude towards the statements in a scientifically accepted and validated manner. This provides the opportunity to quantify the preferences of the respondents (Joshi, Kale, Chandel, & Pal, 2015).

The content of the statements is created by using the usability framework as a guideline, which is shown in Figure 13. This framework is a standard approach to measure user experience and consists of a framework with metrics, such as effectiveness, efficiency, satisfaction.

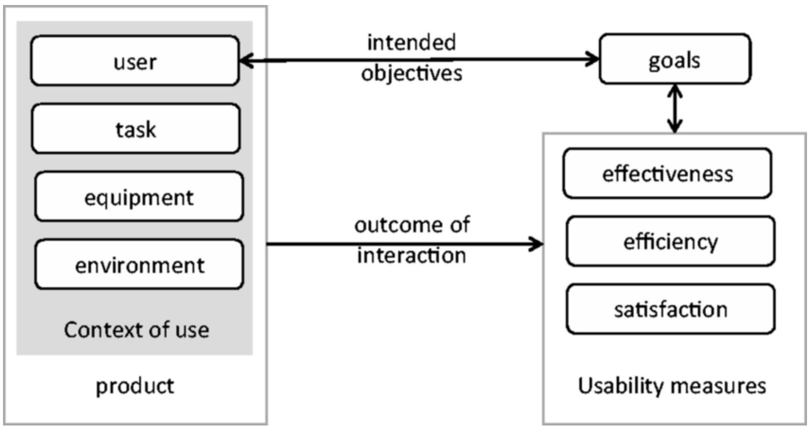

Figure 13. Usability Framework. Derived from ISO 9241-11 (Georgsson & Staggers, 2016)

Concerning the context of use, four factors are elaborated upon: the users, the task, the equipment and the environment. The users of the tool during this stage are the same as the interviewed group of employees during stage 1. The task is to provide answers to the questions asked in the tool. The only equipment necessary is a computer that runs an Excel version that is compatible with the tool. The environment is not relevant: the user uses the tool independently, without assistance or presence of the researcher.

The main goal of the tool is to support companies in the execution of circular business models regarding the organisation of logistics. Concerning the format, the tool should be suitable for this goal and easy to use. Regarding the content, the tool should include the most important factors that influence decisions about logistics. Moreover, the outcome of the tool should provide advice for a circular approach. Lastly, regarding the logic of the tool, the tool should be relying on the right information and argumentation.

The three categories of usability measures are effectiveness, efficiency and satisfaction. The effectiveness is the extent to which the user can achieve a goal with accuracy and completeness. The efficiency is the level of effort and resource usage which is required by the user to achieve a goal in relation to accuracy and completeness. The satisfaction consists of the positive associations and absence of discontent that the user experiences during the performance (Georgsson & Staggers, 2016).

Measurable statements for each category are derived from the set of criteria that Gil Urrutia, Brangier, and Cessat (2017) have created. In total seven dimensions of criteria, allocating 58 criteria, are proposed: accessibility, usability/practicality, emotions/motivations, persuasion, cultural values, management of experience, and socio-organisational context and organisational resources management. As the tool is only a conceptual model that serves as a foundation for development of an actual tool, not all dimensions and criteria are relevant. Besides, other criteria are added which were not included in the criteria set of Gil Urrutia et al. (2017).

The evaluation criteria form can be found in Appendix G and are divided over five categories: General, Format, Content, Logic, and Use. Besides the statements in these categories, suggestions for improvement and feedback were asked. The informed consent that was given to the respondents prior to filling out the form can be found in Appendix H. The evaluation criteria form was made in Qualtrics.

Considering the quantitative approach of the data collection, a descriptive analysis is used to analyse the results. First, the answers to the survey questions are collected in Excel. Based on the Likert statements, the overall experience per respondent and the experience per topic is determined. The open questions are used to support and explain the descriptive results.

6.1.2 Evaluation Criteria Form Results

In this section the results of the evaluation forms are presented. First, general insights are provided concerning the use of the tool. Then, the overall experience and the experience per topic are presented.

As described in Section 6.1.1, the statements could be rated from 1 to 5. All statements were formulated in a positive manner, which means that a high score represents a positive attitude towards the statement and a low score represents a negative attitude. The interpretation of the scores is based on the value of the mean and divided into three categories:

- Mean between 1-3: insufficient
- Mean between 3-4: sufficient
- Mean between 4-5: good

General

In total, ten respondents (n=10) evaluated the use of the tool. Three respondents used a version of Excel that did not support the formula *=Concatenate*, which resulted in the error *#NAME?* in the fourth sheet *Calculations* of the Excel workbook. The other seven respondents could use the tool without any errors.

Overall experience

The overall experience is measured by the mean of the ratings for all statements given by the respondents and has a value of 3.3. This means that the respondents have a positive attitude towards the tool in general. The middle value separating the greater and lesser halves of the given scores is the median, which is 3. The most frequent given score is the mode and is equal to 4. The overall experience per respondent is evaluated by looking at the mean, the median and the modus for all of the statements. The results are given shown in Table 15.

Table 15. Overall user experience per respondent

Respondent	1	2	3	4	5	6	7	8	9	10	Total
Mean	3.4	2.1	3.5	3.0	2.6	4.0	3.2	3.4	3.7	3.6	3.3
Median	3.5	2	4	3	2	4	3	3	4	4	3
Mode	4	2	4	3	2	4	3	3	4	4	4

Eight of the respondents have a positive attitude towards the tool as the mean is 3 or higher. Five out of ten respondents had a rather positive than neutral attitude, which can be derived from the mode. Two respondents have a negative attitude towards the tool as they most frequently disagreed with the statements. While respondent 2 either (strongly) disagreed or felt neutral about all statements, respondent 5 disagreed with half of the statements and was neutral or positive about the other half of the statements. As the tool is very generic with a focus on companies within the entire supply chain performing all sorts of recovery strategies, an explanation for the negative attitude might be that the tool has the worst fit for these companies. Respondent 2 is a service provider of ICT. All the other companies are producers. Respondent 5 is a recycler of products that have reached the final EOL state. As opposed to the other companies, this company is at the end of the supply chain and has a very specific core task: upcycling of metals.

Experience per category

In Table 16 the results of the user experience are presented per category and subcategory. The scores for the format, the content, the logic and the use are very similar as the mean is either 3.2 or 3.3 for each category. The most important findings per category are elaborated upon in the remainder of this section.

Table 16. User experience per category

Category	Mean	Median	Mode
Format	3.2	3	4
Content	3.3	3	4
Logic	3.2	3	4
Use	3.3	4	4

The respondents have a positive attitude towards the format of the tool (mean=3.2). The attitude towards the format of the tool was tested by five different statements: S1-S5. S4 is the only statement with an insufficient score (mean=2.8), which can be seen from Table 17.

One respondent provided feedback regarding the format and states that it is unclear what the strategies are and what purpose they have.

Table 17. User experience results: Format

Statement	Mean	Median	Mode
S1. The presented information is clearly displayed.	3.3	4.0	4
S2. The tool provides enough information and guidance to use the tool.	3.2	3.5	4
S3. The interface design choices are maintained in similar contexts, but differ when the context is different. For example: it is clear which part of the tool belongs to the questionnaire (input) and which to the advice (output).	3.4	4.0	4
S4. The 'If-Then'-construct is a pleasant construct to use.	2.8	3.0	3
S5. The 'If-Then'-construct is a suitable construct for a decision support tool.	3.1	3.0	3

The overall score for the content is a 3.3. This is the result of the scores of the four subcategories, which are presented in Table 18. The respondents have a positive attitude towards the content in general (mean=3.4), the questionnaire (mean=3.3) and the answer possibilities (mean=3.5). The attitude towards the fourth category, advice, is neutral (mean=3.0).

Respondents provided feedback for two subcategories. Regarding the advice, respondent 10 mentioned that the given advice was incomprehensible. Respondent 3 says that the advice should be underpinned as this would lead to higher acceptance. Regarding the answer possibilities, this respondent mentions that products are labelled too soon. The product is then considered to be waste, while the product should be considered as a product that could be recovered to serve a second life.

