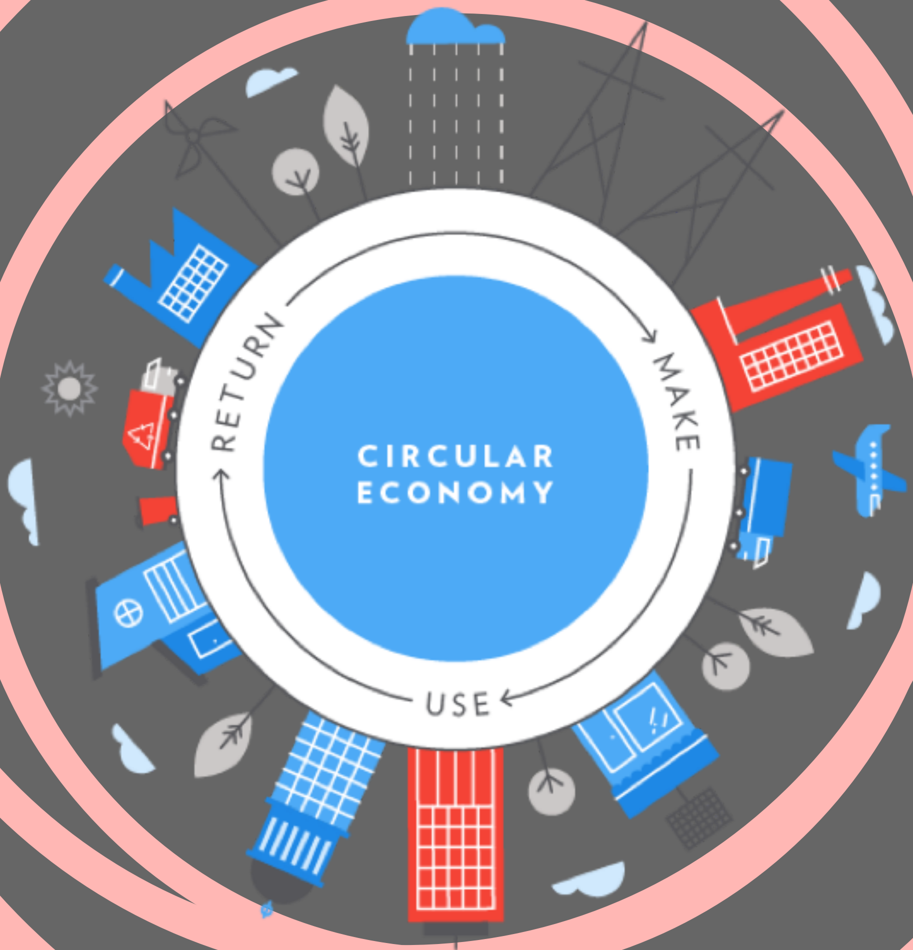
The Design of a Circular Business Model Assessment Tool for the Lithium-Ion Battery Industry

Master Thesis Management of Technology



YOUP MARTIN STRIETMAN

The Design of a Circular Business Model Assessment Tool for the Lithium-Ion Battery Industry

Master Thesis Management of Technology

Youp Martin Strietman

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Abstract: A new Circular Business Model Assessment Tool is developed for companies within the Lithium-Ion Battery Industry. The new Assessment Tool uses statements from an existing Assessment Tool and new formulated statements to calculate a ranking of Circular Business Models. The weight calculations for ranking the Circular Business Models make use of the Normalized analysis method. To validate the Assessment Tool interviews are conducted to determine the usability and representative-ness.

Note: Due to confidentiality reasons, the appendices are excluded from uploading. The Supervisors have taken notice of the Appendices.

First Supervisor: Dr. ir. R.M. Stikkelman, Faculty Technology, Policy & Management, Delft University of Technology
Second Supervisor: Dr. R.M. Verburg, Faculty Technology, Policy & Management, Delft University of Technology
Chairman: Dr. R.M. Verburg, Faculty Technology, Policy & Management, Delft University of Technology

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EXECUTIVE SUMMARY

The continuous growth of the Lithium-Ion Battery Industry is a result of the high demand for electronic devices and Electric Vehicles. Companies in the Lithium-Ion Battery Industry therefore, face major growth in the upcoming years. The downside of this trend is that scarce raw materials where the batteries are made of, will become more expensive. As a result, companies in the Lithium-Ion Battery Industry will need to focus on Reusing, Remanufacturing and Recycling of the batteries. This is explained as the concept of Circular Economy. The Ellen MacArthur Foundation (June 2015) formulated the most widely accepted and up-to-date definition of the Circular Economy, they explain the Circular Economy to be restorative and regenerative by design to exclude the waste and minimize the negative impacts. The concept of Circular Economy is the foundation to categorise Circular Business Models. Circular Business Models are categorised by the ReSOLVE actions; Regenerate, Share, Optimise, Loop, Virtualise and Exchange. By adopting the Circular Business Model, it is expected that companies in the Lithium-Ion Battery Industry use resources more efficiently, while minimising negative impacts.

A new Circular Business Model Assessment Tool is designed to help companies explore the options of Circular Business Models before implementing. The new Assessment Tool, better known as the RA-Tool, consists of a list of statements that a company needs to complete in order to provide an advice on suitable Circular Business Models. These statements focus on product specifications, product usage, reusing and the production process. The RA-Tool generates a ranking of Circular Business Models based on the completed list of statements. The top-ranked Circular Business Models indicate that these are suitable for the current operations of the company and match with their product. These top-ranked Circular Business Models show the biggest improvement of circularity for a company, while the low-ranked Models are not suitable for a company to implement or the company already scores high on the degree of circularity for that specific subject.

Each Circular Business Model relates to a different number of statements, as the statements have different subjects. The statements for the development of the RA-Tool derive from an existing Circular Economy Assessment Tool, Circular Economy indicators and descriptions of Circular Business Models. The formulation of these statements helps to create an improved balance between the number of statements for each Circular Business Model.

A weight analysis method makes it possible to compare the Circular Business Models with each other. Two analysis methods need to be compared to determine the most suitable weight calculation for ranking the Circular Business Models: The Analytic Hierarchy Process method and the Normalized method. Based on a comparison of randomly generated answer simulations the most suitable analysis method to determine the ranking is the Normalized method. By using the calculated weights of the Normalized

method, it is possible to calculate a ranking of Circular Business Models when the list of statements is completed by a respondent.

There are three supply chain positions within the Lithium-Ion Battery Industry that are relevant for the RA-Tool. These are: Component Manufacturers, Lithium-Ion Battery Manufacturers and Service Providers or Retailers. The differences between the categories are different statements and available Circular Business Models to calculate a ranking. To validate the RA-Tool, interviews with employees from different supply chain positions are conducted. A selection procedure to the selection of five interviewees: one company is a Component Manufacturer, two Lithium-Ion Battery Manufacturers and two Service Providers or Retailers.

Four out of five interviewees believe that the ranking is representative for the company its current situation and future opportunities. When combining their quotes with the rankings of the Circular Business Models, an accuracy of 90 percent is achieved. Most interviewees explain that they have no significance influence on the strategy of their company, which makes their opinion in the company not decisive when suggesting a new Circular Business Model. This depends on their position within the company and the size of the company. One target group for using the RA-Tool consists of managers in small- and medium-sized companies in the Lithium-Ion Battery Industry. The second target group is consultancy firms that focus on the Lithium-Ion Battery Industry.

The result of this research is that the development of a Circular Business Model Assessment Tool is possible and helps companies to explore the possibilities of the Circular Economy. The RA-Tool develops a ranking of Circular Business Model within the scope of an individual company. Based on the replies of the interviewees, it is difficult to measure the usefulness of the RA-Tool at this point. This could be assigned to the lack of experience of the interviewer. Nevertheless, the results of the RA-Tool are representative to the current explanation of the circularity within the company and their expectations of the future. That way, the RA-Tool serves as a catalyst to initiate a discussion about Circular Business Models and the opportunities within companies. Before executing, the RA-Tool requires adjustments, which focus on textual changes of the final ranking, clarifications and additional texts providing examples per Circular Business Model.

New exploratory research may investigate the possibilities to use the design of the RA-Tool in other industries. Some of the interviewees mention different type of target groups. More extensive research can elaborate on the specific target groups of the RA-Tool, in which managers of small- and medium-sized companies and consultancy firms will play a key role.
To elaborate on the RA-Tool, it is useful to develop a roadmap from exploring the possibilities of Circular Business Models to the implementation of a Circular Business Model.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
Bocken-Tool	Existing Circular Economy Assessment Tool
CBM	Circular Business Model
CE	Circular Economy
EMF	Ellen MacArthur Foundation
LIB	Lithium-Ion Battery
PSS	Product service-systems
ReSOLVE	Regenerate, Share, Optimise, Loop, Virtualise, Exchange
RA-Tool	Circular Business Model Assessment Tool
SD	Standard Deviation

1. INTRODUCTION

The first chapter introduces the topic of the research. This includes the main-actor and important definitions of the research. After defining the research objective and the Research Question, sub-questions are formulated. An overview of the thesis exemplifies the required steps to come to an answer to the Research Question.

1.1 PROBLEM BACKGROUND

Today there are billions of processes that make use of the 'take-make-dispose' principle. However, when this principle proceeds to be the standard, many problems arise. For instance, a shortage of raw material may occur and the amount of landfill becomes enormous, whereas damage to the environment is unavoidable. Given the developments in the current society, it is no longer acceptable to continue with the 'take-make-dispose' principle as a standard.
By developing a principle, the concept of Circular Economy, products do not end up as waste. The concept of Circular Economy aims to redefine products and services to avoid waste. The Circular Economy promotes more efficient use of products in many different ways. Companies and entire industries shift from the 'take-make-dispose' principle towards a 'cradle-to-cradle' concept (Sempels & Hoffmann, 2013, p.140).
Various articles divide the concept of Circular Economy different (Bocken et al., 2016; Lewandowski, 2016; Planing, 2015). One method is to define various Circular Loops. Whereas, each subsequent loop is bigger as the previous one. The loops start at the customer and loops back to all previous actors in the supply chain, one-by-one, as seen in Figure 1 (Planing, 2015). Small loops are less labor and resource intensive.

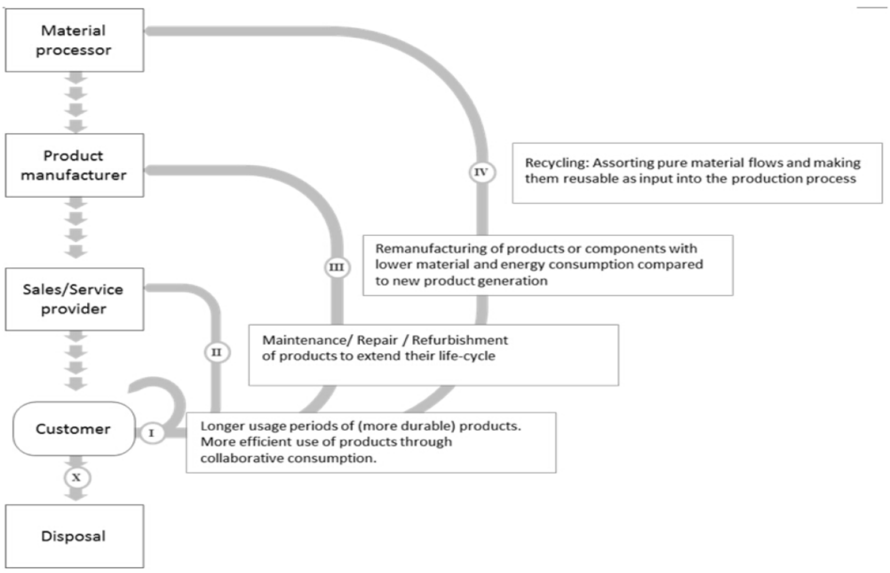

FIGURE 1 CIRCULAR LOOPS (PLANING, 2015)

Not all companies can adopt all concepts of the Circular Economy. The concept can be divided into various Circular Business Models. As all Business Models, the Circular Business Model focuses on value creation. However, it focuses on using the economic value after using the products (Linder & Williander, 2015). The position of a company in the supply chain determines, partially, what kind of Circular Business Model can be adopted.

At the moment, various existing tools support companies to explore the possibilities within the Circular Economy. Each tool offers support what varies from providing a framework to a questionnaire that addresses Circular Economy actions to improve. The existing tools that promote the Circular Economy or Circular Business Models are:

- The Circular Economy Assessment Tool (Bocken et al., 2013); This is an Assessment Tool that gives advice what kind of actions can be taken to improve a company its circularity.
- The Guided Choices Towards a Circular Business Model (Joustra et al., 2013); Tries to help a company, step-by-step, to select a Circular Business Model and implement it.
- The Sustainable Business Model Canvas (Sempels, 2014); The actors fill in a customized Business Model Canvas with special building blocks. This helps the company by giving an overview of implications when adopting a new Circular Business Models.

The main-actor in this research is the Lithium-Ion Battery Industry. The industry is using scarce raw materials for manufacturing Lithium-Ion Batteries, while the demand for Lithium-Ion Batteries is growing (Väyrynen & Salminen, 2012).

Due to the growing electronic device market, there is a higher interest for Lithium-Ion Batteries, especially because Electric Vehicles. The forecast is that lithium demand for Electric Vehicle batteries will grow by factor 62 in 2030 (Bloomberg, 2017). However, expectations show a shortage of lithium in 2025 (Zeng et al., 2014). Companies within the Lithium-Ion Battery Industry have trouble with adopting a suitable Circular Business Model because the Business Model strategies are new and success unproven (Ahmadi et al., 2015).

Thus, companies in the Lithium-Ion Battery Industry are the problem owner of this research. Lithium-Ion Batteries use numerous scarce raw materials. Problems regarding availability and ramping prices may cause production problems of the Lithium-Ion Batteries. Scarce raw materials in Lithium-Ion Batteries are cobalt and rare earth metals, such as titanium (Väyrynen & Salminen, 2012; European Commission, 2011). Socio-political tensions, production bottlenecks and weather conditions disrupt the supply chain of Lithium-Ion Batteries (Olivetti et al., 2017).

When companies within the Lithium-Ion Battery Industry adopt Circular Business Models, the Industry becomes more resource efficient and have a smaller ecological footprint (Ellen MacArthur Foundation, 2012). At the moment, recycling of Lithium-Ion Batteries is more expensive than producing a new battery (McCormack, 2016). Therefore, the number of recycled Lithium-Ion Batteries is low. Until recycling is economically attractive for companies, other Circular Business Models need to be adapted to be as resource-efficient as possible.

The new Circular Business Model Assessment Tool will support companies in the Lithium-Ion Battery Industry to become more familiar with the concept of Circular Economy and explore Circular Business Models that are suitable within their company. The new Tool will support and advice companies by showing the opportunities of Circular Business Models. The companies will need to answer statements that result in a ranking of Circular Business Models, which makes it possible to compare these models. For companies that are already familiar with the Circular Business Models, the ranking will confirm their expectations. And finally, the other option is that this Circular Business Model will not attribute to the operations of the company.

1.2 Research Objective

The problem statement addresses the opportunities of the new Tool, especially for companies in a niche industry, such as the Lithium-Ion Battery Industry. Therefore, the focus of the research objective is on the development of the new Circular Business Model Assessment Tool.

The end-product of this thesis will be a new Tool that focuses on ranking Circular Business Models, what is relevant for companies in the Lithium-Ion Battery Industry. Different companies in different positions in the supply chain require other statements to answer.

The objective of the new Tool is to serve as an advice- and support-Tool for companies in the Lithium-Ion Battery Industry. By displaying a ranking of Circular Business Models, companies become more aware of the possibilities and opportunities of the concept of Circular Economy. The objective of ranking Circular Business Models is to advice companies. This advice is an indication, whereas companies can start focusing on the highest rank and discuss what possibilities emerge. By doing so, companies look more critical to their processes.

Since the Lithium-Ion Battery-industry is rapidly developing. Companies within the industry sell more and more batteries. In a rapidly evolving industry, using products more efficient helps the industry to be more environmentally friendly. When companies continue growing, there is more pressure on the raw materials used. Shortage of raw materials can occur as a result of this growth. The key to avoid such problems is to use resources more efficiently. Companies are unaware of the possibilities the concept of Circular Economy offers. Advice based on the new Tool will help Lithium-Ion Battery companies to think more elaborate on the opportunities and promote the Circular Economy.

The ranking will indicate which Circular Business Models are most suitable for improving a company its circularity. The degree of circularity is the extent to which a company uses the concept of CE.

This thesis will contribute to the academic literature by giving an insight into which aspects influence what kind of Circular Business Models. A company has to answer a list of statements where at the end, the new Assessment Tool generates a ranking of the Circular Business Models. The list of these statements of the new Tool helps to clarify the product and the aspects of the performance of the company more deliberately. By doing so, it will be possible to assess what kind of Circular Business Model is most suitable to a company.

Achieving the final objective, develop a Circular Business Model Assessment Tool for companies in the Lithium-Ion Battery Industry, depends on the available literature. Appendix I explains the steps that are necessary to accomplish the research objective. At the top of the figure, the first steps explain the start of the research. For example, the first step is to Determine Necessary Definitions in Literature, as various articles describe Circular Economy related definitions differently. In this research each step is mentioned in a specific chapter or section. Each step in the appendix contributes to the final research objective.

The final statement of the research objective is:

The objective is to develop a Circular Business Model Assessment Tool for companies in the Lithium-Ion Battery Industry that focuses on ranking Circular Business Models in order to stimulate the Circular Economy within the Lithium-Ion Battery Industry.

1.3 Research Question

The Research Question that can be answered at the end of the thesis is as follows:

How to design a new Circular Business Model Assessment Tool to introduce the concept of Circular Economy to companies in the Lithium-Ion Battery Industry enabling them to explore the opportunities of Circular Business Models?

The answer will help companies to assess the different Circular Business Models by ranking them. Specific companies in the Lithium-Ion Battery Industry will have an advantage of the new Tool. By having a good overview of the ranking, the company can decide what option is best for their situation. The Circular Business Model Assessment Tool has to enable companies to explore the possibilities within the Circular Economy and become more familiar by linking the Circular Business Models to their company operations.

To answer the conclusive Research Question requires various steps, which are the sub-question. The different chapters represent a sub-question. The sub-questions are divided based on the steps described in Appendix I.

Literature

1. What can be addressed as dominant definitions in the literature for the definitions Circular Economy, Circular Business Models and indicators for the Circular Economy to use in the remainder of the research?

The first step is to collect available knowledge and descriptions regarding Circular Economy, Circular Business Models and indicators suitable for the Circular Economy. The landscape of these definition becomes clear, which is critical for the next step in the process. When a mapping of definitions is available, an analysis of the literature determines the selection of the most suitable definition. The selected definition determines the direction of the research. The answer to sub-question 1 is given in Chapter 2.

2. Which existing tools focusing on promotion of the Circular Economy attribute to the development of the new Tool?

There are various tools available that help a company by providing advice or support the exploration of the concept of Circular Economy and Circular Business Models. It is necessary to give an overview of the landscape of these existing tools that will attribute to the development of the new Tool. The analysis of available tools helps to indicate opportunities for the new Tool. Each existing tool is designed to serve a different purpose. One of the existing tools is selected to use as a starting point to develop the new Tool what helps the researcher to develop a new design. The currently available tools are analysed by using available literature.

3. What is the current situation of the Lithium-Ion Battery Industry, based on the supply chain, the product itself and the involved companies?

For the third sub-question, information about the Lithium-Ion Battery Industry is necessary. This requires other resources than academic literature. The supply chain of the Lithium-Ion Battery Industry will show the type of involved companies. The current situation shows main-actors and regions. A sketch of the Industry in section 2.5 forms the basis for the new Tool. A better understanding of the supply chain helps to decide, which positions are useful for developing the new Tool. Besides, by showing the landscape of companies in the Lithium-Ion Battery Industry, it is easier to select companies for validating the new Tool. This is discussed in Chapter 5.

For all three sub-questions, the research methodology used is the Desk-research and more specific the literature research.

Analysis

4. What aspects of the existing tool are useful for developing the new Tool?

An analysis of one of the existing tools will show what aspects are useful for the new Tool. As earlier mentioned one of the tools will be used as a starting point for the development of the new Tool. To transfer the values of the existing tool towards the new design, sub-questions 1, 2 and 3 need to be answered first. By using aspects from one of the existing tools, a basis is formed for the new design. This comprehensive analysis is discussed in section 3.1. Literature research is used as a method to find useful aspects of one of the existing tools.

5. How are the useful aspects of the selected existing tool being improved in the design of the new Tool by making use of literature?

Sub-question 4 shows the useful aspects of the selected existing tool, which makes it possible to determine what adjustments and additions are necessary to develop the new Tool. At first, an analysis of the selection of indicators will clarify what statements are possible for adoption. Thereafter, an analysis of Circular Business Model classifications will help to create new statements. This analysis in combination with one of the existing Tools forms the basis of the new Tool. The analysis identifies new additions by using available literature, for which a desk research is conducted.

Design of new Tool

6. What kind of analysis methodology can be used to rank the Circular Business Models in the design of the new Tool based on the existing requirements?

Based on the previous sub-questions it is now possible to compare different ranking methods for the new Tool. This comparison helps to select the best design method. The designs are discussed and analysed in Chapter 4. The basis of the pre-selected designs is the method of Multi-Criteria Decision Analysis.

Validation

7. How can the reactions of companies within the Lithium-Ion Battery Industry be labelled concerning outcomes and usability of the new Tool?

To validate the new Tool the results of various companies has to be assessed and discussed. Before validating the new Tool, an analysis of the selection method determines the chosen method. The first section of Chapter 5 describes what research method has been used to validate the new Tool.

After selecting the proper research method, the validation is done based on experiences of professionals within Lithium-Ion Battery companies. Their experiences become a valuable asset for the conclusion of the research. The validation can only be achieved when the design of the new Tool is ready for usage. The validation process is discussed in Chapter 5 Interviews & Analysis.

Results

8. Is the new Tool usable for companies in the Lithium-Ion Battery Industry or what kind of improvements are necessary to achieve this result?

The final result of the validation is whether or not the new Tool is usable in the Lithium-Ion Battery Industry. The validation assesses the opinions and experiences of professionals in the Lithium-Ion Battery Industry. The focus is on the value-judgment on the new Tool and not the value-judgment of the outcomes of the result. This is a significant difference to acquire the right result.
All the questions above help to find a final answer to the Research Question. All analysed information will give new insights in order to answer the Research Question. Whereas, the answer will be discussed in the conclusion of the thesis.

1.4 Thesis Layout

The thesis is structured based on previously done research. The sub-questions create chapters of the thesis. The structure of the report can be seen below.

Deliverables
Chapter 1 – Introduction
Chapter 2 – Literature Review
Chapter 3 – Statement Selection & Development
Chapter 4 – Design of RA-Tool
Chapter 5 – Interview & Analysis
Chapter 6 – Conclusion & Recommendations

Appendix I shows a block diagram of the research progression. The numbering in the block diagram of the appendix indicates the flow of the research. Each number represents an abstract step to address the various sub-questions and will lead to a final answer to the Research Question. These steps are mentioned in each chapter or a section hereof.

1.5 Collect Information

It requires a lot of input to develop a new Circular Business Model Assessment Tool. The first source of information is academic literature, where definitions are determined, such as Circular Economy and Circular Business Models. The most suitable definition of these subjects is achieved by analysing literature research. An analysis of the existing tools, that focus on Circular Economy and Circular Business Models, is also achieved by literature research.

The new Tool is developed with support of various literature resources. After the Tool is finalized, the new Tool is validated by conducting interviews. The input of these interviews not only function as a validation method, but also gather information about future expectations and possibilities to implement Circular Business Models for companies. Interviews are commonly used in academic research, however there are some pitfalls for this specific research in the Lithium-Ion Battery Industry that the researcher needs to be aware of:

- Difficult finding professionals in the Lithium-Ion Battery Industry
- High dependency on interviewees and their availability
- Most Lithium-Ion Battery companies are situated in South-East Asia and United States of America
- May lead to unsatisfying results
- Lack of experience in conducting interviews by interviewer

The researcher must take these pitfalls into consideration in order to achieve the best possible result, because the gathered information from interviews is of major importance to draw a conclusion. However, the advantages of the interviews outweigh the pitfalls for this research:

- Practical experience for validating the new Tool
- Easy to clarify discrepancies
- Validating the new Tool by an objective view of the interviewee
- Detect differences between various companies by interviewees their answers
- Gather company information that focuses the implementation of Circular Business Models and detect opportunities

These advantages substantiate the decision to conduct interviews. The likelihood that interviews attribute to the final result of the research is higher than the risks to exclude conducting interviews. There is no other method available to acquire valuable information that focuses on specific companies and their experiences with the new developed Tool.

2. LITERATURE REVIEW

This chapter describes the available literature regarding the necessary topics that form the basis of the research. These topics are the Circular Economy, Circular Business Models, useful Business Model indicators, analysis of existing Tools and an overview of the Lithium-Ion Battery Industry. To find the suitable definitions of Circular Economy and Circular Business Models a literature analysis is required. Thereafter, are the existing tools described, whereas one is selected as a starting point for the development of the new Tool. Finally, is the Lithium-Ion Battery Industry analysed to indicate what opportunities there lie ahead for the new Tool.
Section 2.1 to 2.3 represent the first step of Appendix I, Determine Necessary Definitions from Literature. The selected definitions are used from that point onwards. This will help to analyse the selected existing tool and develop the new Tool.

2.1 CIRCULAR ECONOMY

The Circular Economy is a concept that is derived from multiple schools of thought. The academic literature describes the concept of Circular Economy in many different ways. It is therefore the task to create an overview of the available definitions of the Circular Economy. After outlining the various definitions, an analysis will determine the most suitable definition of the Circular Economy for this research.

2.1.1 CONCEPT OF CIRCULAR ECONOMY DEFINITIONS

It is necessary to find out what is written about the Circular Economy [CE] in the existing literature. This is the first sub-question. It needs to be clear what is written on the subject of CE. An overview of the concept of CE helps to identify what term is used in this thesis.
To find all articles that relate to the concept of the Circular Economy Google and Google Scholar were used. On Google terms as Concept of Circular Economy and Circular Economy were used. While on Google Scholar the terms, Circular Economy, Circular Economy Business Models, Circular Economy Categories, Circular Economy Fundamentals, Circular Economy & Sustainability, Differences Circular Economy & Sustainability, and definition Circular Economy were used. These search terms lead to articles, and in these articles, references were used to find other articles.

The CE concept is initially from the eco-industrial development. The eco-industrial development explains that there can be a balance between a healthy economy and a healthy environment (Geng & Doberstein, 2008). The concept of CE comes from the evolution of various schools of thought, which are (EMF, 2012; Ghisellini et al., 2015; Sauve et al., 2015; Lewandowski, 2016):

- Cradle to Cradle; all involved materials are nutrients. The framework focuses on design to reduce negative impacts and promote positive impacts by reusing materials (Ghisellini et al., 2015; Sauve et al., 2015).
- Performance Economy; focuses rather on selling services than products, while four goals pursue: long-life goods, product-extension, waste prevention and reconditioning activities (EMF, 2012).
- Biomimicry; natural phenomena help to solve human problems by improving design and processes (EMF, 2012).
- Industrial Ecology; is the study of resource flows in industrial systems (Preston, 2012; EMF, June 2015).
- Natural Capitalism; environmental and business interests overlap by interdependencies of production, use of human-made capital and natural resource flows (EMF, 2012).
- Blue Economy; explains that waste of one-product is the input of another product (EMF, 2012).
- Regenerative Design; applications for all type of systems, which form the basis of CE (EMF, 2012).

The Ellen MacArthur Foundation [EMF] focuses on inspiring the community and businesses to accelerate the CE concept. By using global business leaders as partners, like Renault, Nike, Philips, Cisco, Google, and H&M, they try to achieve this mission. Figure 2 indicates the fundamental principles of the CE. The EMF describes this concept as being a more industrial economy, which is restorative and regenerative by design and intention (EMF, 2012).

Figure 2 shows the two different cycles that the EMF distinguishes. The left circles relate to the use of biological materials and their Circular Loops. This is mostly a biological process. While on the right side, the circles relate to technical materials. These relate to the electronic devices, machines and materials used in many industries. Both sides show different loops which the materials make when the concept of CE is being adopted.

Additionally, other articles explain the concept differently. Sauvé et al. (2016) defines the CE as a closed-loop material flow to minimize waste and pollution, which has both economic and ecological objectives. The view of Geng et al. (2013) is based on China its current CE implementation. They explain the CE as an industrial system, in which both material and energy flows are a closed-loop. This has to contribute to long-term sustainability of the economic system as a whole. The CE integrates strategies and policies for better energy, material and water consumption management, and minimize harming the environment (Geng et al., 2013). Yuan et al. (2006) explain the core of CE as "the circular (closed) flow of materials and the use of raw materials and energy through multiple phases." Based on an analysis of dozens of articles, Geissdoerfer et al. (2017) explain the concept of CE as *"a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing,* *closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."* (Geissdoerfer et al., 2017, page 759)

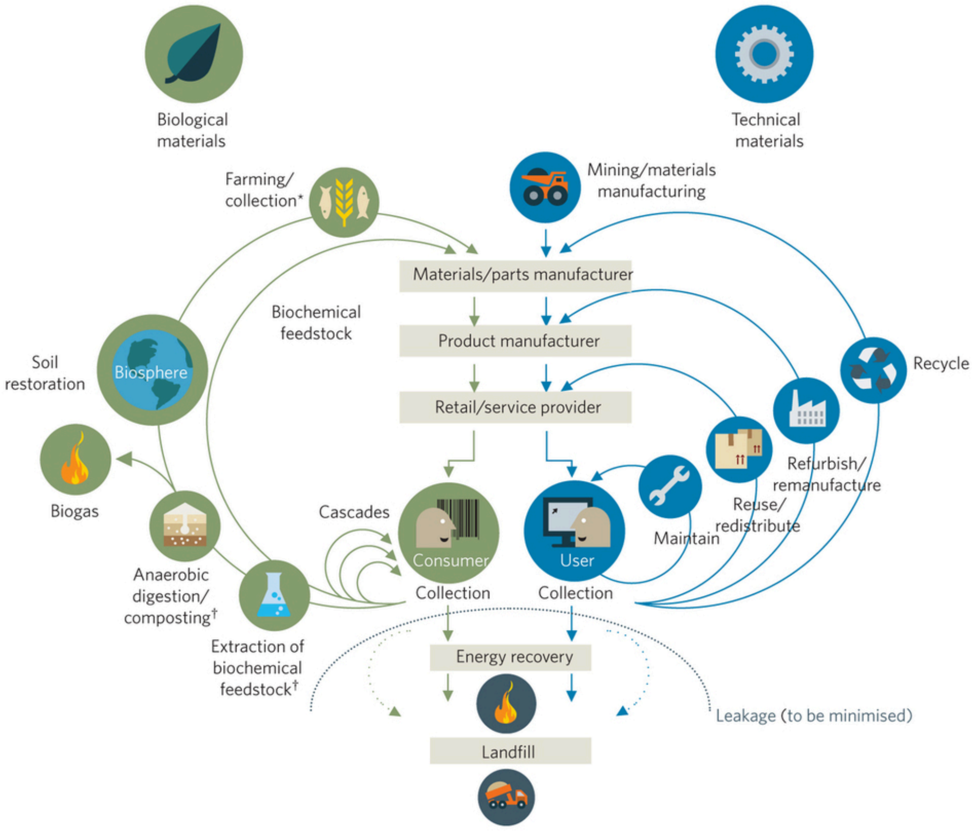

FIGURE 2 CIRCULAR ECONOMY SYSTEM DIAGRAM (EMF, 2012)

All sorts of groups can profit from the opportunities and benefits of CE. Not only industries or companies benefit from these opportunities, but also users and customers benefit from this. The opportunities and advantages for the entire economy, business and users are shown in Table 1.

The table on the next page does not describe the environmental benefits. However, this is one of the primary reasons for promoting and implementing the CE. For example, carbon dioxide emissions can be reduced by 48 % in 2030 by using CE concepts (EMF, 2012).

The reuse of materials will attribute to less mining and create new materials, which will help to reduce the primary material consumption. Used materials will be reused, instead of thrown away (EMF, 2012). As described earlier, scarcity of raw materials forms a fundamental reason to stimulate the CE. The rise in demand for some raw materials forces industries to implement the CE. The result of the increase in demand is the price increase of the raw materials. Therefore, when applying CE, less raw materials are needed.

TABLE 1 ECONOMIC OPPORTUNITIES AND ADVANTAGES (EMF, 2012)

Economy	Businesses	Users & Customers
Substantial material savings	Reduced raw material costs	Lower cost of ownership of products
Reduce demand driven volatility of materials	More customer loyalty and customer interaction	Better options and convenience
Increased rate of innovation, more employment	Controllable lifecycles and lower portfolio complexity	Secondary benefits–environmental benefits
Reduced externalities		
More consistent economies		

Circular Economy Concept Categories

CE concepts can be adopted, implemented and measured on different levels, such as micro-, meso- and macro-level (Ghisellini et al., 2016). The micro-level is a company-based level. The meso-level focuses on an industrial park level, while the macro-level focuses on a city or even larger a region.

Lewandowski (2016), Planing (2015) Geissdoerfer et al. (2017) and Bocken et al. (2016) did extensive literature research on the principle of CE. All these articles divide the concept of CE differently and focus on the micro- and meso-effects of the CE.

The first article by Planing (2015) divides the concept of CE into four particular categories: Recycling, Remanufacturing, Maintenance & Repair, and Extensive Usage. As earlier explained, these categories are the Circular Loops of Figure 1.