Table 18. User experience results: Content

Statement	**Mean**	**Median**	**Mode**
Content	3.3	3.0	4
General	3.4	4.0	4
S6. The presented information is easy to understand.	3.4	4.0	4
S7. I trust the veracity of the information that is used in the tool.	3.3	4.0	4
Questionnaire	3.3	3.0	4
S8. The questions consist of all relevant topics.	3.3	3.5	4
S9. The questions cover all relevant topics.	3.3	3.0	3
Advice	3.0	3.0	3
S10. The advice consists of all relevant topics.	2.9	3.0	3
S11. The advice covers all relevant topics.	3.0	3.0	3
Answer possibilities	3.5	4.0	4
S12. Mutually exclusivity. The answer possibilities for each question are mutually exclusive, such that there is no overlap in the answer possibilities.	3.5	4.0	4
S13. Collectively exhaustive. The answer possibilities for each question are collectively exhaustive, such that there are no answer possibilities missing in the answer possibilities.	3.4	3.5	4

The respondents have a positive attitude towards the logic (mean=3.2). The scores of each of the three statements are quite similar. The scores for S14 are the lowest. The results are shown in Table 19. The feedback received on the logic, regards the advice. Respondent 3 mentions that the advice should be accompanied by more context.

Table 19. User experience results: Logic

Statement	**Mean**	**Median**	**Mode**
Logic	3.2	3.0	4
S14. Based on my answers to the questions, the provided circular approach makes sense to me.	3.1	3.0	3
S15. I trust the advice that the tool provides me with.	3.1	3.0	4
S16. I am convinced that the advice of the tool is based on logic and not randomly generated.	3.3	3.5	4

The respondents have a relatively positive user experience, which can be seen in Table 20. The experience before using the tool was considered the most positive subcategory (mean=3.7), followed by the experience during the use of the tool (mean=3.5). The experience after the use of the tool (mean=2.8) does not have a sufficient score as all three of the statements used to measure the experience after using the tool scored a mean of 2.9 or lower.

Table 20. User experience results: Use

Statement	Mean	Median	Mode
Use	3.3	4.0	4
Before	3.7	4.0	4
S17. The effort required to understand the format of the tool is low.	3.6	4.0	4
S18. The effort required to understand how to use the tool is low.	3.8	4.0	4
S19. The effort required to start using the tool is low.	3.6	4.0	4
During	3.5	4.0	4
S20. I could use the tool independently without asking others for help.	3.3	4.0	4
S21. The effort to use the tool is low.	3.7	4.0	4
S22. The tool guided me sufficiently through the questions and answers to get to the circular approach.	3.4	4.0	4
S23. I have access to sufficient knowledge and data to answer the questions.	3.4	3.5	4
After	2.8	3.0	3
S24. I am convinced that the tool can be of support in formulating a circular approach.	2.9	3.0	3
S25. The tool provided me with a better understanding of the opportunities for a circular approach.	2.9	3.0	3
S26. The advice for a circular approach is displayed transparently and clearly.	2.6	2.5	2

The respondents did not provide any feedback regarding one of the subcategories.

Suggestions for improvement
Three respondents did suggestions for improvement. Respondent 3 mentioned that the tool should have an interface that is less technical such that it is easier for the companies to use. Moreover, the context of the advice should be extended and have a focus on the companies. Respondent 4 states that the tool is incomplete. Respondent 9 suggests creating the tool in a web based interface with a user interface instead of Excel. The advice could then be hyperlinked and visualised with data and examples. The respondent adds that with these improvements, the advice would become clearer.

Feedback
Respondent 5 provided some final feedback, which said that the tool is not built to close loops in order to make the transition to CE.

6.1.3 Evaluation Criteria Form Synthesis

This section presents a synthesis of the evaluation results. This contributes to understanding the results and provides a foundation for improving the tool. The idea for the conceptual tool is based on three elements: format, content and logic. In order to showcase these elements, it has been decided to build a basic version in Excel. This allows the users to use a tool with this format and evaluate the content and logic. Although the tool is just conceptual, all four categories were included in the evaluation criteria: format, content, logic and use. While the results show that the attitude towards the tool is slightly positive and this suggests room for improvement, only limited feedback is provided by the respondents.

Overall experience
The respondents had a similar attitude towards the statements of each of the four categories. However, there were differences between the subcategories of the categories. These can be derived from the scoring of the statements per subcategory. First, the worst and best scoring topics are highlighted. Then, the categories and subcategories are evaluated.

All statements that were rated between 1 and 3 are considered to be insufficient and are included in the worst scoring topics. The five statements that fulfilled these criteria are displayed in Table 21.

Table 21. Worst scoring topics evaluation criteria

Category	Statement	Mean
Format	S4. The ‘If-Then’-construct is a pleasant construct to use.	2.8
Content Advice	S10. The advice consists of all relevant topics.	2.9
Use – After	S24. I am convinced that the tool can be of support in formulating a circular approach.	2.9
	S25. The tool provided me with a better understanding of the opportunities for a circular approach.	2.9
	S26. The advice for a circular approach is displayed transparently and clearly.	2.6

The five statements cover three different categories. The first category, format, shows that the ‘if-then’-construct is not considered as a promising method for this case. It could be that the construct is not functioning properly in such a conceptual tool and needs additional development. Users did not indicate what they did not appreciate about the construct. The other two categories, concerning statements S10, S24, S25 and S26, both regard the final phase of the tool where the advice is being interpreted and the value of the tool is determined. The advice is elaborated upon at the end of this section.

The best scoring topics are the statements that were rated with a minimum of 3.5. The five statements are displayed in Table 22. Regarding the content, users had a quite positive attitude towards the mutually exclusiveness of the answer possibilities. Looking at the use, the results show that the users have a positive attitude towards the tool in the pre-use phase. All three statements, S17, S18 and S19, have a rating between 3.6 and 3.8. Also, one of the statements of during the use phase, S21, is considered positive. This category scores quite well, as the other three statements of this category, S20 and S22 and S23, are rated between 3.3 and 3.4.

Table 22. Best scoring topics evaluation criteria

Category	Statement	Mean
Content – Answer possibilities	S12. Mutually exclusivity. The answer possibilities for each question are mutually exclusive, such that there is no overlap in the answer possibilities.	3.5
Use – Before	S17. The effort required to understand the format of the tool is low.	3.6
	S18. The effort required to understand how to use the tool is low.	3.8
	S19. The effort required to start using the tool is low.	3.6
Use - During	S21. The effort to use the tool is low.	3.7

As can be seen from these results, the use phase is experienced as quite positive before and during the use of the tool. On the contrary, users did not experience the after-use phase positively.

Unclarities

The results show that it was not entirely clear what the strategies entail and what purpose they have. This can be a result of lack of information about each strategy. As a definition does not seem enough, the strategies should be elaborated upon such that there is no ambiguity on the meaning of each strategy. In both the manual and the tool, it was mentioned that the strategies are possibilities of a specific strategy factor and that these together make up the circular approach. The explanation of the strategy factors was limited.

The tool in Excel

Based on the files that the companies sent back with their answers of the tool, the answer sheet in Excel was not a suitable method. Although, users got instructions on how to enter the answers, the closed questions with multiple answers possibilities created problems. There were no error messages when the users entered the answers in the wrong way. Resulting in users not being aware of the errors. The drop-down menu for closed questions with just one answer possibility worked out well. Excel gives an error message when users tried to provide other answers than listed or more than one answer.

Another disadvantage was that users do not only see the questions and answers, but also the calculations. As a first version of the tool, it was not the intention to provide a perfect user interface. However, feedback from users indicated that this was hindering the testing and evaluation of the tool. The tool should be designed such that it fulfils the requirements and wishes of companies, which means less technical elements in sight. It would have been better to have an interface which only shows questions and answers. A web-based interface provides a solution to these problems. Moreover, visualisation of data and examples could be added to enhance user experience. Besides, it could contribute to the proper presentation of the advice.