Different methods can be divided in the concept of CE. The second article splits the principle of CE into three separate categories: slowing resources, closing resources and narrowing resources, as seen in (Bocken et al., 2016; Geissdoerfer et al., 2017). Where slowing resources focus on designing long-life products and product-life extension. Closing resources focus on technological-cycles, biological-cycles, and dis- and re-assembling. Narrowing resources focus on using fewer resources for products (Bocken et al., 2016).

Figure 3 consists of three axes. Each ax represents a different category of the CE according to Bocken et al. (2016). The Y-ax shows the slowing resource category. This category extends the lifecycle of a product. The X-ax represents the closing resource flow, or in other words

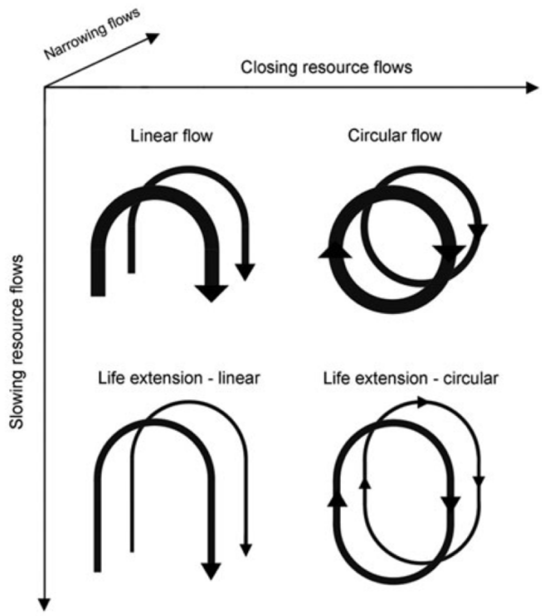

FIGURE 3 CATEGORIES CIRCULAR ECONOMY APPROACHES (BOCKEN ET AL., 2016)

make the flow of products circular. With this method, there is no waste, and all materials are reused. The Z-ax narrows flows. To achieve this, a company reduces its waste and use materials more efficient.

On the other hand, the EMF (2015), as well as Lewandowski (2016), refer to the ReSOLVE framework, which is the abbreviation for:

- **Re**generate
- **S**hare
- **O**ptimise
- **L**oop
- **V**irtualise
- **E**xchange

Each action is a category and stimulates the circularity differently. The degree of circularity is the extent to which a company uses the concept of CE.
All articles categorize the concept of CE by different actions. The variations are not right or wrong, however it describes the concept of CE from a different perspective. Chapter 4 describes which method is used to categorize all available business models by using an analysis.

Circular Economy versus Sustainability
There are various scientific articles written about sustainability within companies and the CE. Especially Geissdoerfer et al. (2017) describe what the differences and similarities are between sustainability and CE. To explain this, multiple articles were analysed. The most important similarities between sustainability and CE are: global models, cooperation of different stakeholders necessary, intra- and intergenerational commitments, central role of private business, and business model innovation is key for industry transformation (Geissdoerfer et al., 2017). The main differences are shown in Table 2. Probably the most crucial finding is that sustainability is more directly focused on societal objectives, while the CE only focuses on economic and environmental objectives (Sauvé et al., 2016).

In the section above regarding CE and sustainability, Geissdoerfer makes clear what the differences are between the CE and sustainability. One of the main differences is that CE focuses on economic and environmental effects, whereas with sustainability the focus is on the environment, economy and society.

There are various views on the concept of CE, which is based on the different categorizations. In the end, the different views want to achieve the same result, namely to have products that are as efficient as possible by design and use.

TABLE 2 COMPARISON SUSTAINABILITY VERSUS CIRCULAR ECONOMY

Sustainability	Circular Economy
Open-ended	Closed-loop to eliminate all resource input
Benefits for environment, economy and society	Economic actors are core, economy and environment focus on, society benefits from environment
Multitude of goals depends on involved agents	Better use of resources, waste and leakage
Shared responsibility	Economic advantage for business, less pollution and resource mining for environmental improvements

2.1.2 Selected Concept of Circular Economy

To decide which definition of the concept of CE is most useful, various articles are analysed. Firstly, articles are chosen based on their comprehensive description of the concept of CE and due to their contribution to the academic literature. A comparison of articles helps to identify which terms are relevant and which articles have the most significant attribution on the concept. The analysis determines what is the most suitable CE term to use. This is part of the answer of sub-question 1, to define key definitions of the research.

Appendix II shows which article mentions what terms regarding the CE. The mentioned articles refer to each other, which shows that the theory builds further on the existing concept. The Appendix helps to specify what articles are critical for the concept of CE. A selection of quotes regarding the CE creates an insight into which articles use what kind of resources for its formulated CE concept. The used reference of the quote in the article indicates which articles form the basis of the concept of CE.

The analysis of the concept of CE shows the importance of three explicit articles as seen in Table 3. Their beliefs on the CE are in line with each other. Stahel is seen as one of the founders of the CE concept and referred to in many articles that try to define the concept (Preston, 2012; Geissdoerfer, 2017).

TABLE 3 TOTAL REFERRALS IN ANALYSIS

Referred to	Number of referrals
EMF (2012)	5
Stahel (1982)	3
Yuan et al. (2006)	2

Stahel (1982) emphasized selling utilisation instead of ownership of goods as the most relevant sustainable business model for a loop economy, allowing industries to profit without externalising costs and risks associated with waste.

The "three R" principle: recycle, reuse and reduction is used in most literature. This statement was made in an early stage of the concept of CE. Still, many scientists refer to the 3R principle. In recent years, the concept further developed. One of the most important instigators for promotion and research on CE is the EMF. To substantiate this, the analysis of the concept of the CE shows a significant attribution of the EMF literature.

The publications of EMF are often used in literature written after 2012. It can, therefore, be accepted as the foundation of the present concept of CE in the academic literature and for business purposes. The foundation of EMF its concept of CE is based on Stahel (1982)

As earlier mentioned, Geissdoerfer et al. (2017) analysed multiple articles related to the concept of CE. Based on their analysis, they developed their vision of the CE. Most of these articles refer to the articles of Stahel (1982), Yuan et al. (2006) or EMF (2012). Based on this observation and because the vision of the EMF is widely accepted and used in the academic world, their statement is adopted.

EMF (2015) its definition states that the CE is restorative and regenerative by design and tries to keep products including materials and components at their highest value, while differentiating the technical and biological cycles. This first part of EMF (2015) its explanation shows that the CE starts with the product design. This is in line with considerations of the researcher, because adjustments to the product design attributes to a longer lifecycle or makes reusing easier, reducing environmental impact. The researcher states that the design of a product is of high influence for what Circular Loops can be used. The EMF (2015) complements its definition by stating that the CE offers solutions for resource-related challenges for companies and the entire economy, in addition it could generate growth, create more jobs and reduce the environmental impacts. The researcher supports the fact that the rise of the CE attributes to economic growth, while reducing the environmental impact of products. By using different Circular Loops, it becomes possible to reduce the production of new products and reuse and remanufacture existing products.

The EMF is leading in the research field of CE. Their definition covers multiple important aspects, such as the technical and biological cycles, being restorative and regenerative by design and indicating the economic growth by implementing the CE. In comparison to other explanations the EMF (2015) explains the CE very elaborated and is therefore used as the CE definition in this research.

The decision to choose the statement of the EMF (June 2015) as the concept of CE in this thesis is a partial answer to sub-question 1, that is about determining the suitable concept of CE. The analysis shows that the concept of CE that the EMF uses is the most widely-accepted one in current literature.

2.2 Definition of Circular Business Models

The categories to divide the Circular Business Models are different in various articles. To select a suitable Circular Business Model categorization, the general term of Business Models is discussed. Followed by the available categorizations of the Circular Business Models. In the last section an analysis determines the most suitable categorization of the Circular Business Models for this research.

2.2.1 Business Models

The next step is to take a closer look at the definitions of business models and specifically Circular Business Models. This will answer the next part of sub-question 1, which is to determine what the most suitable definition of a Circular Business Model is.

To find all articles that relate to the concept of Business Models and Circular Business Models, Google and Google Scholar were consulted. Other search terms were used such as, Business Models, Circular Business Models, Sustainability Business Models, Promote Circular Economy Business Models, Business Model Categories, Business Model Canvas, and Pigneur Business Model Canvas.

Business models

Business models are developed within companies to create- and appropriates economic value (Osterwalder & Pigneur, 2010). The literature describes the concept of a business model in many different ways. The use of business models is for product commercialization and technological innovations, according to Chesbrough (2010). Teece (2010) on the other hand, believes that there always should be a link between a developed product and a business model. Since no single product or technology assures the success of a company. A company vision helps to achieve to look for opportunities, which can relate for instance, to the type of customer, sales channels and partnerships.

The value that a business create is captured by transferring this towards their customers in terms of a fee for its product or service. Various conceptual frameworks of business models specify this in detail. Osterwalder & Pigneur (2010) have developed the Business Model Canvas that identifies nine key elements of a business model. Figure 4 indicates the nine elements that determine the business model of a company, according to Osterwalder (2004).

A company can change the attitude towards one of the subjects in the figure and can use a different type of business model. For instance, when a company uses a different model to receive revenues, from buying the end-product to paying per time the consumers uses the product.

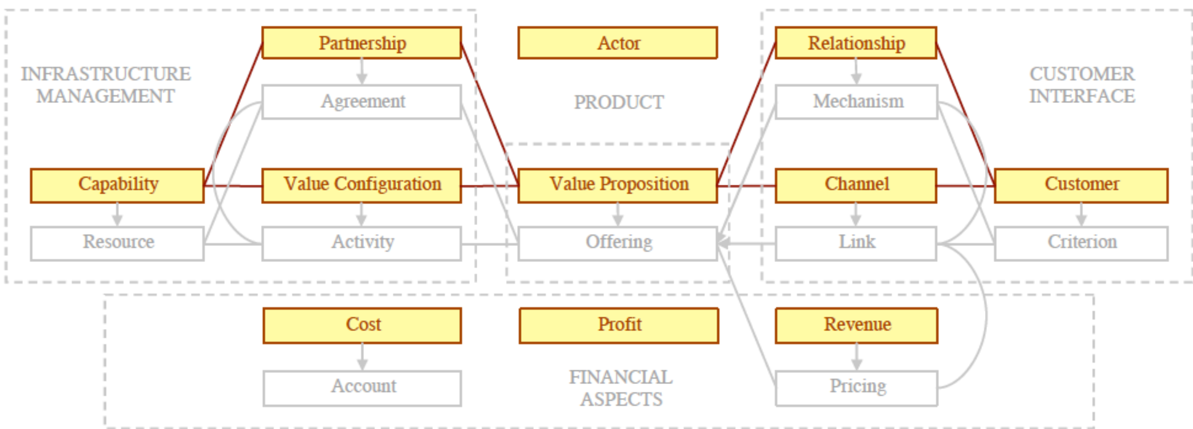

FIGURE 4 BUSINESS MODEL ONTOLOGY (OSTERWALDER, 2004)

2.2.2 Different Circular Business Models Categories

The definition of Circular Business Models [CBMs] is formed based on the concept of CE and business models. Linder & Williander (2015) describe the CBM as a flow of products that users return to the producers, this can be via companies or services in between the two parties. This flow consists of ReSOLVE actions.

There are different views on how to categorize the concept of CE. The distribution of CBMs is consistent with this approach. Consequently, this section uses the same articles.

Lewandowski (2016) categorizes different CBMs based on the six business actions of the ReSOLVE framework, as described in Table 4. Each of these actions indicate a business opportunity focused on circularity and improves the circularity of a business in its particular way (EMF, June 2015). After categorizing all CBMs, Lewandowski (2016) uses the business model canvas to show what business model components change in each of the six ReSOLVE actions. The canvas indicates what business components change with the of use of a CBM within a ReSOLVE actions. For example, when focusing on the action sharing, the following business model components are influenced: partners, value proposition, customer and revenue.

TABLE 4 RESOLVE FRAMEWORK FOR CIRCULAR BUSINESS MODELS

ReSOLVE Action	Circular Business Models
Regenerate	Energy Recovery, Circular Supplies, Efficient Buildings, Sustainable Product Locations, Chemical Leasing
Share	Maintenance & Repair, Collaborative Consumption, Product Service-Systems [PSS]: Performance-Based, PSS: Availability-Based, PSS: Product Lease, PSS: Product Renting, sharing or Leasing, Next Life Sales, Upgrading, Product Attachment & Trust, Bring your Own Device, Hybrid Model, Gas-Exploiter Model
Optimise	Asset management, Produce on Demand, Good Housekeeping, Lean Thinking, Fit Thinking, PSS: Activity Management/Outsourcing, Waste Reduction
Loop	Remanufacture, Recycling, Recycling 2.0, Resource Recovery, Upcycling, Circular Supplies
Visualize	Dematerialized Services
Exchange	New Technology

The next method of categorizing different CBMs is to identify business models within the different Circular Loops, as mentioned in section 1.1 in Figure 1 (Planing, 2015). Planing has created this framework based on seven various sources and combining all mentioned business models.

The marks in Table 5 represent the different Circular Loops. Planing (2015) categorizes the business model strategies based on a hierarchical order of efficiency, where I is the most efficient and IV the least. CE Loop X is the final CBM, which does not form a Loop. By using the product to recover energy as fuel, energy or electricity the product does not end as waste. There are no specific CBMs mentioned, only business model strategies. This is a broader definition.

TABLE 5 CIRCULAR BUSINESS MODELS BASED ON CIRCULAR ECONOMY LOOPS (PLANING, 2015)

CE Loops	Circular Business Models
X.	Energy Recovery
I.	Access Model, Collaborative Consumption
II.	Performance Model, Product-as-a-Service, Result-Based Models, Reuse, Refurbish, Redistribute
III.	Product Transformation, Upgrading, Remanufacturing, Next Life Sales, Hybrid Model, Gas-Exploiter Model
IV.	Product Recycling

Another definition of CBMs is that of Bocken et al. (2016), who make a difference between product design strategies and business model strategies. Contrary to previously discussed articles, they make a distinction between product design strategies and business model strategies.

The product design strategy in a CE focuses on product specifications. It is complicated to change the product design after production. Only minor changes to the product are possible. Business models on the other hand, define 'go to market' and 'capture value' strategies. The difference between product design strategies and business model strategies is that the product design does not create success itself (Bocken et al., 2016).

As earlier mentioned, Bocken et al. (2016) divide the business models into three different CE Loops: narrowing, slowing and closing resources. These three CE Loops make the distinction between the various CBM strategies as shown in Table 6. Slowing-the-Loop extends the product lifetime. By recycling products, it becomes possible to Close-the-Loop. By Narrowing-the-Loop a company uses less resources for a product to produce. The mentioned business model strategies, in Table 6, describe more specific CBMs. For example, car sharing is a particular CBM within the Access and Performance Model to Slowing-the-Loop. CBMs enable economically viable ways to reuse products and materials continually and use renewable resources where possible (Bocken et al., 2016).

Three different articles describe three different divisions for the CBMs. Lewandowski (2016) uses the ReSOLVE actions. Planing (2015) defines the Loops that the CE uses of for technical materials. Bocken et al. (2016) divides three categories that explain how the product is influenced.

TABLE 6 CIRCULAR BUSINESS MODEL CATEGORIES (BOCKEN ET AL., 2016)

Circular Economy Loop	Circular Business Model Strategies
Slowing-the-Loop	Access and Performance Model, Extending Product Value, Classic Long-Life Model, Encourage Sufficiency
Closing-the-Loop	Extending Resource Value, Industrial Symbiosis
Narrowing-the-Loop	Product Efficiency

2.2.3 Decision Circular Business Models Categorisation

This section will determine what the most suitable categorisation of the CBMs is for this research, which forms the answer to a part of sub-question 1. The articles of the articles of Planing (2015), Bocken et al. (2016) and Lewandowski (2016) categorize the CBMs differently. The goal of this section is to select the most suitable categorization of the CBMs, based on the concept of CE defined by the EMF. All three articles are considered. By selecting one of the three articles, the decisive categorization of CBMs is chosen. After that, an assessment of all possible CBMs will clarify whether they are suitable for adoption in the Lithium-Ion Battery Industry or not.

The EMF divides the CE into various actions, namely ReSOLVE actions (EMF, June 2015). In Figure 5, examples are given of these different activities. The EMF does not mention CBMs that match the six actions. Therefore, a separate article is used to illustrate the possible CBMs classified by the ReSOLVE actions (Lewandowski, 2016).

In order to build on the vision of the EMF, the ReSOLVE actions and the CBMs needs to be combined. To avoid discrepancies between different articles, the EMF is used as the basis. The EMF mentions the ReSOLVE actions as six possible actions within the CE. This leads to the distribution of CBMs based on the six ReSOLVE actions as shown in Figure 5. On the left side, all ReSOLVE actions are explained briefly. While, on the right side, all CBMs are linked to the ReSOLVE actions. Within the concept of CE, it is clear that some of the ReSOLVE actions result in multiple types of CBMs. Appendix III shows the entire list of CBMs according to Lewandowski (2016), including a description of each CBM.