Advice

The advice was given in bullet points and only the possible strategies for each strategy factor were listed. However, there was no guiding text as in Section 5.2.2 or other context. Users indicated that more context would have been useful to understand the advice. It is important to include a guiding text, but even more important would be to provide implications for each strategy. However, it must be kept in mind that the tool was designed to provide a direction for companies that needs human expertise and interpretation in order to come up with a circular approach. When adding context to the advice, one must consider what focus is required for the user in order to tailor to the needs of a company.

Target group

The target group for this tool seems too diverse in order to design one general tool. Not all questions were applicable to each respondent, because of the company characteristics or the products and services that the company provides. This led to problems in answering the questions. As all answers to the questions were linked to the advice, the advice could be different than expected by the companies. The tool is too general to serve certain companies, but too specific to serve other companies. For example, some companies use waste as input flow so they do not consider this input as waste. They state products are labelled too soon as such. Another example is that companies do not use returned products to perform recovery strategies. Nevertheless, companies did not indicate what questions specifically were not useful for them or what questions might be missing.

6.2 Conclusions

The overall experience of using the tool is positive. There is room for improvement, which can be expected from a conceptual first version. It can be concluded that the tool is too general to provide guidance in choosing a circular approach. A more specific tool should be made, but in that case the target group should be more homogeneous. Furthermore, the use of the 'if-then'-construct is questionable as a suitable decision support method. Additions should be made to obtain a properly functioning tool. Concerning the output of the tool, the advice should be supported by context and explanation. Finally, the experience of users would be greatly enhanced when using a web interface instead of an Excel approach.

7. Discussion and Conclusion

In the previous chapters, the research questions are answered. Section 7.1 provides a discussion of the research: an interpretation of the results is given, the academic and practical contributions are elaborated upon and the limitations are covered. Section 7.3 presents recommendations to use the results of this research and proposes ideas for future research. In the final section, Section 7.1, the conclusions will be drawn together and provide an answer to the main research question.

7.1 Discussion

Section 7.1.1 provides an interpretation of the results. In Section 7.1.2 the contributions of this research are elaborated upon. The limitations of this research are discussed in Section 7.1.3.

7.1.1 Interpretation of results

This section provides the interpretation of the most important results. This regards the challenges companies face, the influence of product characteristics on recovery strategies, the format, content and logic of the tool, and the differentiation between transition agendas.

Companies in the metal industry that perform activities related to urban mining and CE face several challenges. During the interviews it became clear that the challenges that companies face are in line with the reviewed literature. Three of the most important challenges concern legislation, coordination complexity, and awareness amongst the government, consumers and companies. The organisation of reverse logistics did occur as a challenge but it seems that companies mainly struggle with rules instead of the organisation regarding logistics. According to the literature companies should in- or outsource the organisation of logistics depending on their capabilities and resources. Due to the diversity of the companies, there was a high variety in their capabilities and resources. Nevertheless, almost all companies outsourced logistics, although they often own logistics resources.

According to the literature product characteristics influence the suitability of recovery strategies in various ways. In line with the literature, the results suggested that a higher market value allows for more recovery strategies. The same holds for a higher EOL value. Furthermore, the volume of products is important as the combination of low product value and high volume might result in a beneficial business model. On the other hand, the number of users, change of pace, concentration and contamination, and state of a product do not seem to influence the opportunity for recovery strategies in a negative way. In contrast with the reviewed literature, companies do not rank recovery strategies equally. The ranking is dependent on possible strategies and the product to be recovered.

The tool is evaluated by the intended users on criteria regarding the format, content, logic and use. The users were included in an early stage as this provides valuable data and it contributes to acceptance in a later stage. However, the evaluated version of the tool might have been too conceptual. Respondents seemed to focus on the application of the tool instead of the format, content, and logic. The literature on user experience highlighted the importance of clarity, transparency and looks. The respondents provided feedback that supported this information.

Literature stressed the importance of a differentiation between transition agendas and clusters of companies. While the target group was demarcated to companies operating in the metal industry processing e-waste, the group was characterised by a high variety. This could be noticed from the positions of the companies in the supply chain and products that the companies sell. As a result, the results from the interviews and the development of the tool are harder to interpret due to this variation. As the literature stated, there is not one simple approach for overcoming barriers to its implementation.

7.1.2 Contributions

This section reflects on the contribution of this research. A distinction has been made between academic and practical contributions.

With this research, academic contributions are made to the existing literature in the following ways. First, this research contributes to making the gap smaller between the theory and the implementation process of CE. The challenges that companies face are connected to potential opportunities that CE presents. This helps companies to overcome these barriers when making the transition to CE.

Second, the topic of CE is rather old. However, now more than ever, the importance of this field of study is stressed. An important feature to successfully make the transition towards CE and put the theory to practice, is to apply logistics concepts. However, academic literature does not widely discuss supply chains and logistics in combination with CE yet. This research contributed to connecting these topics in the field of urban mining.

Third, this research looked into the concepts of CE from a firm-oriented perspective while most research in the field are closely linked to a system-oriented perspective. The interviews were held amongst eleven companies that are pioneering towards CE. There were at least two advantages to their recent transition towards a circular business model. In this research the companies were asked questions regarding their business model and strategies, which could be answered rather detailed. Besides, this research aimed to identify challenges and barriers as well. Companies either considered or experienced this while implementing or after implementing circular business models. The inclusion of eleven companies of different stages of the supply chain with different core business ensured that a variety of companies were represented in the research.

Fourth, this research shows the importance of tailored approaches for overcoming barriers. As there is not one simple approach for overcoming barriers in implementing circular business models. The decision support tool should target a cluster of comparable companies in order to be effective.

The following practical contributions have been made. First, to the best of the researcher's knowledge, this is the first research that explores the requirements for building a tool that supports logistics decisions in making the transition towards circular business models. This research comes up with a foundation for such a tool, which is built on a combination of existing scientific literature, and the knowledge and experience of companies, which are experts in the field. Not only the required content of the tool is determined, but also the format and the logic of the tool. The result is a conceptual version of the tool, which expresses the format and incorporates the content and logic. Such a tool is not designed before and it provides a stepping stone for developing an actual tool.

Second, ten business cases are involved to use the tool and evaluate the tool. This led to interesting information whether the tool is a promising concept and what needs to be improved from a user perspective. This is rather important to decide on the format of the tool, which is a part of the usability. The involvement of users is useful as they are stakeholders which have an important role in the development and use of the tool. Furthermore, the users can be seen as experts in the field as they implement circular strategies and have to face the challenges of making the transition to CE.

Third, this research helps UPCM in determining the needs of companies in order to make the transition to CE. This contributes to their goals set by MinEZK and the government of helping the Netherlands become circular in 2050.

7.1.3 Limitations

Naturally, this research has its limitations, which are explained in this section.

Business cases

It would have been valuable to include more companies in the stage of conducting the surveys. Ten interviews are a minimum when conducting qualitative research. A bigger sample size would have enabled performing quantitative analyses on the closed questions of the survey. In order to reach a minimum acceptable amount of companies, it is important to keep in mind that the number of companies that (recently) made the transition towards CE is limited. However, considering the diversity of the group and the qualitative aspect of this stage, a saturation of information has been achieved.

Tool validation

The ten companies that used the tool and evaluated the tool were really useful in determining the user experience of the tool. Nevertheless, a substantial number of additional cases is necessary to confirm the logic behind the tool. In order to validate the outcome of the tool, many similar cases should be included as well as a huge variety of cases. Due to a lack of time no more companies were included in this research, which resulted in suboptimal validation of the content and logic of the tool.

Literature
As the field of CE and, more specifically, the combination of CE and logistics is rather new in scientific literature, research is quite limited. This posed some difficulties in determining the content and logic of the tool. In this research, the logic is mainly based on the data gathered by the interviews. Research and case studies provide proof on what content needs to be included and, maybe even more important, what relations between the input and output exist.