Not all CBMs in Figure 5 are useful for the Lithium-Ion Battery Industry. Appendix IV describes each CBM, which points out whether a CBM is beneficial for the use in the Lithium-Ion Battery Industry or not. A reason for excluding a CBM is when there is no focus on the core business operations of a company. While, a reason to include a CBM, is when the CBM is able to improve the operations of the current situation of a company.

The EMF its statement regarding the concept of CE forms the basis for the selection of the suitable CBM categorization. Lewandowski (2016) elaborates on the aspects of the CE and ReSOLVE actions according to the EMF. During the remainder of this research, is the categorization for CBMs of Lewandowski (2016) used. This determination is a next step in the answer of sub-question 1, to define the suitable terms for the CE, CBMs and CBM indicators.

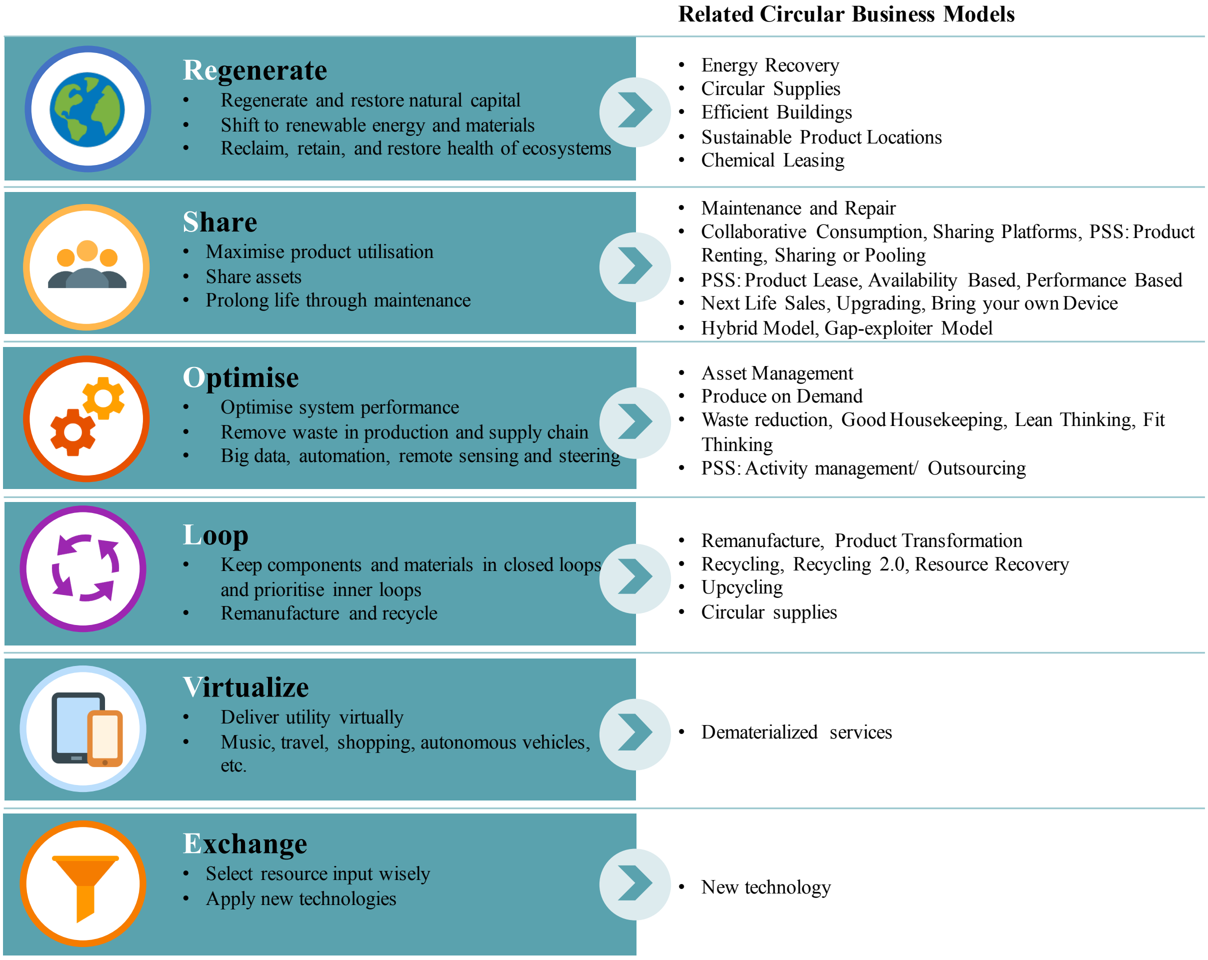

FIGURE 5 CIRCULAR BUSINESS MODELS IN RESOLVE FRAMEWORK (EMF, JUNE 2015; LEWANDOWSKI, 2016)

2.3 BUSINESS MODEL INDICATORS

This section shows what kind of useful indicators can measure the concept of CE, which will support to answer sub-question 1 partially. An overview of these indicators will help to define which are most useful for measuring the concept of CE. The indicators stem from the literature that mentions indicators regarding sustainability. Earlier, in section 2.1.1, differences between sustainability and CE were made clear. This section identifies the suitable literature to select the correct indicator. These indicators are useful when new statements are formulated in section 3.2.

To determine which indicator is most suitable for the concept of CE, many search terms were used via Google Scholar. The terms are Business Model Indicators Sustainability, Indicators Circular Economy, Measure Circular Economy, Sustainability versus Circular Economy, Circular Economy Indicators China, Company Indicators Circular Economy, Differences Circular Economy Sustainability, measure sustainability level companies, Sustainability assessment & performance indicators and Circular Economy Indicators measure China. Similar to all previous sections these articles refer to other articles that were used as well.

Most of the indicators that companies use, focus on financials and supply chain performances. However, within the concept of CE not only these performances matter, but also environmental aspects. Within the CE, societal objectives are a result of the improvements in environmental aspects. Societal objectives focus on the society who benefits from the environmental benefits from using less resources and less pollution. The societal objectives and environmental aspects determine boundaries of indicators to measure the degree of circularity (Geissdoerfer et al., 2016). The degree of circularity is the extent to which a company uses the concept of CE.

In China, there is currently a focus on regulating and adopting CE. The transition towards a CE has to start somewhere. This transformation begins at company-level, followed by industrial parks and then cities and regions. Indicators are used to keep track of the progression of circularity improvement. The indicators are divided by environmental development, economic development and human development (Zhijun & Nailling, 2007). However, the researchers use indicators that focus solely on national level. Therefore, the indicators will not be used for this research.

Geng et al. (2012) mention different indicators that the Chinese industry uses. The focus is on meso- and macro-levels of the industry. The meso-level focuses on industrial park level and the macro-level on a city or region level. These lower level indicators, create an opportunity to use the indicators of the Chinese industry for this research. In recent years various guidelines for improving CE policies were developed. These guidelines consist of measuring performance indicators, eco-efficiency indicators and unidimensional indicators. For this research, the attributing indicators consist out of energy- and material flow analysis, lifecycle analysis, CO2 emissions, economic returns and ecological footprints (Geng et al., 2013).

Golinska et al. (2015) assessed the sustainability level of remanufacturing companies. The indicators used, are shown in Table 7. To measure indicators, different methods are applied such as quantitative assessment or metric-units (Golinska et., 2015).

However, as earlier explained, Geissdoerfer et al. (2016) conclude that the human development is a benefit from environmental development, or in other words human development is a result of environmental improvement. For instance, less CO2 emissions are better for the environment, and at the same time a benefit for the society.

The gap between the difference of sustainability and CE is too big to copy the indicators as the definitions show various differences. To bridge the gap between the definitions a comparison is made and sustainability indicators are selected when the indicators match the concept of CE.

TABLE 7 INDICATORS ASSESSING LEVEL OF SUSTAINABILITY (GOLINSKA ET AL., 2015)

Economic Performance	Environmental Performance	Social Performance
Overall equipment effectiveness	Energy consumption level	Employment
Remanufacturing process flow	Waste generation level	Staff training
Adequacy of remanufacturing process planning	Material recovery rate	Harmfulness of the remanufacturing process
Availability of machines and tools	Generated emissions level	Average level of comfort at work
Level of executed orders		Innovation level
Availability of materials		

Farrell & Hart (1998) describe that indicator selection depends on two questions. The first is what one wishes to know and the second is what information will be used (Farrell & Hart, 1998). In other words, the selection of indicators need to meet the differences described in Table 2. Whereas sustainability focuses on the environment, economy and society. The CE focuses on the economy and environment, in which the society benefits from the environmental improvements. The two questions of Farrell & Hart (1998) form the start of the selection of indicators in section 3.2 Indicator.

Veleva and Ellenbecker (2001) explain how they have selected indicators to measure sustainable production. They make use of the existing five-step model, the Lowell Center for Sustainable Production indicator framework, to select the indicators. The five-step model differentiates the indicators into various levels. The use of additional indicators helps companies to become more aware and be able to measure their progress to a sustainable production system. These additional indicators are represented by Level 4, Supply Chain and Product Life-cycle Indicators and Level 5, Sustainable Systems Indicators. Each level represents a different level of indicators. As the level increases the type of indicators focus more on specialized topics and topics that are important in the current society.

Not the entire answer to sub-question 1 is given, because the specific CE indicators will be mentioned in section 3.2. However, a selection of literature regarding the indicators shows what indicators are used and how the different literature uses their own categorization method. By using the indicators of the selected literature, new insights will attribute to the design of the new Tool.

2.4 Circular Economy Tools

There are three existing tools that show overlap with the expected design of the new Tool. One of the overlapping existing tools will be selected to use as a starting point in this research. Using certain aspects of one the existing tools, will attribute in developing the new Tool. This is described as the second step in Appendix I: Select Existing Tool as Starting Point for Development of New Tool. All three analysed tools are developed to help companies indicate what opportunities there are within the company to focus on CE or sustainability. The question how to determine what tool is most suitable to use as a starting point for the development of the new Tool will be answered in sub-question 2.

2.4.1 Guided Choices Towards a Circular Business Model

The first out of three existing tools, the Guided Choices Towards a Circular Business Model, is a five-step approach that promotes the CE and guides companies to find a suitable CBM. This tool is a workbook consisting of five-steps, as shown in Figure 6, where each step contains a number of questions that the company needs to answer (Joustra et al., 2013). The first step is to read about the basics of the CE. These provide insight in the differences between the current Linear Economy and Circular Economy. When understanding the basics, a company is aware of the up-to-date CE concepts. The second step is to learn about the readiness of a company to implement a CBM and whether the supply chain is ready for adoption. Once a company has read and learned about the possibilities for adopting a concept of CE. They will have to talk about the probable redesign of their product that will make it possible to concentrate on a CBM. When a redesign is discussed within a company, a service model redesign will have to be developed. Such a service model is focused on providing Product-as-a-Service, where customers use a service rather than owning a product. The final step is to test if the new CBM seems profitable for the company. If this is not the case the company will not implement the new CBM.
This five-step approach by Joustra et al. (2013) helps a company to find what CBM is suitable for them. The tool provides steps where numerous questions are answered.

FIGURE 6 FIVE-STEP APPROACH OF CHOICES TOWARDS A CIRCULAR BUSINESS MODEL (JOUSTRA ET AL., 2013)

The downside of the five-step approach of Joustra et al. (2013) is that it is solely a roadmap for companies to arrive to a new CBM. The roadmap only advices the company on what steps need to be taken, without giving advice on what CBM is most suitable to the company. The Guided Choices Towards a Circular Business Model guides companies to find a model that suits the company best by using these five steps, while not proposing any CBM.

2.4.2 Sustainable Business Model Canvas

The Sustainable Business Model Canvas is a customized Business Model Canvas with special building blocks, which focus on sustainable aspects within a company (Sempels, 2014). The Canvas supports a company by giving an overview of implications when adopting new CBMs. The Business Model Canvas is described in French in Table 8. The Sustainable Business Model Canvas introduces some changes to the original Business Model Canvas, which are Positive & Negative Externalities, Productivity Drivers and Organizational Effectiveness & Efficiency.

The blocks in the Canvas give an overview what aspects within a company change when a company shifts from selling products to providing Products as a Service. The Business Model Canvas supports companies by indicating what essential aspects change within a company. Like the Guided Choices Towards a Circular Business Model, the Sustainable Business Model Canvas is a framework too that needs to be completed by a company. The Canvas does not offer advice on any aspect or what kind of options most suitable are for a company. The Sustainable Business Model Canvas offers just a framework that a company needs to complete. For companies without any knowledge on sustainability or CE, the Canvas is ineffective, because the Canvas is not a tool that supports companies to explore the possibilities of the CE and the available CBMs. Therefore, it is not possible to use the Business Model Canvas as a starting point for the design of the new Tool.

TABLE 8 SUSTAINABLE BUSINESS MODEL CANVAS (SEMPELS, 2014)

<table>
<tr><td rowspan="6">Externalités positives</td><td colspan="4">Gouvernance et légitimation</td><td rowspan="7">Système d'acteurs et partenariats clés</td></tr>
<tr><td rowspan="2">Activités stratégiques
(ce qu'il faut faire)</td><td rowspan="2">Organisation du travail
(comment le faire)</td><td rowspan="2">Proposition de valeur</td><td>du point de vue des bénéficiaires</td></tr>
<tr><td>pour bâtir l'avantage concurrentiel</td></tr>
<tr><td colspan="2" rowspan="2">Ressources clés
(dont les ressources immatérielles)</td><td colspan="2">Gestion de la relation aux acteurs</td></tr>
<tr><td colspan="2">Accessibilité & appropriation</td></tr>
<tr><td colspan="4">Déterminants de productivité</td></tr>
<tr><td>Externalités négatives</td><td colspan="2">Structure et flux de coûts</td><td colspan="2">Structure et flux de revenus</td></tr>
</table>

2.4.3 Circular Economy Assessment Tool

The Circular Economy Assessment Tool (Bocken et al., 2013), is referred to as the Bocken-Tool and is an Assessment Tool that advices a company in what kind of actions are required to improve its circularity.

The Bocken-Tool consists of numerous statements that focus on various subjects within a company and its product specifications. Each statement in the questionnaire of the Bocken-Tool has three options: Circular Statement, in between or Linear Statement. The Circular Statement and the Linear Statement are opposites. When selecting a Circular Statement, a respondent indicates that the company is focused on CE within that specific subject. While selecting the Linear Statement, the respondent states that there is room for improvement. A respondent has to complete the entire questionnaire by answering all statements by selecting one of the three options.

By answering the questionnaire, the Bocken-Tool identifies what potential improvements a company can make to become more circular. According to the Bocken-Tool, the proposed actions to become more circular are shown in Figure 7. When having completed the questionnaire, the circles indicate what actions are possible to improve the degree of circularity within a company. The green markings indicate a high improvement potential and the yellow markings indicate medium improvement potential.

The downside of the Bocken-Tool is that it only shows what Circular Loops a company should focus on (Planing, 2015; Ellen MacArthur Foundation, 2012). These are the Circular Loops according Figure 1. The result is not a specific CBM nor a ranking of CBMs. The Bocken-Tool is developed to give advice what actions are possible to take within a company, but it ignores the supply chain position of a company. Even though, this is required to be filled in at the beginning of the questionnaire, it is not changing the results at all.

FIGURE 7 EXAMPLE OF BOCKEN-TOOL
(BOCKEN ET AL., 2013; WWW.CIRCULARECONOMYTOOLKIT.ORG)

The Bocken-Tool is a sufficient starting point for developing the new Tool, as the Bocken-Tool makes use of a questionnaire that is easy to complete by various companies. Therefore, the threshold to complete the Bocken-Tool is low for companies, which makes it interesting to use some aspects for the design of the new Tool.

The Bocken-Tool is also useful to advice on future opportunities for a company. The new Tool should be able to give advice based on a list of statements, which is suitable as a first step towards selecting a CBM. However, the problem in Lithium-Ion Battery Industry is that there is no guidance for the selection of CBMs. The Bocken-Tool proposes actions that a company need to focus on instead of CBMs. Concluding the above, some aspects of the Bocken-Tool show potential to use for the new design, so the starting point is the Bocken-Tool.

2.4.4 THE CIRCULAR BUSINESS MODEL ASSESSMENT TOOL

From this point onwards, the Circular Business Model Assessment Tool is referred to as the RA-Tool. The new developed RA-Tool will help companies in the Lithium-Ion Battery [LIB] Industry to explore the possibilities of the CE by creating a ranking of CBMs. It will serve as a support- and advice-tool. The RA-Tool will have new additionalities by which it differentiates itself from existing tools. The additionalities of the RA-Tool are:

- Use a selection of Circular Business Models
- Create a ranking of Circular Business Models
- Weight calculation for ranking is based on an analysis method
- Answer each statement with True or False
- Create different list of statements for various supply chain positions, that result in a different Circular Business Models

Moreover, the RA-Tool will make a distinction between different supply chain positions in the LIB Industry, which will be discussed in section 2.5. Each supply position is linked to a different number of CBMs, as some CBMs are useful in a supply chain position and others are not. The number of CBMs is different in other supply chain positions. The subjects of the statements vary per supply chain position, because certain subjects are relevant for one supply chain position but not for another position. When the list of statements is completed by a company, a ranking is calculated. This ranking shows in ascending order what CBMs are suitable for a company to implement. The top-ranked CBMs have most room for improvement within a company, while the lower-ranked CBMs indicate that the company is on these aspects already circular or that these CBMs are not possible to implement. Therefore, companies should leave the lower ranked CBMs out of account.