Online interviews
At the time of research, physical meetings were discouraged and undesirable because of COVID-19 measures. As a result, the interviews had to be held online, either through video calls or regular calls. A number of disadvantages of online meetings over physical meetings were experienced. One disadvantage is the wavering quality of sound, video and internet connection. This makes it harder to understand each other and interpret the intention of the other. Another disadvantage is the fact that it is harder to establish a connection between researcher and respondent. Furthermore, both parties do not see and thus not read each other's body language. Both reasons reduce the ability to use social cues.

Content interview
The survey designed for the interview consisted of 40 questions, which covered a variety of topics. It was a huge limitation to not know upfront which topics were of great value and which not. Decisions on what topics to include and which not had to be made to limit the length and duration of the survey. The outcome of these decisions caused a lack of content on some topics, while some others might have been excluded from the start.

Terminology interview
The terminology of the topics and concepts in the survey were listed and explained to the respondents. However, due to the high variety in companies and their products that were included for the interview it was not possible to quantify all answer possibilities. This was the case for the answer possibilities: high, medium and low. Furthermore, employees of companies have different opinions and considerations. For example, producers might not be aware of the EOL harm of their products. This results in different responses, which are hardly objectively quantifiable.

Evaluation survey
The evaluation criteria form is now distributed in form of a survey. While the users were forced to give their opinion about the statements, the open feedback questions were not mandatory. This led to a low response rate to the open questions. This is a limitation as the open feedback would explain the scoring of the statements. It would also provide suggestions from the users, who could have given their expert opinion on the topics. A forced answer entry probably does not solve this case, so instead a structured interview would have been a better method to conduct this step of the research.

7.2 Recommendations and Future Research
In this section the recommendations and suggestions for further research are covered.

7.2.1 Recommendations
The following recommendations for UPCM on how to use the results of this research are proposed:

Using the tool
The format and content can be used as a starting point to further develop the tool. When the proposed format is used to further develop the tool, the outcome of the tool should be used as a guideline only and not as a solution. The outcome is an advice that guides the decision maker in a direction for a solution. Human expertise should always be included to interpret the outcome of the tool. The implications of adopting the circular approach that the tool advices should be investigated and considered.

Overcoming logistics challenges
This research shows the need for revising current regulations created by the government. First, subsidies and incentives should constitute an attractive reuse market. Companies should rather recover products than recycle or even dispose them. Second, regulations should be observed and maybe revised. For example, the regulations that label products as waste too soon. This hinders companies to transport, export and import specific products that are now labelled as waste, while companies are actually meaning to recover these products to serve a second life.

Creating a database with company data
A database can be created, which could be used to gather information on the process and the progress of companies that transition from linear to circular business models. In this research, eleven companies were included, but extending this would provide a better basis for decision tools. The variety in companies can distinguish different needs for decision tools. The similarities in companies can provide a foundation for the content and logic of each decision tool. Scenarios can be defined based on this database, which could help identify clusters of companies, their features and their needs.

7.2.2 Future Research
In this section the opportunities for further research are introduced in order to strengthen and extend this research, and to explore and broaden the topics of this research.

The following five suggestions are proposed as to strengthen and extend this research.

Data collection on challenges
A nationwide survey could be conducted in order to identify barriers that companies in the Netherlands experience. In order to support companies and facilitate the transition from a linear to circular business model, the ability to provide tailored support is important. Data on the challenges that Dutch companies experience, identifies the needs for tailored support. The challenges can be connected to the actors of the supply chain of each company. This way the companies can be clustered into groups within the transition agenda of the manufacturing industry.

Connection challenges and strategies in CE
The experienced logistics challenges and the strategies in CE could be linked. Case studies could provide insight in what strategies are useful to overcome challenges and which are not. A model could be trained to identify the opportunities or successful approaches such that it can set an example for other companies. As a starting point the cluster of mechanical engineering within the transition agenda of the manufacturing industry should be used. The agenda covers a wide range of companies from consumer electronics to windmill parks offshore. Mechanical engineering is a suitable cluster to start with as it is positioned in the middle of the spectrum. This cluster enables the determination of the basic characteristics and parameters to include as input for the tool.

The content of the tool
The tool should be adapted according to the target group it is supposed to support. Depending on this group, the model should be extended with more questions or other questions. The questions should be tailored to the group such that all questions are relevant. Furthermore, the advice should consist of strategy factors which are useful for this group. Both the questions and the strategy factors should be identified for each group.

The development of the tool
The tool can be further developed into a working product. Users should be engaged in the development to reflect on the format, content and logic of the tool. Moreover, the environment of the tool should be decided upon after researching the opportunities for an Excel based tool, a web-based interface or another application for example. The 'if-then'-construct should be extended such that multiple criteria can be included. This could be in the form of a MCDA method, which could be developed to assess the criteria found for a specific cluster of companies. UPCM uses a time horizon of zero to five years for operational solutions. MCDA is suitable method to give effect to the targets for this time horizon.

Impact measurement of the tool
The tool can be extended with at least the three topics: costs, environment and legislation. Currently, the inclusion of company characteristics and circular strategies provides a guideline for a circular approach. It would be very useful to include the mentioned topics as the feasibility, the effectiveness and viability can be measured as well.

The following three topics for further research are suggested to explore and broaden the topics of this research.

Complexity calls for IT systems
The increase in e-waste leads to a growing number of products returned from the customer to retailers. The result is a growing need to manage backward materials and information flows in the domain of supply chains. The increasing complexity and scope mean that the information infrastructure behind supply chains requires novel approaches based on ICT. The opportunities of integrating ICT or even IoT should be explored in order to overcome the challenges in transition from a linear to a circular economy. ICT and IoT could provide a faster and more sustainable solution at a lower cost.

Electronic vehicles
As the use of electric vehicles is growing, there is a need to address the EOL management of electric vehicle batteries. Governments support the use of electric vehicles and it is an upcoming waste stream. This group of products is thus a relevant and important cluster to create tailored EOL management for.

Legislation
Transportation of products that are labelled as waste already is difficult due to legislations. It could be very useful to look into these legislations and how to revise them in order to support companies in the organisation of logistics. In further research the needs for changes can be identified and tested.

7.3 Conclusion
In this section, an answer is provided to the main research question which is formulated to address logistics challenges:

What logistics concepts that are applicable to companies in the metal industry can be incorporated in a tool in order to support decision making in the execution of circular business model strategies?

This research started with identifying the logistics challenges that companies face in the transition towards CE as today's industrial development is still thriving on a linear economy. Implementation of CE into business models require a change in the organisation of a firm's logistics. The shift from a linear to circular business model is hard as the transition is in an early stage and the number of logistics types and the logistics' complexity increases. Companies face challenges such as socio political, economic, and environmental barriers. Furthermore, they face challenges in distribution, service, reverse and third-party logistics.

Five logistics concepts are explored which provide opportunities to overcome these challenges. The first concept, recovery strategies, revealed six main strategies that can be adopted: reproposing/rethinking, remanufacturing, refurbishing, reusing, repairing, and recycling. The second concept regards reverse logistics, which have to be implemented to establish a sustainable or closed loop supply chain. The method of collection is the third concept which covers the collection of commodities in order to perform the strategies. The fourth concept is the level to which the strategies are performed and is referred to as the product level. Depending on the level of the product, the decision maker can identify the opportunities to perform a strategy. The fifth and final concept is the place of recovery, which provides a solution to the insourcing or outsourcing of logistics activities.

The logistics concepts that serve as an opportunity for the challenges are connected by means of a conceptual tool. The foundation for the tool is built by reviewing other decision support methods. The design science framework that is used to develop DSS and the steps of the MCDA method provided relevant features to build the tool. The chosen format of the tool is based on business rules. The content of the tool covers the input and output of the tool. The input was based on literature and interviews amongst employees of companies that have made the transition towards CE. The output consisted of an advice based on literature. The input consists of 19 topics covered in four categories, which are: General, Company Characteristics, Product Characteristics, and Logistics and Reverse Logistics. The output consists of five strategy factors: Circular Strategies, Product Level, Product Category, Place of Recovery, and Method of Collection. The topics and concepts incorporated in the tool are considered relevant by the respondents, but the format of the tool yielded moderate results. The results show that decision makers prefer a more user-friendly user interface. Furthermore, the tool should provide context along with the advice. Respondents indicate that it is ambiguous what the advice means and that is not tailored to their specific business case.

To conclude, this research achieved the predefined research goal:

Establish a foundation for a tool consisting of logistics concepts and circular strategies that are applicable to companies in the metal industry in order to support decision making in the execution of circular business model strategies.

A foundation is established with this research as the content of the tool connects logistics concepts and circular strategies that help overcome challenges in the execution of circular business model strategies. This foundation can be used to further develop a tool, but there are three issues to take into account. First, the content of the tool is too general and should be designed for a specific target group. Mechanical engineering is a suitable starting point within the transition agenda of the manufacturing industry. Second, the format and application of the tool should be reconsidered. The 'if-then'-construct could be extended to a method that includes multiple criteria, such as the MCDA method. Third, the advice should be provided with some context and guidelines. This enhances the user experience and acceptance of the tool. In order to complete the content of the tool, the three topics costs, legislation and environment should be part of the foundation as well.

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Appendix A
Figures of Section 3.4.1

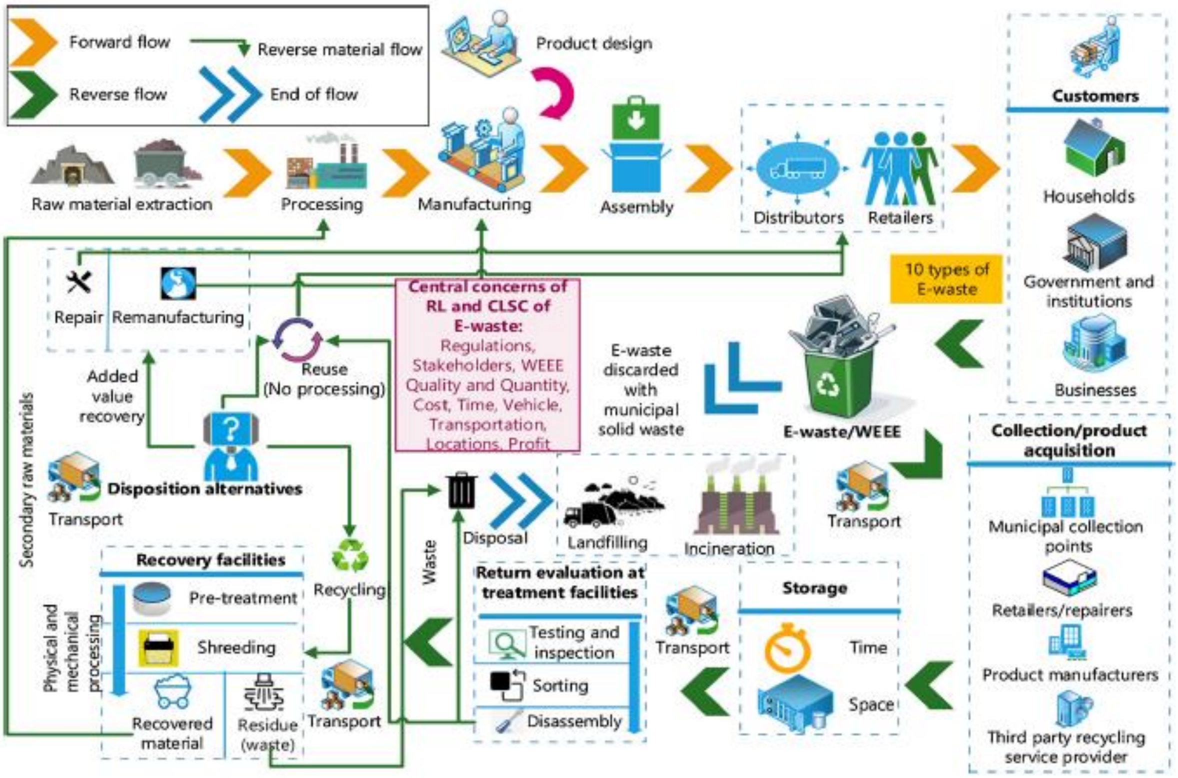

Figure A1. Detailed representation of a logistics network (Islam & Huda, 2018)

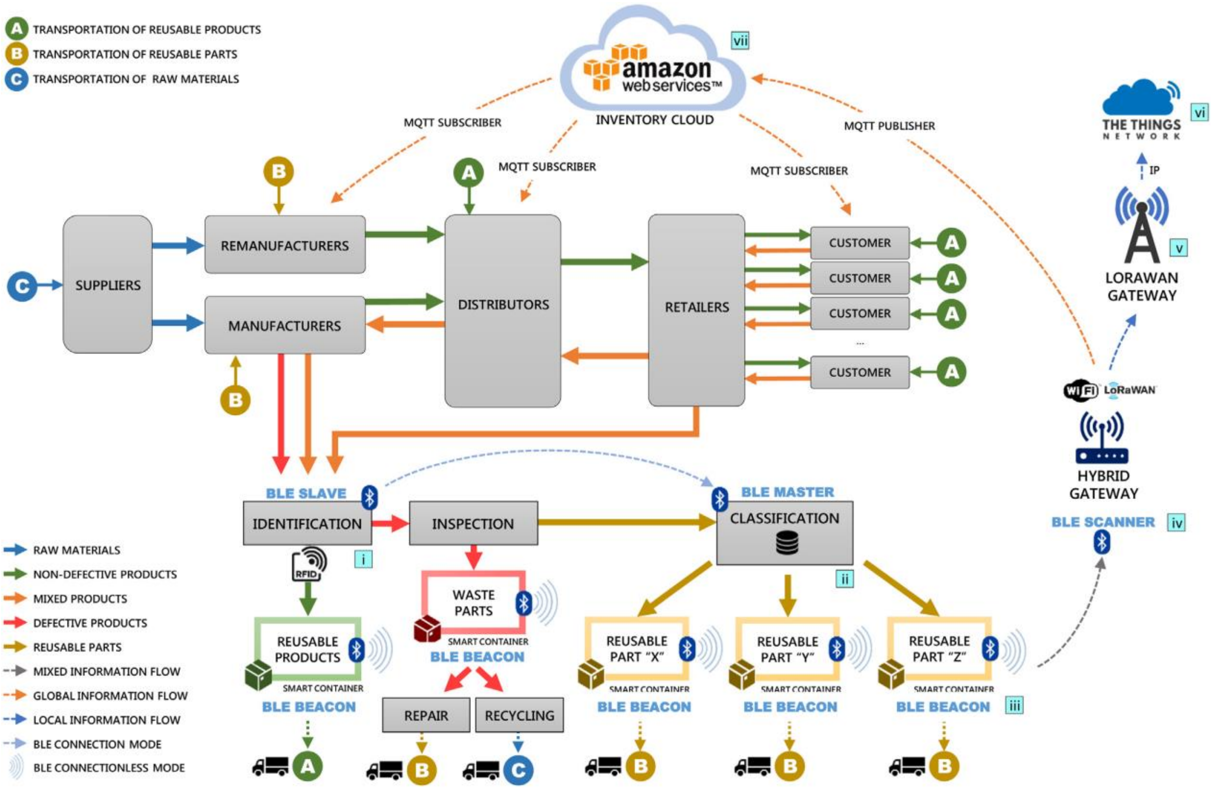

Figure A2. Supply Network (Garrido-Hidalgo et al., 2019)