As the Bocken-Tool will be used as a starting point, aspects of that tool are used for developing the RA-Tool. These aspects especially focus on the used statements and to what CE actions these statements are linked. The new RA-Tool will use existing statements from the Bocken-Tool, when the subject of a statement is suitable for a specific supply chain position. The RA-Tool will help companies in the LIB Industry to become more familiar with possible CBMs in their operating field. It will help to explore CBMs for companies a lot easier. For companies in the LIB Industry, it is useful to have a ranking of the CBMs to compare and see what the possibilities of CBMs are.

2.5 Lithium-Ion Battery Industry

The next section describes the current status of the LIB Industry, the steps within the supply chain and the companies involved in the LIB Industry. The LIB Industry is the main-actor in this research. By introducing the important aspects of the LIB Industry, an answer is given to the third sub-question. This is the third step in Appendix I, Analyse LIB Industry. The overview of the industry will form a basis of the RA-Tool its design.

To find more information regarding the LIB Industry two resources were used. The first one is Google, where the following search terms were used: Lithium-Ion Battery companies, Lithium-ion industry, LIB Industry, LIB companies, LIB companies worldwide, Scarce materials worldwide, rare earth materials worldwide, supply chain Lithium-Ion Battery Industry, value chain Lithium-Ion Battery Industry and working Lithium-Ion Battery. The second source used is Google Scholar, where the following search terms were used: Lithium-Ion Batteries, Lithium-Ion Battery Industry, Lithium-Ion Battery materials, LIB Industry, LIB companies industry, progress Lithium-Ion Battery, future Lithium-Ion Batteries, working Lithium-Ion Battery, Supply chain Lithium-Ion Battery Industry and Supply chain Lithium-Ion Battery. Again, by using these search terms, specific articles led to new articles.

At the moment, recycling LIBs is possible (Zeng et al., 2014). However, using recycled raw materials for new LIBs is more expensive than using new raw materials. The recycling process is a complicated method. A LIB consists of much more raw materials and rare earth metals than a lead-acid battery or a nickel-metal-hybrid battery (Gaines, 2014). This makes it difficult to recover all materials. Different LIBs, have a different composition, which makes it hard to standardize the recycling process. Next to this, a LIB-pack has much more individual LIB cells compared to lead-acid or nickel-metal batteries. The number of cells makes the recycling process more comprehensive.

The LIB Industry is making significant progress regarding price and production efficiency of LIBs. However, to comply with the demand in a few years, many new facilities need to be built (Väyrynen & Salminen, 2012). LIBs have twice the potential of lead-acid batteries and nickel-metal-hybrid batteries, in terms of density and lifecycle performance. The price of LIBs is expected to be three times lower in 2025. This price drop makes the LIBs more attractive to use for even more applications (Nykvist & Nilsson, 2015). Nevertheless, the declining price will have negative effects on the number of spent LIBs. It becomes less interesting to recycle the LIB as new Libs are cheaper. The amount of LIB waste is expected to grow to 26 billion units in 2020, while in 2012 the amount of waste was 2,6 billion units (Zeng et al., 2012; Xu et al., 2017).

The recycling process of LIBs is a form of closing-the-loop, whereas the materials are being processed for reusing. Other companies within the LIB Industry developed different loop extensions to extend the lifecycle of a LIB. A currently used option used for end-of-life LIB of Electric Vehicles is use them as secondary lifecycle, for instance as Energy Storage Systems (Ahmadi et al., 2015). To reuse the LIB, it has to be remanufactured. The focus in the remanufacturing process is on testing the battery performance and preparing for a new application (Ahmadi et al., 2015). After this process, the LIB is ready for reuse. In literature, the most common reuse application is for Energy Storage Systems (Lih et al., 2012; Ahmadi et al., 2015; Martinez-Laserna et al., 2016). An Energy Storage System offers the possibility to store renewable energy, to use it at a different time. To store renewable energy is economically attractive as energy is not always necessary when it is generated.

2.5.1 Supply Chain of Lithium-Ion Batteries

In this section the entire supply chain of the LIB Industry is mapped to highlight important positions or actors in the industry. To achieve this, the European Commission did research on the supply chain of LIBs in the car manufacturing industry (Lebedeva et al., 2016). Lebedeva et al (2016) introduce the LIB Industry including the supply chain positions, whereas they proceed to the car manufacturing industry.

The EMF (2012) explains the supply chain of both biological and mechanical materials. This was explained earlier in Figure 2. The figure shows both the linear supply chain steps and the cycles that relate to the CE concept. The linear supply chain steps they mention are:

1. Materials/ Parts manufacturer
2. Product Manufacturer
3. Retail or Service Provider
4. User
5. Energy recovery
6. Landfill

Both explanations of the supply chain agree on the supply chain its current status and positions. The supply chain of the LIB Industry is divided into eight positions, as shown in Figure 8. Each position in the process is responsible for a different task. The companies that are responsible for the process of the LIB supply chain are left out of scope. An insight in the involved companies will be discussed in section 2.5.2.

In order to achieve more insight in the position of companies in the supply chain using the 'take-make-dispose' supply chain of the LIB Industry. Chung et al. (2015) created a supply chain of LIB in the car manufacturing industry. These three articles and different supply chains helped to identify the LIB supply chain. The LIB supply chain helps to understand the positions and the companies involved in the LIB Industry.

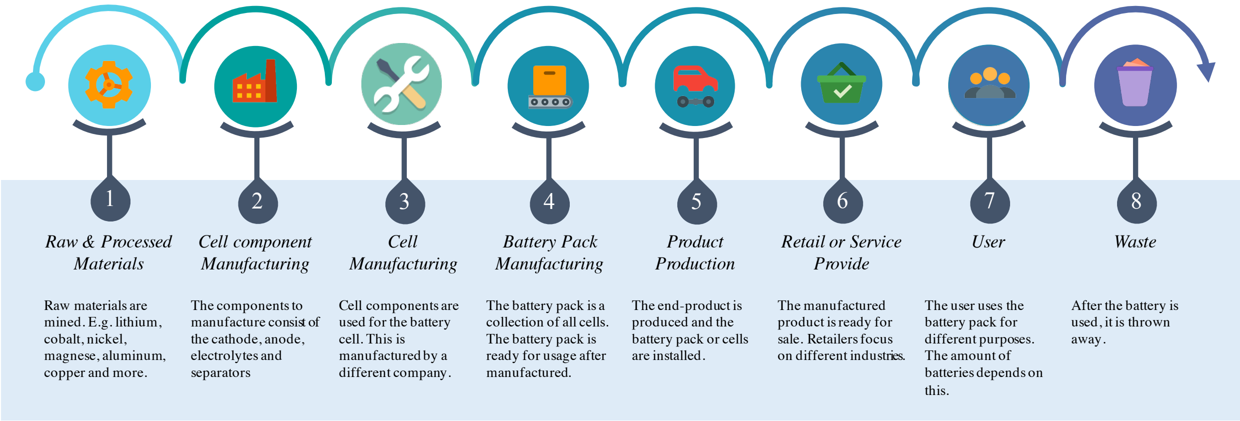

FIGURE 8 SUPPLY CHAIN OF LITHIUM-ION BATTERY INDUSTRY

In the supply chain of LIBs, first various raw materials and rare earth metals are mined and processed. By purifying and creating a specific composition, the materials are being processed. Next, new components are produced, which form the basis of battery cells. These components are (Lebedeva et al., 2016):

- Cathode
- Anode
- Electrolytes
- Separators

The components form the basis of battery cells. After the production of the components, a company can put the battery cells together.

The next step, battery pack manufacturing, is only applied in bigger batteries battery production. For instance, in the car manufacturing industry, a large number of battery cells is required. Therefore, battery packs are put together using battery cells.

The shipment of battery cells or battery packs is sent to the product manufacturer when the batteries are ready for use. The LIB is installed in the end-product. After producing the end-product, Retailers or Service Providers receive the product. As sales numbers of LIB electronic devices and Electric Vehicles are increasing rapidly, new business opportunities arise, and attention towards efficiency is rising (Lebedeva et al., 2016).

Consumers make use of the end-product by buying it or use the Product as a Service. By using the LIBs, the product downgrades and when the product cannot meet the demands, the product becomes useless. The LIB is thrown away and ends as waste.

2.5.2 Companies in LIB Industry

The number of companies involved in the supply chain process of LIBs is innumerable. Each involved company fulfils a different task of the supply chain. Some companies make use of vertical integration. Or in other words, they perform various tasks of the supply chain. For instance, Johnson Matthey produces not only cell components, but also battery cells and battery packs. Table 9 shows a list of major companies within the worldwide LIB Industry. The table represents companies in combination with their position in the supply chain. This is only an overview based on the information of Lebedeva et al. (2016). Currently, there are a few major companies in the field of LIBs that cover almost the entire supply chain. All these companies are focused on Electric Vehicles: BYD, Mitsubishi and Tesla.

The company list focuses on the production process of LIBs. The list of companies for Retailer or Service Providers is innumerable. Since there are many LIB applications.

TABLE 9 COMPANIES INVOLVED IN LITHIUM-ION BATTERY SUPPLY CHAIN

Supply Chain Position / Company	2. Cell Components Manufacturing	3. Cell Manufacturing	4. Battery pack Manufacturing	5. Product Production	6. Retail and Service Provider
Leyden-Jar Technologies	X				
Umicore	X				
Johnson Matthey	X	X	X		
Nichia	X				
UACJ Corporation	X				
Nippon Denkai	X				
Sumitomo Light Metal Industries	X				
Furukawa Electric	X				
CapChem	X				
Zhangjiagang Guotai-Huarong	X				
Asahi Kasei	X				
Toray	X				
SK	X				
DuPont	X				
Daikin	X				
Panasonic	X	X	X		
LG Chem	X	X	X		
BYD	X	X	X	X	X
Mitsubishi	X	X	X	X	X
Samsung SDI		X	X	X	X
Tesla		X	X	X	X
Sony		X			
Leclanché		X	X		
EAS Batteries GmbH		X	X		
BMZ-Group		X	X		
European Batteries		X	X		
Coslight		X			
Maxell/Hitachi		X			
BAK		X			
Lishen		X			
Nissan			X	X	X
Simplo		X			
Apple				X	X

2.5.3 Supply Chain Options

Each position in the supply chain has a different task. For the RA-Tool development, only the use of certain positions is necessary. This is based on the requirement whether the implementation of a CBM attributes to improving the CE of the LIB Industry. Whereas, the focus on the product operations is namely on the LIB, LIB components, production process of the LIBs, efficient production and efficient usage of the LIBs. Therefore, not all supply chain positions are used in the RA-Tool. Table 10 explains which supply chain position is selected as a category in the RA-Tool or not.

The next step is to assess which CBMs are suitable for which position. Appendix V shows the selection of CBMs in all three selected supply chain positions. This analysis explains why to use CBM in that specific supply chain position. The cell manufacturer and battery pack manufacturer tasks are to manufacture LIBs. Therefore, these two supply chain positions are merged to one category in the RA-Tool.

TABLE 10 SELECTION OF POSITIONS IN SUPPLY CHAIN

Position in Supply Chain	Selected?	Reason
Raw & Processed Materials	No	The focus of this process is mainly on mining and processing raw materials. The goal of the CE is to reduce this step as much as possible by closing-the-loop of all available materials. Besides this, there is a limited number of possible CBMs for this step due to the type of operations.
Cell Components Manufacturer	Yes	Different Component Manufacturers form the basis of a LIB. Implementation of many different CBMs is possible in this position of the supply chain.
Cell Manufacturer	Yes	The cell manufacturing attributes to the supply chain by assembling LIBs. In this operation, the LIB is key. Many CBMs can improve the process and efficiency.
Battery Pack Manufacturer	Yes	The battery pack manufacturers merge individual cells. In most cases, these are the same manufacturers. Therefore, these two positions are used as one.
End-product Manufacturer	No	The end-product manufacturer uses LIBs for the performance of its product. However, they do not attribute to the LIB CE. The LIBs are installed and transported. This makes the implementation of CBMs that focus on LIBs, difficult.
Retailer or Service Provider	Yes	Retail and Service Providers have a lot of influence on the CE of LIBs. If they can use CBMs, this would be the most efficient loops of the CE. This position offers a lot of CBMs that focus on the concept Product as a Service.
Users	No	Users only make use of the products. They cannot use a CBM. The Retailers and Service Providers can change to CBMs. Whereas the type of payment or usage changes for the users.
Waste	No	By promoting the CE by adopting CBMs, the waste step is excluded. Therefore, there are no CBMs to implement in this step.

The identification of the supply chain positions of the LIB Industry, resulted in eight different positions. These are Raw & Processed Materials, Cell Component Manufacturers, Cell Manufacturers, Battery Pack Manufacturers, End-product Manufacturers, Retailer or Service Providers, Users and the product ends as Waste. Where after, an overview is given of large companies in the supply chain of the LIB Industry. Finally, the decision is made, which supply chain positions are relevant to use in the development of the RA-Tool. The following supply chain positions are used:

- Component Manufacturers
- LIB Manufacturers
- Service Providers or Retailers

The LIB Manufacturers is a combination of the Cell Manufacturer and the Battery Pack Manufacturer. Appendix V shows which CBMs attribute to what supply chain positions. An elaborated explanation why the CBMs are useful on that specific supply chain position clarifies the usability of the CBMs.

3. Statement Selection & Development

Chapter 3 describes the analysis of the Bocken-Tool as it is used as a starting point for the development of the RA-Tool. The first stage in this chapter is to analyse the statements of the Bocken-Tool and addresses what kind of additional information is necessary to develop the RA-Tool. This is the answer on sub-question 4 and the fourth step in Appendix I, Analysis of Selected Existing Tool.

The next stage in this chapter is to elaborate on the aspects selected from the Bocken-Tool, what represents the fifth step in Appendix I: Develop New Statements for RA-Tool. This is where the analysis of the Lithium-Ion Battery [LIB] Industry becomes useful, as various supply chain positions require new statements. The main focus is on Circular Economy [CE] indicators and the literature that describes characteristics of the Circular Business Models [CBMs]. These subjects will help to develop new statements for the new RA-Tool. This step answers the fifth sub-question, which focuses on additions to the useful aspects of the Bocken-Tool.

3.1 Bocken-Tool Analysis

When analysing the Bocken-Tool, it becomes clear what further steps are necessary relevant aspects from the Bocken-Tool. Each statement of the Bocken-Tool consists of a Linear Statement and a Circular Statement. For the design of the RA-Tool only the Circular Statement remains useful. All statements of the Bocken-Tool, available on http://circulareconomytoolkit.org/Assessmenttool.html, focus on different actions of improvement. To find out what statements are useful and what statements influence what kind of CBMs, an analysis is required.

There are four steps to analyse the Bocken-Tool and divide the CBMs with the statements and make a selection of statements for each supply chain position.

The first two steps are shown in Appendix VI:

1. Assign ReSOLVE actions to each statement of the Bocken-Tool.
2. Analyse per statement what the proposed improvement is, as shown in the colour indications in Figure 7.

The next step is described in Appendix VII:

3. Based on the previous set ReSOLVE actions, link each CBM to the statements. These statements will then be assessed and will show which CBMS are affected by the answer to the Statement.

The final step is described in Appendix VIII:

4. Select the necessary statements for each supply chain position and mark the unusable CBM red.

By taking these steps all supply chain positions connect to various statements what matches with their requirements and their operations. The result is that each CBM is mentioned a different number of times

in each supply chain position. The analysis helps to indicate what kind of statements are suitable statements for the RA-Tool.
Table 11 is a summary of the number of times each CBM is mentioned in the selected statements for each supply chain position. The table includes the CBMs that do not correspond with the supply chain position, these are marked red. All CBMs that were selected in Appendix IV, are used in this table.
Cells with red text in Table 11 indicate that the CBM is excluded from that specific supply chain position. Note, the previously eliminated CBMs are listed too, but will be ignored from this point onwards. Moreover, it is evident that there are significant differences between the number of times a CBM is mentioned in the statements. To achieve a more relevant ranking, one requirement is that the number of statements for these CBMs is improved. When a CBM only has one statement the ranking is biased, because this CBM will always end very high or low.

The analysis of the Bocken-Tool shows that the statements are useful for the design of the RA-Tool. The limitation of the statements is the number of statements for certain CBMs. The red text in Table 11 indicates that not all of the CBMs are useful in the RA-Tool, Appendix IV explains the selection of CBMs more deliberately. The selection of CBMs varies for each of the three supply chain positions. Whereas multiple CBMs, in different supply chain positions, do not have a sufficient number of statements to lead to a valuable comparison of the CBMs and requires extra attention. The answer to the fourth sub-question is that the useful aspects from the Bocken-Tool are the statements and their link to the CE actions. These CE actions are transferred to CBMs, which is required for the design of the RA-Tool.