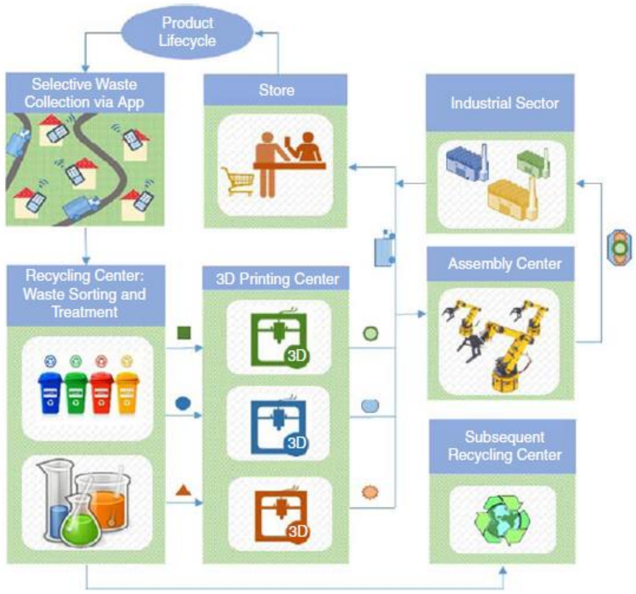

Figure A3. Closed Loop Production System (Luiz et al., 2018)

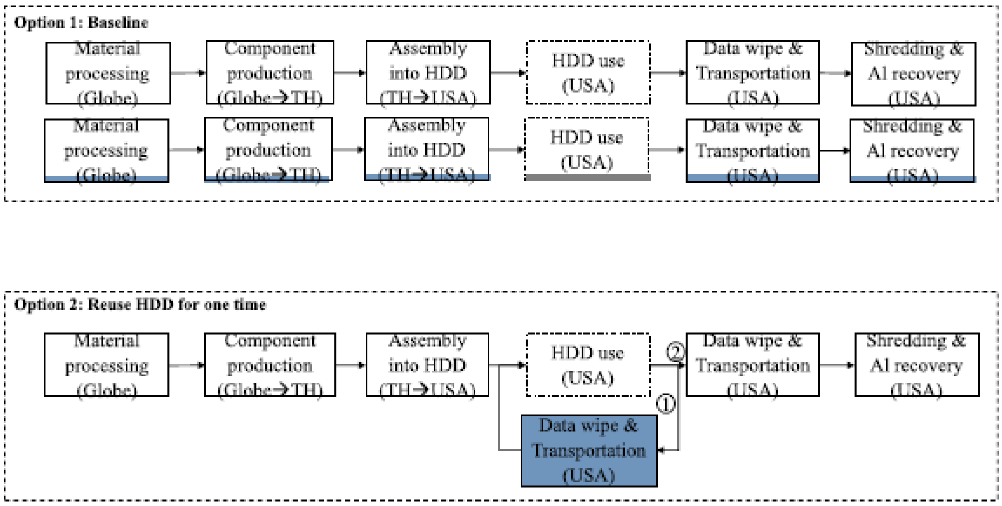

Figure A4. Two process flows representing the logistics of two alternatives (Jin et al., 2020)

Appendix B

Survey

Qx = Open or closed question x

General

Q1. What is the name of your company? In the remaining questions this will be referred to as 'the company'.
Open

Q2. What is the main sector in which the company is operating?
Open

Q3. What is the core business of the company?
Open

Q4. We would like to know about the type of customers of the company. What type of customers does the company deliver to? Multiple answers possible.
End-users. For example: consumers, businesses and/or the government.
Producers. For example: manufacturers or assemblers.

Q5. Which products are part of the company's assortment? Multiple answers possible.
Category 1: Temperature exchange equipment (TEE)
Category 2: Screens, monitors, and equipment containing screens having a surface greater than 100 cm2
Category 3: Lamps
Category 4: Large equipment (any external dimension more than 50 cm). Not category 1, 2 or 3.
Category 5: Small equipment (no external dimension more than 50 cm) including luminaires. Not category 1. 2 3 or 6.
Category 6: Small IT and telecommunication equipment (no external dimension more than 50 cm).
Category other: ___

Q6. We would like to know about the type of materials that are being supplied to the company. Which types of materials does the company purchase? Multiple answers possible.
Raw materials and resources
Parts and semi-manufactured products
Components
Product

Q7. We would like to know what products and materials are being supplied to the company. What products and materials form the input flow of the company?
Open

Supply Chain Characteristics

Q8. Which actors are present in the supply chain? Multiple answers possible.
Supplier
Manufacturer
Assembly
Distributor
Retailer
Sales
User
Collection
Inspection
Recovery

Disposal
Q9. We would like to know the position of the company in the supply chain. Which actors are predecessors of the company in the supply chain. Multiple answers possible.
Supplier
Manufacturer
Assembly
Distributor
Retailer
Sales
User
Collection
Inspection
Recovery
Disposal

Q10. We would like to know the position of the company in the supply chain. Which actors are successors of the company in the supply chain. Multiple answers possible.
Supplier
Manufacturer
Assembly
Distributor
Retailer
Sales
User
Collection
Inspection
Recovery
Disposal

Q11. We would like to know which flows take place in the company. Which flows take place? Multiple answers possible.
Production
Distribution
Consumption
Collection
Inspection
Recovery
Redistribution
Disposition

Logistics and Reverse Logistics
Q12. Is there a return policy? If yes, please describe what the policy looks like.
Yes: ___
No

Q13. Are logistic operations managed by inhouse logistics or third party, outsourced, logistics? Multiple answers possible.
Inhouse
Third party

Q14. Does the company own (external) logistic resources? For example: a truck fleet.
Yes
No

Q15. Does the company own a warehouse?
Yes
No

Q16. Does the company any perform R-strategies inhouse?
Yes
No

Only if 'Yes' is selected as answer to Q16, then Q17 is displayed.
Q17. Which R-strategies does the company perform? Multiple answers possible. Please add any in case an R-strategy is not listed.
Reproposing/Rethinking
Remanufacturing
Refurbishing
Reusing
Repairing
Recycling
Other, namely: ___

Only if 'No' is selected as answer to Q16, then Q18 is displayed.
Q18. In case the company does not perform R-strategies inhouse, these activities take place somewhere else. Is there a direct link between the company and the recovery plant?
Yes
No

Q19. We would like to know about the input flow of products and materials of the company. The input flow is the one that is used to perform recovery strategies in case the company performs R-strategies. Does the input flow consist of returned products and materials or products and materials from suppliers? Multiple answers possible.
Returned products
Suppliers
Other, namely: ___

Only if 'Returned products' is selected as answer to Q19, then Q20 is displayed.
Q20. In which way(s) does the company collect products that need to be returned? Multiple answers possible.
Products can be returned for free.
Products can be returned for a fee.
Products can be brought to designated locations, like shops.
Products can be collected by the company.
Products can be collected by the municipality.
Products can be brought to a recycling centre (Dutch: milieustraat).
Products are collected via promotions.

Q21. The company has to comply with certain legislations. This could create barriers in the execution of circular strategies. Does the company have to deal with these barriers. If yes, please mention the what type of legislation.
Yes: ___
No

Q22. Which logistic problems, challenges or questions does the company face or have?
Open

Product Characteristics

Q23. Product Value. The value of products and materials determines the justification of investment in recovery. This is the case in both a high value and a high end-of-life. How does the company considers the market value of the product?
High
Medium
Low

Q24. Product Value. The value of products and materials determines the justification of investment in recovery. This is the case in both a high value and a high end-of-life. How does the company considers the technical value of the product?
High
Medium
Low

Q25. Product Value. The value of products and materials determines the justification of investment in recovery. This is the case in both a high value and a high end-of-life. How does the company considers the end-of-life value of the product?
High
Medium
Low

Q26. Product Value. The value of products and materials determines the justification of investment in recovery. This is the case in both a high value and a high end-of-life. How does the company considers the end-of-life harm, environmental impact, of the product?
High
Medium
Low

Q27. Control, Collection, and Communication. In case it is possible to control or reliably collect a known quantity of materials or products, circular models are more likely to succeed. How many users have used the product in general before the product reaches end-of-life?
One user
Two users
Multiple users

Q28. Control, Collection, and Communication. In case it is possible to control or reliably collect a known quantity of materials or products, circular models are more likely to succeed. How many products are sold on a yearly basis? Please indicate the amount in numbers. For example: ‘1000’; not ‘a thousand’.
Open