TABLE 11 SUMMARY TOTAL NUMBER CBMS MENTIONED IN USEFUL BOCKEN-TOOL STATEMENTS
A = USEFUL FOR SUPPLY CHAIN POSITION?; B = TOTAL MENTIONED IN SELECTED STATEMENTS; * = ALREADY EXCLUDED

Supply Chain Positions							
		Components Manufacturers		LIB Manufacturers		Retailers & Service Provid-ers	
ReSOLVE Actions	**Circular Business Model**	**A**	**B**	**A**	**B**	**A**	**B**
Regenerate	Energy Recovery	Yes	3	Yes	3	No	0
	Circular Supplies	Yes	3	Yes	4	No	2
	Efficient Buildings *	No	0	No	0	No	0
	Sustainable Product Locations*	No	0	No	0	No	0
	Chemical Leasing *	No	0	No	0	No	0
Share	Maintenance and Repair	No	4	No	14	Yes	15
	Collaborative Consumption *	No	0	No	0	No	0
	Sharing Platforms *	No	0	No	0	No	0
	PSS: Product Renting, Sharing or Pooling	No	0	No	0	Yes	0
	PSS: Product Lease	No	0	No	0	Yes	2
	PSS: Availability-Based	No	0	No	0	Yes	2
	PSS: Performance-Based	No	0	No	0	Yes	2
	Next Life Sales	No	4	Yes	10	Yes	7
	Upgrading	No	2	Yes	13	Yes	14
	Product Attachment and Trust *	No	0	No	0	No	0
	Bring your own Device *	No	0	No	0	No	0
	Hybrid Model	No	4	Yes	12	No	12
	Gap-exploiting Model *	No	2	No	3	No	5
Optimise	Asset Management *	No	0	No	0	No	0
	Produce on Demand	Yes	5	Yes	5	No	0
	Waste Reduction	Yes	3	Yes	3	No	0
	Good Housekeeping	Yes	6	Yes	5	No	0
	Lean Thinking	Yes	5	Yes	5	No	0
	Fit Thinking	Yes	6	Yes	5	No	0
	PSS: Activity management/ Out-sourcing	Yes	2	Yes	2	No	0
Loop	Remanufacture	No	5	Yes	18	No	12
	Product Transformation	No	5	Yes	18	No	12
	Recycling	Yes	5	Yes	6	No	1
	Recycling 2.0	Yes	5	Yes	6	No	1
	Resource Recovery	Yes	5	Yes	6	No	1
	Upcycling	Yes	6	Yes	16	No	12
	Circular Supplies	Yes	3	Yes	3	No	1
Virtualize	Dematerialized Services *	No	0	No	0	No	0
Exchange	New Technology	Yes	2	Yes	2	No	0

3.2 Indicators Analysis

The indicators that were discussed in section 2.3, point out which instruments are useful indicators to measure the concept of CE. Based on these indicators that fit within the concept of CE, new statements are developed to elaborate on the statements from the Bocken-Tool. This contributes to the answer on sub-question 5, to improve the useful aspects of the Bocken-Tool. Besides, this is step 5 of Appendix I: Develop New Statements for RA-Tool. These aspects focus on the statements the RA-Tool uses, but the RA-Tool requires more statements for a selection of CBMs.

The collection of articles regarding sustainability helps to select indicators that connect to the concept of CE. By dividing the indicators, a distribution of valuable indicators is obtained from the literature selection previously discussed in section 2.3. A list of useful indicators is the result.

Each useful indicator is linked to subjects that relate to the subject of the indicator. Suitable subjects for the statement formulation have to influence at least one CBM. Table 11 shows which CBMs are rarely mentioned in the Bocken-Tool. Certain CBMs require more statements to answer, as the limit of statements for each CBM is set at a minimum of four in the RA-Tool. Otherwise, the difference between the number of statements of CBMs is too far apart from each other.

The focus is on the following CBMs when developing new statements:

- Energy Recovery
- Circular Supplies
- Provider Service-Systems [PSS]: Product renting, Sharing or Pooling
- PSS: Product Lease
- PSS: Availability-Based
- PSS: Performance-Based
- PSS: Activity Management/ Outsourcing
- New Technology

Appendix IX shows the indicators of different articles. An assessment based on the differences between sustainability and CE identifies which indicators meet the requirements to the CE. The requirements focus on the link with the concept of CE. The indicators that meet these requirements do not imply the direct use of these indicators for the RA-Tool. The selection will continue in the process to assess whether the indicators are useful. This process discusses possible subjects and statements for the RA-Tool.

As explained, the next step is to link subjects to the selected indicators. The goal is to find suitable subjects to formulate new statements. The subjects relate to matching CBMs, that are influenced by the subject. Appendix X shows the selected indicators, from Appendix IX, with a list of matching subjects including the suitable CBMs.

Each row in the Appendix X has a different colour, indicating the usability of the subject, statement or CBMs. If a certain subject is not used, it means the subject already exists in the Bocken-Tool. There could be various reasons for not using the listed statements. The first reason is that the mentioned CBMs already have sufficient statements in the Bocken-Tool. Another reason is that answering the statement is too complex for a company.

Table 12 provides a summary of the Appendix X. Analysing the table, it can be concluded that the number of indicators not used is significantly higher than the indicators that are useful. The suitable indicators will be used to derive statements from.

TABLE 12 SUMMARY OF APPENDIX X

Colour	Number of Times Used	Definition
Yellow	21	The subjects already have significant attention in the Bocken-Tool and the CBMs that are influenced by these topics have sufficient statements
Red	21	The subject is irrelevant for the CBMs that require additional statements
Orange	3	The subject is too difficult to answer for a company or the process to acquire the answer is too complicated
Green	12	Suitable subject to use in the RA-Tool and so are the CBMs which the statement affects

Table 13 shows new statements that are ready to use in the RA-Tool. Each statement affects a different CBM. In Appendix XI a more extensive analysis is described of the development of new statements. It identifies why and how the selected indicators are combined and lead to the formulation of these statements.

As earlier mentioned the RA-Tool uses only one statement, which need to be answered by 'True' or 'False'. For example, when answering the statement: *'The ratio mass of used materials versus end-product is 1'* from Table 13 with 'True' it states that a company is already focused on the CE. Therefore, the affected CBMs in the right column are not of influence to this statement. However, when a respondent answers 'False', the affected CBMs are useful for the company to implement.

Indicators that focus on CE help to formulate new statements that attribute to the design of the RA-Tool. By doing so, sub-question 5 is answered partially. However, to cover improve the useful aspects of the Bocken-Tool regarding the number of statements, more statements are required. In this section, six new statements were formulated as stated in Table 13. The new statements focus on CBMs that have a low number of statements after the analysis of the Bocken-Tool.

TABLE 13 SUMMARY OF NEW STATEMENTS BASED ON INDICATOR SELECTION

Statement	Affected Circular Business Models
The ratio mass of used materials versus end-product is 1	Waste Reduction, PSS: Activity Management/Outsourcing
Spent materials are harmful to the environment when transferring to energy (e.g. for producing heat, fuel or electricity)	Energy Recovery
No new technologies (materials or production process) are available to improve efficiency, reduce environmental effects or save costs	Waste Reduction, Good Housekeeping, Lean Thinking, Fit Thinking, New Technology
Make use of renewable energy for production process	Circular Supplies
Make use of local suppliers for raw materials or product components	Produce on Demand, Waste Reduction, PSS: Activity Management/ Outsourcing
The product is used in wide surroundings, which takes longer time to use the product	Product Renting, Sharing or Pooling PSS: Availability based

3.3 STATEMENTS BASED ON LITERATURE

To realize more statements, descriptions regarding each CBM in literature are analysed. Based on these descriptions and CBM characteristics, new statements are developed. This in order to meet the lower limit of four statements for each CBM, by doing so sub-question 5 is answered. The sub-question requires to improve the useful aspects of the Bocken-Tool, namely the statements. The descriptions of the CBMs were found by using the references in the work of Lewandowski (2016).

Appendix XII explains per statement why they are useful. This includes literature references and explanations about what the contribution of the statements is. Table 14 shows a summary of the statements, influencing which type of CBM. If the respondents answer the statement with ‘False’ the CBMs are interesting for them.

The new statements in Table 14 mainly focus on the Retailer and Service Provider supply chain position. This supply chain position had an insufficient number of statements to make a proper RA-Tool. Especially the Provider Service-systems [PSS] CBMs. By developing new statements, the various similar-like CBMs can be differentiated. These similar-like CBMs are the following PSS CBMs: Product renting, Sharing or Pooling, Product lease, Availability-based and Performance-based. It is necessary to indicate the differences by formulating statements that affect not all of these CBMs. The new statements create the possibility to differentiate these CBMs in the ranking of the RA-Tool.

When a respondent disagrees with the statement, the mentioned CBMs in Table 14 are applicable. If the respondent agrees with the statement, none of the CBMs are suitable. In case the statement is ‘True’, it means that a company cannot implement the CBM or it implies that the company is already CE focused.

TABLE 14 SUMMARY OF STATEMENTS BASED ON LITERATURE

Statement	Affected Circular Business Models
The product usage period is short (think of few hours to maximum a few days)	PSS: Product Lease, PSS: Performance-Based
The product has a long usage period (months or years)	Product Renting, Sharing or Pooling PSS: Availability-Based
There is no possibility to change the performance of the product	PSS: Performance-Based
The purchase value is lower than €15.000, -	PSS: Product Lease
The company has no service platform for its users	PSS: Product Renting, Sharing or Pooling, PSS: Availability based
The product requires little or no scheduled maintenance	PSS: Product Lease, Performance-Based, Availability-Based
Procurement of recycled raw materials is more expensive than mined materials	Recycling, Recycling 2.0, Circular Supplies
Spent materials to landfill is cheaper than to use it for energy recovery	Energy Recovery
The production process has the most optimized processes in comparison to other specialized companies in terms of efficiency and costs	PSS: Activity Management/ Outsourcing, New Technology

An answer to sub-questions 4 and 5 are given in this chapter. Sub-question 4 identifies the useful aspects of the Bocken-Tool. The most useful aspect is the statements including the CE actions, however these actions of the Bocken-Tool had to be transferred to CBMs. Sub-question 5 requires an answer to improve the useful aspects of the Bocken-Tool for implementation in the RA-Tool. The statement aspect is improved by formulating 15 new statements that focus on the CBMs that require new statements.

4. DESIGN OF RA-TOOL

In this chapter the goal is to select the best analysis-method to rank the Circular Business Models [CBMs] based on the statements. This answers at the same time sub-question 6, which is to find the most suitable method to rank the CBMs in each of the supply chain positions. An analysis is required to select the suitable analysis method for the RA-Tool.

The analysis method has to comply with three requirements. The first requirement is to rank all CBMs, since the RA-Tool is an advice and support-tool for companies. The ranking of the RA-Tool indicates which CBM is most useful based on the statements. A second requirement is that the answers to the statements consist of 'True' and 'False'. A third requirement, is that the weights to compare the CBMs are not related to specific statements because this makes it impossible to compare the CBMs.

Clímaco & Craveirinha (2005) explain numerous Multi-Criteria Decision Analysis methods. These methods evaluate conflicting criteria in a model. By complying with the three requirements stated above, two analysis methods are selected from Clímaco & Craveirinha (2005), which are the Analytic Hierarchy Process [AHP] method and the Normalized method.

One of the two selected analysis methods is chosen by comparing them by running separate simulations. These simulations make it possible to select the most suitable analysis method. Each analysis method is run 10.000 times by using randomly generated results. The simulation of randomly generated answers is performed on the statements of the supply chain position of Lithium-Ion Battery [LIB] Manufacturer. Automatically generated answers create outcomes, whereas a ranking is calculated. By comparing the deviation of the two simulations, the method with the least Standard Deviation is preferred. The best analysis method is used for the developing the RA-Tool. This is the sixth step in Appendix I, Select One Analysis Method. When this is achieved, it is possible to combine step 5 and 6 to develop the RA-Tool, which is step 7 of Appendix I.

The first method which meets the three requirements stated above, is the AHP method. In the AHP method various criterions represent the list of statements of the RA-Tool. The selected criterions are based on the efficiency levels in the Circular Economy [CE]. The AHP method uses pairwise comparison to calculate the importance of each criterion. Through pairwise comparison is each criterion compared with the other criterions, one-by-one. After the comparison calculations, each criterion receives a weight. The weight is transferred into a specific weight for each Statement in the RA-Tool. In the AHP method, each Statement of a CBM has a different weight.

The second analysis method is the Normalized method. This method is used in many Multi-Criteria Decision Analysis methods as a step to compare the values of the analysis. The Normalized method calculates the same value for the statements of a specific CBM. The equivalent weight of the statements for a CBM make sure that each Statement is equally important.

Before comparing the AHP method and the Normalized method, it is explained why only one statement is used instead of a Circular statement and Linear Statement as the Bocken-Tool. Reasons why the RA-Tool statement is formulated as a Circular statement are given. Following this, a matrix is constructed, using a selection of statements in combination with the predetermined CBMs. Only by constructing the correct matrices, it is possible to calculate the weights for each CBM.

4.1 Circular Business Model Matrix Construction

The framework of the design of the RA-Tool consists of the selected statements in combination with a matrix to compare all CBMs. The RA-Tool uses only one statement, while the Bocken-Tool uses two opposite statements. After the selected statement is clarified, a matrix needs to be constructed. By using the designed matrix, a minimum and maximum score per statement in combination with a CBM can be calculated.

4.1.1 Statement Selection

The useful statements from the Bocken-Tool, analysed in 3.1, in combination with the developed new statements, from 3.2 and 3.3, create three separate list of statements for three selected supply chain positions.

The Bocken-Tool uses two opposite statements. The approach in this research uses only one statement, which is the Circular statement from the Bocken-Tool. The reason for using this statement only is that the answer to the statement is 'True' or 'False', which applies to only one statement.

It is decided to use one statement for a number of reasons. The first reason is when using two opposites the respondent may doubt, which can result in not answering the statement at all. The second reason to use the statement that is formulated as a Circular Statement, is that it is expected to achieve the best result in the RA-Tool according to the researcher. When answering the statement as 'True', no CBMs are of influence because the statement already indicates circularity. If the answer is 'False', there is room for improvement and the pre-selected CBMs are useful for that specific statement.

By formulating the statement for the RA-Tool as a Circular Statement it immediately shows if there is improvement possible, because when a respondent answers 'False' that specific subject can be improved. The range of 'False' is wider as agreeing with the statement, as 'False' may implicate a different understanding by the respondent such as 'Slightly False', 'False' and 'Strongly False'.

Due to these reasons it is decided why there is only one statement selected in the design of the RA-Tool and why the formulation of the statement is focused on the Circular Economy.

4.1.2 Matrix for Design RA-Tool

The matrix for the RA-Tool indicates the minimum and maximum score per statement for each CBM. As discussed in Chapter 3, the statements are linked to CBMs. When the answer to a statement is

‘False’, the selected CBMs receive a point.

In the different supply chain positions, some CBMs receive points for the same statements. These CBMs are merged to reduce the number of columns. As the descriptions of the CBMs are almost similar, this will not cause a distorted image in the ranking. The merged CBMs are shown in Table 15.

TABLE 15 SUPPLY CHAIN POSITIONS AND MERGED CIRCULAR BUSINESS MODELS

Supply Chain Position	Circular Business Models merged
Component Manufacturer	Good Housekeeping, Lean Thinking, Fit thinking
	Recycling, Recycling 2.0
LIB Manufacturer	Good Housekeeping, Lean Thinking, Fit thinking
	Remanufacture, Product Transformation
	Recycling, Recycling 2.0
Service Provider or Retailer	None

In this section the matrix of the LIB Manufacturer is shown, as this position is used in simulation of the two analysis methods. The matrix consists of the statements on one axe, and the CBMs on the other axe. The dimension of the matrix is depending on the number of statements by the number of CBMs. The following matrix (1) identifies 35 statements and 14 CBMs, which reflects to the position of LIB Manufacturer:

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{135} \\ a_{21} & a_{22} & \cdots & a_{235} \\ \vdots & \vdots & \ddots & \vdots \\ a_{141} & a_{142} & \cdots & a_{1435} \end{bmatrix} = A \quad (1)$$

The matrix (1) is a small example of how the entire matrix looks like. Appendix XIII shows the entire matrix for the design of LIB Manufacturers. The horizontal axis of the matrix represents the different CBMs, whereas the vertical axis represents the statements that need to be answered. The matrix indicates which CBMs receive a point when a statement is answered ‘False’, because as discussed, when the answer is ‘True’ no CBM receives a point. In the matrix this difference is marked by stating (0) or (0,1). Only the elements in the matrix that show (0,1) will receive a point when the answer is ‘False’. By connecting the statements with the matrix, the framework of the RA-Tool is completed to test the two analysis methods.