Q29. Control, Collection, and Communication. In case it is possible to control or reliably collect a known quantity of materials or products, circular models are more likely to succeed. How many of the products sold will be returned on a yearly basis? Please select the right percentage.
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%

Q30. Ease of recycling, remanufacturing, and reuse. Circular systems are more likely where the physical characteristics or products or materials make them easy to transform. Which R-strategies are suitable strategies to recover the product? Multiple answers are possible. Please add any in case an R-strategy is not listed.
Reproposing/Rethinking
Remanufacturing
Refurbishing
Reusing
Repairing
Recycling
Other, namely: ___

Q31. Ease of recycling, remanufacturing, and reuse. Circular systems are more likely where the physical characteristics or products or materials make them easy to transform. Which R-strategies is the most promising in terms of adding value to the product. Please rank the R-strategies listed below. Only the predefined R-strategies are listed.
Reproposing/Rethinking
Remanufacturing
Refurbishing
Reusing
Repairing
Recycling
Other, namely: ___

Q32. Ease of recycling, remanufacturing, and reuse. Circular systems are more likely where the physical characteristics or products or materials make them easy to transform. At which level are R-strategies performed on the product, that serves as the input flow?
Raw materials and resources
Parts and semi-manufactured products
Components
Product

Q33. Pace of change. If product or material function changes too rapidly, investment in recovery may not occur. This is especially an issue where material substitution, technological development, or fashion changes demand rapidly. How does the company consider the pace of change of the product, that serves as the input flow?
High
Medium
Low

Q34. Concentration and contamination. Where materials are dissipated or contaminated. Recovery is either more expensive or impossible. Which hazardous materials or substances does the product contain, that serves as the input flow?
Open

Q35. Concentration and contamination. Where materials are dissipated or contaminated. Recovery is either more expensive or impossible. Which percentage hazardous materials or substances does the product contain, that serves as the input flow?
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%

60-70%
70-80%
80-90%
90-100%

Q36. Concentration and contamination. Where materials are dissipated or contaminated. Recovery is either more expensive or impossible. Which critical materials or substances does the product contain, that serves as the input flow?
Open

Q37. Concentration and contamination. Where materials are dissipated or contaminated. Recovery is either more expensive or impossible. Which percentage critical materials or substances does the product contain, that serves as the input flow?
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%

Q38. Product quality. The quality of the returned product has an influence on the possible recovery of the product. How does the company consider the quality of the product, that serves as the input flow?
High
Medium
Low

Q39. Product quality. The quality of the returned product has an influence on the possible recovery of the product. In what kind of condition is the product, that serves as the input flow? Multiple answers possible.
Working
Broken

Remarks
Q40. Do you have any additions, remarks or questions?
Open

Appendix B
Informed Consent (Interview)

Dear Sir/Madam,

First of all, thank you for participating in my research. This research is part of my study Industrial Engineering and Management, which I follow at the University of Twente. The assignment is commissioned by the Ministry of Economic Affairs and Climate Policy.

Companies might face various logistic challenges in implementing a (new) circular business model. This research is aimed at creating an overview of these challenges. Subsequently, a decision support tool is developed to help companies find a solution.

The research consists of three stages, in which we would like to include companies to gather data. The first stage is a structured interview to obtain insight in the companies, their activities and their product. This data provides a basis for the next step. Then, we are going to develop the decision support tool. This is the second stage and the purpose is to support companies in making decisions and provide them with a possible solution. The third stage consists of the evaluation of the impact and the experience of the usage of the tool. We perform this stage in order to assess the added value of the tool.

This interview is the first stage of the research. The interview will take up to 30 minutes. The data and results will be processed anonymously and confidentially. In case you have given us permission, we will record the interview. The data, results and recordings will be used solely for analysis and will not be shared with others. You retain the right to withdraw at any time during participation without giving any reason.

In case you have any questions, you may always contact me via:
m.mooij@student.utwente.nl or 0650193962.

Trusting to have provided you with sufficient information.

Mara Mooij

Do you declare you:
- have been informed sufficiently and clearly about the methods and the purpose of the research;
- participate in this interview completely voluntarily;
- completely agree with the information as described in the informed consent?

Appendix C
Definition of concepts and answers of the survey

Product categories
The product categories are based on the categorisation that WeCycle.nl uses. See the following link: https://my.wecycle.nl/productlist-external

The market value or sales price
The market value is expressed as a category: either high, medium or low. The absolute value of the product expressed in terms of money is irrelevant as the price per product or per product category can differ considerably. The categorisation is based on the average price per product. In case a product is considered to have a high value, it is useful to implement one of the higher R-strategies. In case of a medium value product, the use of implementing a R-strategy has to be decided upon. Low value products should only be used to perform cheap R-strategies, which are lower in ranking.

The technical value or supply price
The technical value is a term for the value of the product without the marketing. In other words, it does not concern the price for which the product is sold but the actual value of a plain product based on the materials that the product is made out of. A product can have a high market value, but the technical value can be very low. In case a product has a high technical value it should be considered for R-strategies. When a product has a medium technical value it depends on the market value whether it is useful to perform a R-strategy. A product with a low technical value should be considered for a high R-strategy in case the market value is high, otherwise lower R-strategies should be considered.

End-of-Life value
The End-of-Life value is referred to the value that a product has when it has been disposed for the first time by a user. The value is considered high, when the product is suitable for recovery strategies. This means that it is worth to perform the strategies as these are easy to perform and it is beneficial in terms of money. The End-of-Life value is medium when there are recovery strategies possible and it is beneficial to recover the product, while the margins are not very high. The value is considered low when there are no suitable strategies due to the characteristics of the product.

End-of-Life harm
The end-of-life harm is determined by evaluating the impact that the product has on the environment when no recovery strategies are performed. This is determined by the dissipation and contamination of the product, and the concentration of critical materials in the product. In case a product fulfils al these criteria, the End-of-Life harm is considered to be high. In case a product does not contain or hardly contains critical and hazardous materials, the product is considered as low. In other cases, the End-of-Life harm is medium.

Pace of change
The pace of change is depicted by the pace the demand for the product changes based on material substitution, fashion or technological development. A product is considered to have a high pace of change in case it is subject to trends which change within zero to two years. A product with a medium pace of change is subject to change every two to ten years. A product that lasts for a minimum of ten years or is not subject to change at all is considered to have a low pace of change.

Quality
This has to be defined by the company as the company should determine whether it is easy to recover a product or not. In case of high quality, the product is such a condition that it is easy to recover. In case of medium or low quality, it is either more difficult or almost impossible to recover.

State
The state of the product can either be working or broken. In case it is working, it might not be in original state or optimally working, but it does function. In case it is broken the product no longer functions and does not serve its original purpose anymore.

Number of users
The number of users that have used the product in general before the product reaches the end-of-life state is defined as follows: it is the number of users that uses the product between the first time the product is distributed to the market and the first time it is disposed by the user because it has reached its end-of-life state according to the user. This means the number only refers to the period after the first time it reaches the end-of-life state and re-enters the supply chain for the first time.

Appendix D
Input Tool – Questionnaire
Qx = Open or closed question x

General
Q1. What is the name of your company?
Open

Q2. What product does the company sell or what service does the company provide?
Open

Q3. Which products are part of the company's assortment? Multiple answers possible.
Category 1: Temperature exchange equipment (TEE)
Category 2: Screens, monitors, and equipment containing screens having a surface greater than 100 cm2
Category 3: Lamps
Category 4: Large equipment (any external dimension more than 50 cm). Not category 1, 2 or 3.
Category 5: Small equipment (no external dimension more than 50 cm) including luminaires. Not category 1. 2 3 or 6.
Category 6: Small IT and telecommunication equipment (no external dimension more than 50 cm).
Metals
Consumer electronics
Batteries
IT and telecommunication equipment (external dimension more than 50 cm)
Category other: ___

Q4. Which statement describes the ambition of the company best?
Life cycle extension
Less use of critical materials
Less use of hazardous materials
Other

Company Characteristics
Q5. Is there a possibility to perform an R-strategy inhouse?
Yes, easy.
Yes, difficult.
No.