4.2 Select Analysis Method

This section discusses the two analysis methods for ranking the CBMs, the AHP method and the Normalized method. At first, each analysis method is discussed separately and a simulation generated random results. The two analysis method simulations are compared to select the most suitable method. This section refers to step 6 in Appendix I, which is Select One Analysis Method.

4.2.1 Analytic Hierarchy Process Method

The AHP is the first selected analysis method. This method uses comparing criteria to rank the CBMs. Each criterion is pairwise compared. AHP uses a scale, that detects the importance of each of the criterions. By comparing the criterion, a ranking is developed. The ranking indicates which criterion is the most important in terms of a cumulative percentage. Or in other words, each criterion receives a weight. The AHP method requires various categories, therefore all statements are divided into different categories. These categories consist out of various Circular Loops, additional product improvement and process improvement to assign remaining statements. The importancy categories are:

1. Product Improvement
2. Process Improvement
3. Maintenance & Repair
4. Reuse & Redistribute
5. Refurbish & Remanufacture
6. Recycling
7. Energy Recovery

The importance of each category determines the weights. The numbering indicates the level of importance, where the most efficient method of the CE is ranked first, and the least efficient on the last place. The most energy-consuming and less efficient loops are marked as less important, which are the lower ranked categories. This assumption does not account for all products related to the concept of CE, but for the LIBs this is the case.

All the statements need to be categorized in one of the seven importancy categories. However, if a Statement relates to multiple CBMs, it may occur that the CBMs relate to various importancy categories. By selecting the highest importancy category for each statement, it is possible to assign one importancy criterion for each statement. For example, when a statement relates to a CBM that focuses on Maintenance & Repair and another focuses on Recycling, the chosen importancy category is the lowest category, 3 Maintenance & Repair.

After the category is chosen, the AHP weights are calculated. Appendix XIV shows the AHP calculations of each CBM. The matrix in
Table 16 shows the relationship between the different importancy categories. Category 1 is the most important category, while category 7 is the least important. The categories refer to the importancy categories above. The Normalized Principal Eigenvector is calculated and is regarded as the normalized value, or weight per importancy category.

TABLE 16 AHP MATRIX ALL CATEGORIES

Matrix	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6	Category 7	Normalized principal Eigen-vector
Category 1	0	2	3	4	5	6	7	35,43%
Category 2	1/2	0	2	3	4	5	6	23,99%
Category 3	1/3	1/2	0	2	3	4	5	15,87%
Category 4	1/4	1/3	1/2	0	2	3	4	10,36%
Category 5	1/5	1/4	1/3	1/2	0	2	3	6,76%
Category 6	1/6	1/5	1/4	1/3	1/2	0	2	4,48%
Category 7	1/7	1/6	1/5	1/4	1/3	1/2	0	3,12%

The importance of the seven categories is shown in ascending order. Importancy categories are excluded when it does not appear in the statements of the CBM, as shown in Appendix XIII. Nevertheless, the order of importance remains the same. The Normalized Eigenvector Value (N) of the AHP method is divided by the number of statements in a importancy category for one specific CBM (Q). The formula (2) is:

(2)
$$N_i \Big/ \sum_{n=1}^{N} Q_i = R_i$$

The result is a weight for each element in the matrix of Appendix XV. The new matrix shows the maximum score possible. When a company completes the statements, the final scores are calculated by using the scores from the matrix of Appendix XV. When the answer to a statement is 'True', there is a 0 in the entire column of a statement. When the answer is 'False' the entire column receives the highest score possible, as shown in Appendix XV. When completing the list of statements, the rows are summed up (3). Based on these relative scores, a ranking is created of all CBMs.

(3)
$$\begin{pmatrix} a_{11} + a_{12} + \cdots + a_{135} \\ a_{21} + a_{22} + \cdots + a_{235} \\ \vdots \; + \cdots + \cdots + \; \vdots \\ a_{141} + \cdots + \cdots \; + a_{1435} \end{pmatrix} = Ranking$$

By conducting a simulation of 10.000 times of the list of statement answers, it is feasible to test the AHP method on striking differences between various CBMs. The simulation makes use of the previously explained matrix in combination with randomly generated answers 'True' or 'False'. In Appendix XVI, the extensive analysis of the simulation is shown. Figure 9 illustrates the cumulative percentages of each ranking number of the CBMs.

What is striking in the graph is the great differences between various CBMs. Upcycling (M) and New Technology (N) stand out, as these two CBMs show opposite results. Not only at the top- and lower-rank is the difference considerable, but also for the ranks in-between.

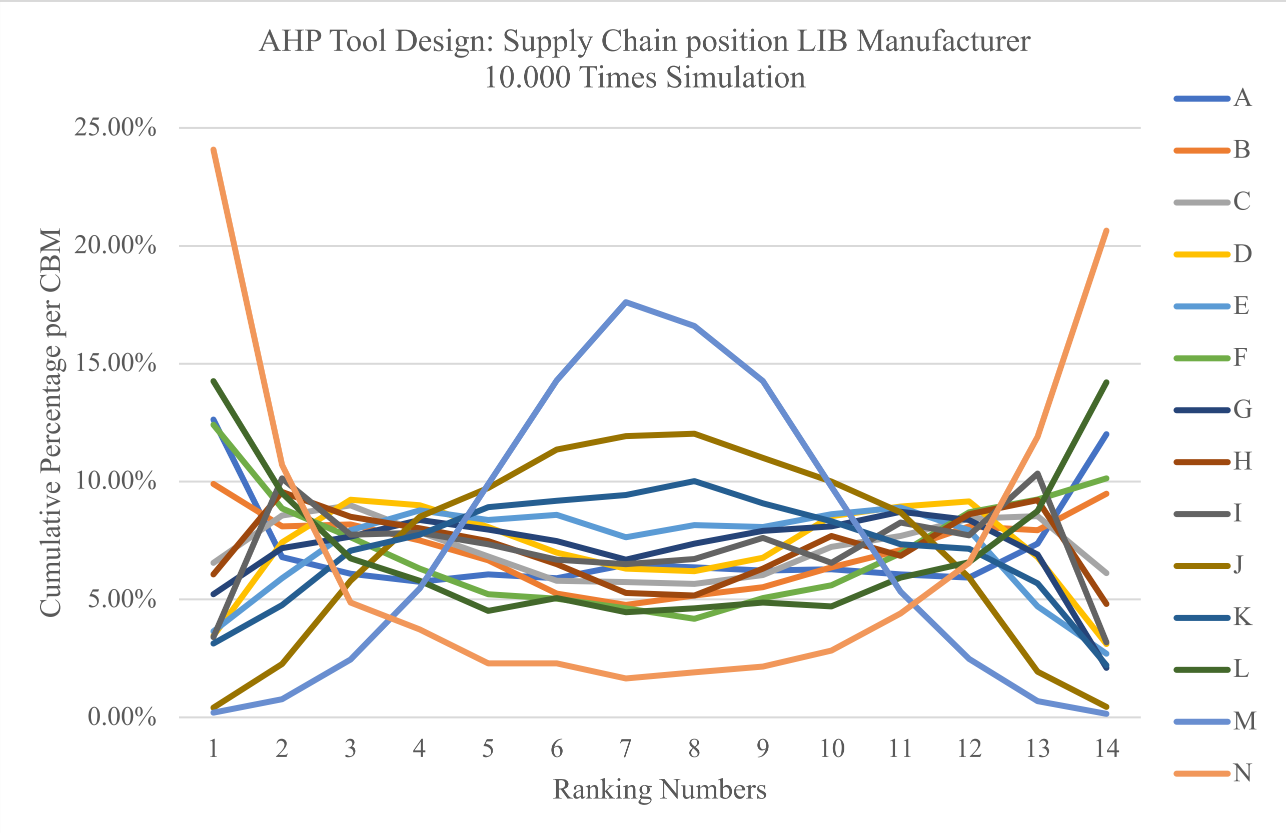

FIGURE 9 AHP; CUMULATIVE PERCENTAGE OF EACH CBM, SUPPLY CHAIN POSITION: LIB MANUFACTURER (A=ENERGY RECOVERY; B=NEXT LIFE SALES; C=UPGRADING; D=HYBRID MODEL; E=PRODUCE ON DEMAND; F=WASTE REDUCTION; G=GOOD HOUSEKEEPING, LEAN THINKING, FIT THINKING; H=PSS: ACTIVITY MANAGEMENT/OUTSOURCING; I=REMANUFACTURE, PRODUCT TRANSFORMATION; J= RECYCLING, RECYCLING 2.0; K= RESOURCE RECOVERY; L=CIRCULAR SUPPLIES; M=UPCYCLING; N=NEW TECHNOLOGY)

4.2.2 Normalized Method

The Normalized method is an analysis method, which makes it possible to compare results with different scales by adjusting the results to a notionally common scale. This is the case for the RA-Tool. Each CBM relates to a different number of statements.

The Normalized method calculates an evenly valued answer for each statement of a CBM. The formula (4) used for normalizing the answers is as follows:

(4) $$a_{max} / \sum_{n=1}^{N} S_i = x_i$$

The a_{max} score is the maximum achievable score for one element in the original matrix. This score is 0 or 1. S_i is the sum of the number of statements. This results in a normalized score, $\mathbf{x}_i$, for each row (5). To calculate the results of the completed statements, the original matrix (1) is multiplied with vector **x** (5). This results in formula A**x** (6).

(5)
$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{14} \end{bmatrix} = \mathbf{x}$$

(6)
$$A\boldsymbol{x}$$

The result of calculating the normalized numbers is vector **x** and the sum of all rows in the matrix is 1. In other words, per CBM the maximum score is 1.

To test the normalized numbers, a random answer generator is used to generate automatic answers for each statement in the RA-Tool. Similar to the AHP method, the answers to the list of statement are randomly generated 10.000 times. After the simulation the relative numbers, the sum of the total statement s per CBM, are transferred into a ranking. Figure 10 shows the cumulative percentage of each CBM per ranking position. In Appendix XVII extensive results of the Normalized method analysis are shown.

The graph shows that most CBMs have an average percentage between ranking numbers three to thirteen. However, the top-rankings are led by four CBMs, namely Energy Recovery (A), PSS: Activity Management/Outsourcing (H), Circular Supplies (L) and New Technology (N). CBMs that have a high top-ranking percentage also have a high low-ranking percentage. While on the other hand, CBMs that tend to have a lower top-ranking percentage have a lower percentage at the lower-ranking as well.

The most probable reason for these differences between the rankings is the number of statements per CBM. CBMs that have fewer statements in the total list, have more chance to end top-ranked or low-ranked. However, this simulation is not a reason to remove statements from the entire list. Because when a business completes the list of statements, their answers are not randomly generated.

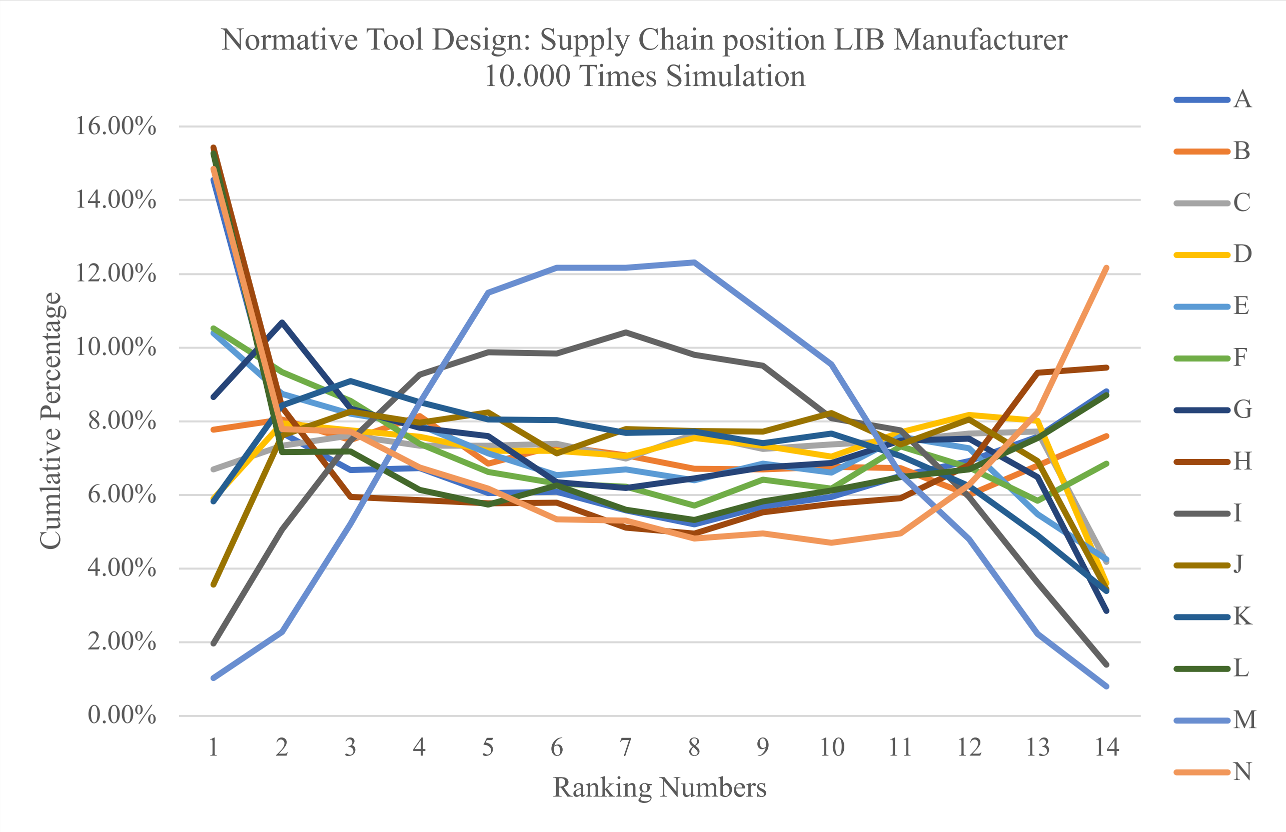

FIGURE 10 NORMALIZED; CUMULATIVE PERCENTAGE OF EACH CBM, SUPPLY CHAIN POSITION: LIB MANUFACTURER

(A=ENERGY RECOVERY; B=NEXT LIFE SALES; C=UPGRADING; D=HYBRID MODEL; E=PRODUCE ON DEMAND; F=WASTE REDUCTION; G=GOOD HOUSEKEEPING, LEAN THINKING, FIT THINKING; H=PSS: ACTIVITY MANAGEMENT/OUTSOURCING; I=REMANUFACTURE, PRODUCT TRANSFORMATION; J= RECYCLING, RECYCLING 2.0; K= RESOURCE RECOVERY; L=CIRCULAR SUPPLIES; M=UPCYCLING; N=NEW TECHNOLOGY)

4.2.3 Comparison Normalized & Analytic Hierarchy Process method

To determine which analysis method is most suitable for ranking the CBMs of the RA-Tool a comparison is required. One method to compare the AHP method and the Normalized method, is by comparing the Standard Deviation [SD] of the two simulations. The SD expresses how spread out a set of data is. The smaller the outcome of the SD, the less spread out the data is. In this case, the SD of both methods is calculated based on the cumulative percentage as shown in the previous graphs regarding the rankings. As the answers are randomly generated, the preferred SD is as low as possible. Because the more evenly the CBMs are distributed in the ranking, the more suitable the list of statements is for ranking CBMs. Table 17 shows the comparison of SDs of the AHP method and the Normalized method. The comparison of each rank is in favour of the Normalized method. In other words, the Normalized method is more constant, which indicates a tighter distribution of the analysed values.

There is another aspect of the AHP method that creates an imbalance in the importance of the statements. Each category is pairwise compared, resulting in various weights for each category.

Table 16 shows the matrix of the categories including the Normalized principal Eigen-vector, the weight of each category. However, the lowest ranked category has almost no importance at all, namely 3,12 percent, while the highest category has a weight of 35,43 percent. The difference between the highest and lowest category is significant.

For instance, in the RA-Tool matrix with the AHP method, a specific weight of a statement is 2 percent of the total number of statements for a specific CBM. While on the other hand, another statement for the same CBM has much more influence, namely 42 percent. This results in a highly skewed ratio between the various statements.

TABLE 17 SD COMPARISON OF NORMALIZED METHOD & AHP METHOD

Ranking Number	Normalized SD	AHP SD	In favour of
1	4,947%	6,537%	Normalized
2	1,970%	2,917%	Normalized
3	1,038%	1,806%	Normalized
4	0,951%	1,532%	Normalized
5	1,612%	2,077%	Normalized
6	1,794%	2,973%	Normalized
7	1,981%	3,865%	Normalized
8	2,061%	3,692%	Normalized
9	1,581%	2,920%	Normalized
10	1,217%	1,969%	Normalized
11	0,793%	1,420%	Normalized
12	0,918%	1,732%	Normalized
13	1,917%	3,083%	Normalized
14	3,388%	5,993%	Normalized
Average	1,110%	1,576%	Normalized

The conclusion to decide which method is most relevant for the RA-Tool is based on the SD comparison and the big differences between weights. The Normalized method shows the lowest deviation, which is most suitable for the RA-Tool. The AHP method show characteristics and results that are not in favour of the RA-Tool. The weights are too diverged, which results in a biased comparison and the SD is higher than the number that the Normalized method indicates. Therefore, the Normalized method is chosen for calculating the weights in the RA-Tool. This is the answer to sub-question 6, to determine which method is most suitable.