Q6. Is the company a direct or indirect supplier of the supply chain?
Direct
Indirect

Q7. Which actors are present in the supply chain? Multiple answers possible.
Supplier
Manufacturer
Assembly
Distributor
Retailer
User
Sales
Collection
Recovery
Disposal

Q8. Which processes take place within the company? Multiple answers possible.
Production
Distribution
Collection
Inspection
Recovery
Redistribution
Disposal

Product Characteristics
Q9. What is the market value of the product?
High
Medium
Low

Q10. What is the technical value of the product?
High
Medium
Low

Q11. What is the volume of returned products?
High
Medium
Low

Q12. On which product levels are R-strategies performed?
Product
Component
Parts and semi-manufactured products
Raw material and resources

Q13. What is the state of the returned product?
Working
Broken
Both working and broken

Q14. What is the quality of the returned product?
High
Medium
Low

Q15. What are possible R-strategies for the returned product?
Repropose/rethink
Reuse
Refurbish
Remanufacture
Repair
Dispose
Recycle

Logistics and Reverse Logistics
Q16. Is there are a return policy?
Yes
No

Q17. Are reverse flows B2B or C2B?
B2B
C2B
Both B2B and C2B

Q18. What type of collection method is desired by the company?
Active
Passive

Q19. What are the transportation opportunities of the company?
Logistics network present to organise reverse logistics
Potential logistics network to organise reverse logistics
No logistics network in place

Appendix E
Dutch Tool Manual – Purpose, method and use

Een ondersteuningstool voor logistieke beslissingen in een circulaire aanpak

De tool betreft een vragenlijst, waarbij de gegeven antwoorden leiden tot een bepaald advies. Onder het kopje Doel vindt u informatie over het advies. Bij Methode wordt de logica van de tool beschreven. Ten slotte wordt bij Gebruik uitgelegd hoe de tool gebruikt dient te worden.

Doel

Het doel van de tool is om bedrijven te ondersteunen in het formuleren van een circulaire aanpak. Het advies voor een circulaire aanpak is de *output* van de tool. Deze aanpak bestaat uit een set van vijf factoren, die de strategiefactoren vormen:

1. Circulaire strategie
2. Product level
3. Product categorie
4. Plaats van uitvoering van circulaire strategie
5. Inzamelingsmethode

Elke strategiefactor heeft een aantal mogelijke strategieën. Deze staan in de tabel aan het einde van dit document.

Methode

Het format van de tool betreft een vragenlijst. De vragenlijst is de *input* van de tool. De antwoordmogelijkheden zijn gekoppeld aan mogelijke strategieën. Dit betreft een zogenaamde 'als-dan'-constructie.

Voorbeeld:
Als het antwoord op vraag 1 gelijk is aan A, dan is de mogelijke strategie van strategiefactor 1 gelijk aan strategie B.

Deze voorwaarden zijn bepaald en verwerkt voor elke nodige en relevante link tussen de antwoordopties van de vragenlijst en mogelijke strategieën van de strategiefactoren.

Op die manier is de input aan de output gekoppeld en levert een bepaalde set aan gegeven antwoorden, een specifieke set op van strategieën: een bedrijfsspecifieke circulaire aanpak.

Gebruik

De gebruiker kan wijzingen aanbrengen in cellen die horen bij het blok *Vragenlijst*. In het blok *Advies* dienen geen wijzigingen te worden aangebracht: deze cellen veranderen automatisch mee.

De vragenlijst bestaat uit twee open vragen. De overige vragen zijn gesloten vragen met enerzijds één antwoordmogelijkheid en anderzijds meerdere antwoordmogelijkheden. Dit is aangegeven per vraag. De antwoordmogelijkheden worden aangeduid met letters.

1. Vul antwoorden op de open vragen in door het antwoord in de cel te typen
2. Vul de antwoorden op de gesloten vragen met meerdere antwoordmogelijkheden in door in de cel de letters van het antwoord in te typen.
3. Vul antwoorden op de gesloten vragen met een enkele antwoordmogelijkheid in door het antwoord in te typen of door het drop down menu te gebruiken.

In het blok *Advies* verschijnt nu een overzicht met de mogelijke strategieën per strategiefactor. Dit is de circulaire aanpak, die wordt geadviseerd op basis van de door u gegeven antwoorden.

Appendix F
Evaluation Criteria Form

Qx = Open question x
Sx = Statement x scored by a five point Likert scale.

General
Q1. Name
Open

Q2. Could you use the tool without the *#NAME?* error?
Yes
No

Format
S1. The presented information is clearly displayed.
S2. The tool provides enough information and guidance to use the tool.
S3. The interface design choices are maintained in similar contexts, but differ when the context is different. For example: it is clear which part of the tool belongs to the questionnaire (input) and which to the advice (output).
S4. The 'If-Then'-construct is a pleasant construct to use.
S5. The 'If-Then'-construct is a suitable construct for a decision support tool.
Q3. In case you have any feedback regarding the format of the tool, you can provide the feedback here.

Content – General
S6. The presented information is easy to understand.
S7. I trust the veracity of the information that is used in the tool.

Content – Questionnaire
S8. The questions consist of all relevant topics.
S9. The questions covers all relevant topics.
Q4. In case there are any topics that should have been included or excluded in the questionnaire of the tool, you can provide them here.

Content – Advice
S10. The advice consists of all relevant topics.
S11. The advice covers all relevant topics.
Q5. In case there any topics that should have been included or excluded in the advice of the tool, you can provide them here.

Content – Answer possibilities
S12. Mutually exclusivity. The answer possibilities for each question are mutually exclusive, such that there is no overlap in the answer possibilities.
S13. Collectively exhaustive. The answer possibilities for each question are collectively exhaustive, such that there are no answer possibilities missing in the answer possibilities.
Q6. In case there any answer possibilities that should have been included or excluded in the answer possibilities of a certain question, you can provide them here.

Logic
S14. Based on my answers to the questions, the provided circular approach makes sense to me.
S15. I trust the advice that the tool provides me with.
S16. I am convinced that the advice of the tool is based on logic and not randomly generated.
Q7. In case you have any remarks regarding the advice that is provided to you, you can provide them here.

Use – Before
S17. The effort required to understand the format of the tool is low.
S18. The effort required to understand how to use the tool is low.
S19. The effort required to start using the tool is low.

Use – During
S20. I could use the tool independently without asking others for help.
S21. The effort to use the tool is low.
S22. The tool guided me sufficiently through the questions and answers to get to the circular approach.
S23. I have access to sufficient knowledge and data to answer the questions.

Use – After
S24. I am convinced that the tool can be of support in formulating a circular approach.
S25. The tool provided me with a better understanding of the opportunities for a circular approach.
S26. The advice for a circular approach is displayed transparently and clearly.
Q8. In case you have any other experiences regarding the use of the tool, you can provide them here.

Suggestions
Q9. Do you have general suggestions for improvement regarding the format, the content or logic of the tool?

Feedback
Q10. Do you have any remarks, questions or feedback?

Appendix G
Informed Consent (Evaluation)

Dear Sir/Madam,

Thank you for participating in this research.

The research consists of three stages, in which we would like to include companies to gather data. Stage 1, the online interview, and stage 2, the tool, are already done. Step 3 is the evaluation of the use and the experience of the tool.

This evaluation form concerns the third and last stage of the research. It will take 5-10 minutes to fill in the form. The data and results will be processed anonymously and confidentially. The data and the results will be used solely for analysis and will not be shared with others. You retain the right to withdraw at any time during participation without giving any reason.

In case you have any questions, you may always contact me via:
m.mooij@student.utwente.nl or 0650193962.

Trusting to have provided you with sufficient information.

Mara Mooij

Do you declare you:
- have been informed sufficiently and clearly about the methods and the purpose of the research;
- participate in this interview completely voluntarily;
- completely agree with the information as described in the informed consent?