4.2.4 Normalized Method Simulation for Other Two Supply Chain Positions

The construction of the Normalized method within the RA-Tool for the other two supply chain positions is required. By conducting the simulation, it becomes clear which CBM shows deviant results. Therefore, the same steps as in 4.2.2 need to be taken to get the same statistics.

Figure 11 shows the simulation of the supply chain position Component Manufacturer. The graph shows the same trends as the previously discussed normalized supply chain position. Remarkable CBMs are Energy Recovery (A), PSS: Activity Management/Outsourcing (E), Resource Recovery (G) and New Technology (J). The extensive results of the analysis of the supply chain position is shown in Appendix XVIII.

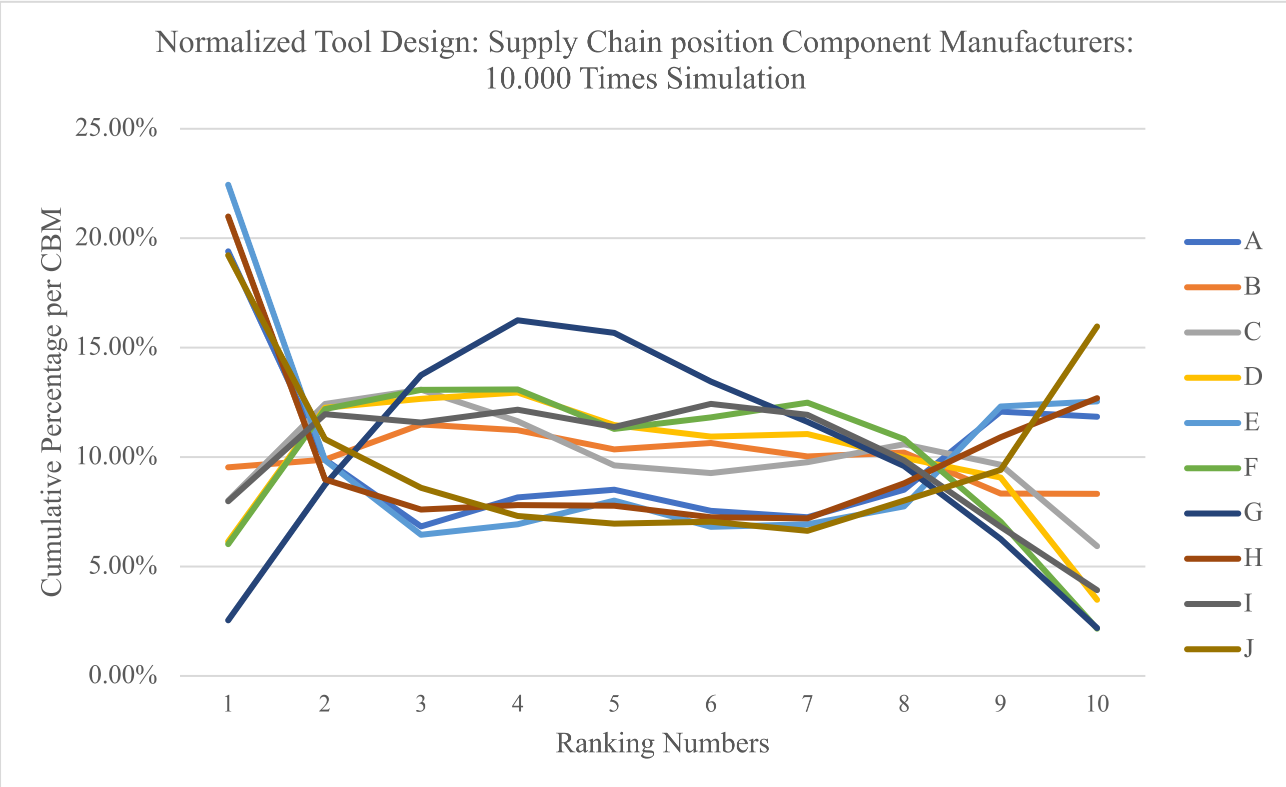

FIGURE 11 NORMALIZED; SUPPLY CHAIN POSITION COMPONENT MANUFACTURERS (A=ENERGY RECOVERY; B=PRODUCE ON DEMAND; C=WASTE REDUCTION; D=GOOD HOUSEKEEPING, LEAN THINKING, FIT THINKING; E=PSS: ACTIVITY MANAGEMENT/OUTSOURCING; F=RECYCLING, RECYCLING 2.0; G=RESOURCE RECOVERY; H=CIRCULAR SUPPLIES; I=UPCYCLING; J=NEW TECHNOLOGY)

The supply chain position Service Provider or Retailer consist of less suitable CBMs for their position. Some of the CBMs only vary in one or two statements. Figure 12 shows the results of the randomly generated simulation.

The CBMs PSS: Product Lease (C) and PSS: Performance-Based (E) both have only one statement that is different. Therefore, the results in the graph show similarities. The most notable CBM is the Next

Life Sales (F). This CBM has one of the highest percentage of a top-ranking, but also the highest percentage for a bottom-ranking. This is a striking result, because it does not have the most statements. Appendix XIX shows the full details of the results.

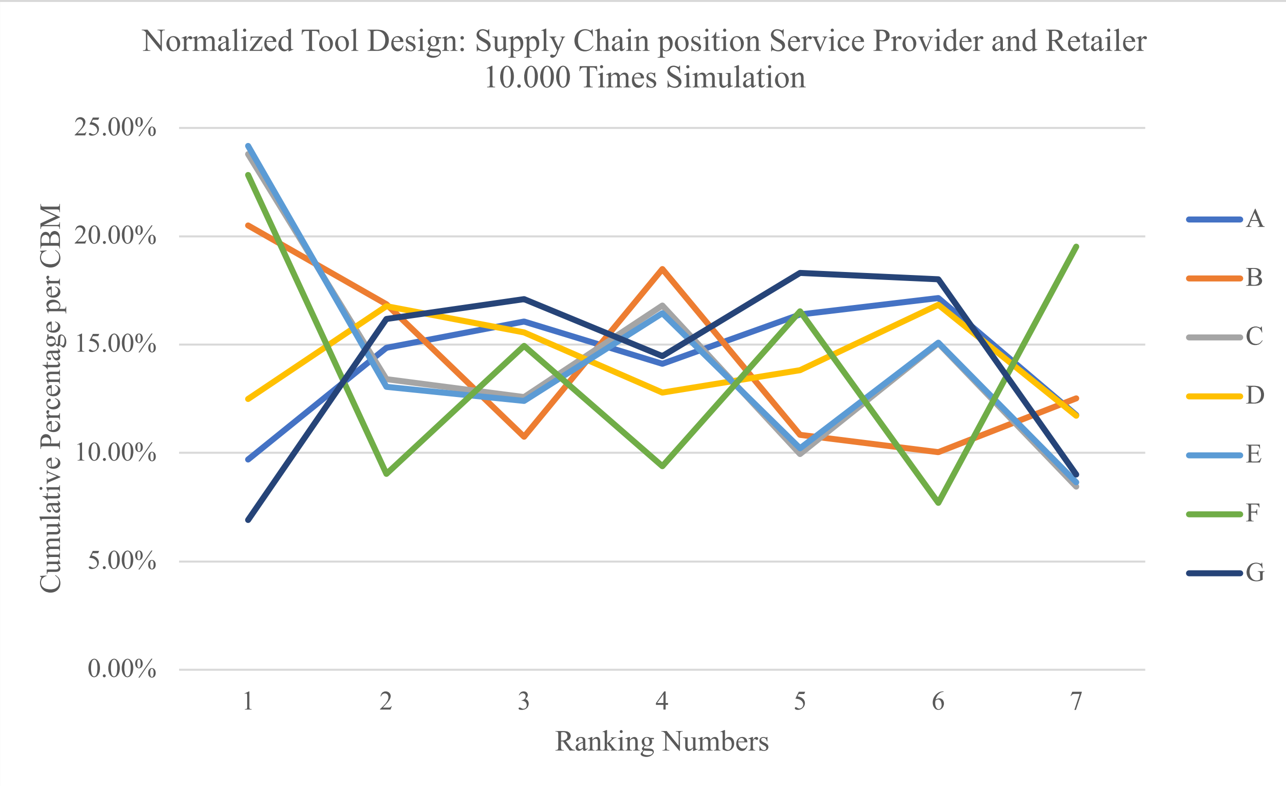

FIGURE 12 NORMALIZED; SUPPLY CHAIN POSITION SERVICE PROVIDER AND RETAILERS (A=MAINTENANCE & REPAIR; B=PSS: PRODUCT RENTING, SHARING OR POOLING; C=PSS: PRODUCT LEASE; D=AVAILABILITY BASED; E=PSS: PERFORMANCE BASED; F=NEXT LIFE SALES; G=UPGRADING)

4.3 Additional Option in Tool

At the moment, the answers to the statements are limited to 'True' and 'False'. The task is now to determine whether the 'Don't know' option should be used in the RA-Tool or not.

The use of the 'Don't know' is dependent on the nature of statements. Adding this option makes sense for factual statements. For example, when a statement requires factual knowledge and the respondent does not know the answer, the 'Don't know' option ensures the results are not biased. In other words, when a respondent is forced to answer 'True' or 'False', but does not know the answer, the data is biased.

Another argument to add 'Don't know' as an option would be when a respondent does not fully understand the statements (Feick, 1989). In such a case, the respondent would randomly guess an answer. This will create false data and will influence the final ranking of the CBMs.

On the other hand, the 'Don't know' option attributes to the easy way out for the respondent: not to answer the statement. This can be a result of the amount of work the respondent has to put in answering the statement (Krosnick, 1991). The respondent could then be looking for the easiest way out.

Another argument in opposition to the 'Don't know' option, is that it gets people encouraged to answer the statements. Naturally, the goal is to encourage people to answer the statements, rather than to discourage people from giving them the option 'Don't know'. Mondak & Davis (2001) concluded their research that people tend to know more than they think. This implicates that when someone is forced to answer the statement, they make an educated guess.

The arguments against the 'Don't know' option are more relevant for the RA-Tool. There is a firm belief that the people using the RA-Tool have sufficient knowledge regarding the topics of the statements. To substantiate this assumption, the RA-Tool is primarily meant for companies in the LIB Industry. Therefore, the people that use the RA-Tool have sufficient knowledge on the topics as they are professionals in their field of expertise. Even when the respondents are not sure, their educated guess is expected to be more valuable than no answer at all.

Besides this, the number of statements for each CBM is limited. Consequently, when a statement is answered with 'Don't know', this statement will be excluded. As shown in the AHP simulation and Normalized simulation, the fewer statement s for a CBM, the higher the chance for an extreme ranking. In other words, the higher the chance for a high- or low-ranking for specific CBMs.

4.4 RA-TOOL DESIGN

When all criteria have been met for developing the RA-Tool, the RA-Tool is ready for construction and usage. This is represented by step 7 of Appendix I: Develop RA-Tool for Different Supply Chain Positions, where all previous steps are merged into the new RA-Tool design.

An overview is given regarding the final design of the RA-Tool. Figure 13 illustrates the design of the RA-Tool including the implemented Normalized analysis method for weight calculations. The supply chain position of LIB manufacturers is used as example, while Appendix XX describes the figure in more detail.

The construction of the RA-Tool starts with the different lists of statements. Each of the three supply chain positions has its own list of statements. These lists are partially derived from Appendix VIII. Each position has its unique set of statements from the existing Bocken-Tool. The CBMs linked to each statement are used for the ranking, which is calculated by the sum of the total number of statements. Other useful statements are derived from sections 3.2 and 3.3, where new statements are formulated. Statements are only used for a specific supply chain position when the affected CBMs are mentioned in Table 11.

The first column of Figure 13 shows the selection of statements. The second column are the answers, which is completed by a respondent with 'True' or 'False'. The respondent will only see the first two columns when completing the list of statements. The Normalized analysis method determines the weight calculations for each column of the CBMs. The weight calculations are deriving from formula 4 in section 4.2.2. In Figure 13 the CBMs are listed alphabetically from A to N, in which some cells in these columns are marked green. The markings are green for a clearer view for the reader, as the green cells implicate a weight calculation for that specific CBM when answering the statement.

When all statements are completed by the respondent, a ranking is calculated and shown to the respondent like in Figure 14. The Relative Ranking is the sum of each CBM column, which is transferred to a ranking. The highest Relative Ranking, which is the third column of Figure 14, receives the highest Ranking, which is the second column of the figure.

Statement	Answer [True/False]	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Materials used															
No material is used in excess, product is totally dematerialised	True	0,00	0,00	0,00	0,00	0	0	0	0,00	0,00	0	0	0	0	0,00
100% Biodegradable	False	0,00	0,00	0,00	0,00	0,00	0,17	0,00	0,20	0,00	0,00	0,00	0,00	0,00	0,00
100% Recycled materials used	False	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,14	0,17	0,20	0,06	0,00
No scarce materials used in product (scarce materials, e.g. Antinomy, Cobalt, Gallium, Geranium, Indium, Platinum, Palladium, Niobium, Neodymium and Tantalum)	False	0,00	0,00	0,00	0,00	0,17	0,00	0,17	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Materials are highly eco-efficient (low energy and carbon emissions to produce)	True	0	0,00	0,00	0,00	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
No toxic materials in product	False	0,00	0,00	0,00	0,00	0,17	0,00	0,17	0,00	0,06	0,14	0,17	0,00	0,06	0,25
Zero waste factory; all waste is used as input to another process/factory	False	0,20	0,00	0,00	0,00	0,17	0,17	0,17	0,00	0,06	0,14	0,17	0,00	0,06	0,25
Product Specifications															
Product failures rarely occur	True	0,00	0	0	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0	0,00
Product has a very long lifetime	True	0,00	0	0	0	0,00	0,00	0,00	0,00	0,00	0	0	0	0	0,00
Difficult to get access to internal workings	True	0,00	0,00	0	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0	0,00
Complex workings, difficult to understand	True	0,00	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
No components, connectors, modules or leads are standardised	False	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Difficult to find fault	False	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Difficult to disassemble	True	0,00	0,00	0	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0	0,00
Significant damage caused to product or part when disassembling	True	0,00	0,00	0	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0	0,00
Impossible to identify parts once disassembled	False	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
No parts are modular, preventing switch in-switch out	False	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
Many mechanical connections, e.g. welds, screws, rivets, etc.	False	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
Many tools required to disassemble	True	0,00	0,00	0	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0	0,00
The ratio mass of used materials versus end-product is 1	False	0,00	0,00	0,00	0,00	0,00	0,17	0,00	0,20	0,00	0,00	0,00	0,00	0,00	0,00
Reusing															
No market for second hand sales	False	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
Comprehensive second hand sales already offered	False	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
Expensive refurbishment/ remanufacturing costs	False	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Expensive collection costs to return product to factory	False	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,14	0,17	0,00	0,00	0,00
All products are returned and refurbished/remanufactured	False	0,00	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Impossible to upgrade parts	False	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,06	0,00
Few material combinations used in the product	False	0,00	0,10	0,00	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
No encased materials(e.g. if materials are easy to separate at recycling)	False	0,00	0,10	0,00	0,08	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00
Procurement of recycled raw materials is more expensive than mined materials	True	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0	0,00	0	0,00	0,00
Energy Usage															
Spent materials are harmful to the environment when transferring to energy (e.g. for producing heat, fuel or electricity)	False	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Make use of renewable energy for production process	False	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,00
Spent materials to landfill is cheaper than using for energy recovery	True	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Production Process															
No new technologies (materials or production process) are available to improve efficiency, reduce environmental effects or save costs	False	0,00	0,00	0,00	0,00	0,00	0,17	0,17	0,00	0,00	0,00	0,00	0,00	0,00	0,25
Make use of local suppliers for raw materials or product components	True	0,00	0,00	0,00	0,00	0	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00
The production process has the most optimized processes in comparison to other specialized companies in terms of efficiency and costs	False	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,00	0,00	0,00	0,00	0,25
	Relative Ranking	0,60	0,70	0,46	0,54	0,50	0,67	0,67	0,80	0,72	0,57	0,67	0,40	0,56	1,00
	Ranking	5	10	13	13	6	6	6	5	18	7	6	5	16	4

FIGURE 13 DESIGN RA-TOOL

Circular Business Model	Ranking	Relative Ranking
Energy recovery	8	0,60
Next Life Sales	4	0,70
Upgrading	13	0,46
Hybrid model	11	0,54
Produce on Demand	12	0,50
Waste Reduction	5	0,67
Good Housekeeping, Lean Thinking, Fit thinking	5	0,67
PSS: Activity management/Outsourcing	2	0,80
Remanufacture, product transformation	3	0,72
Recycling, Recycling 2.0	9	0,57
Resource Recovery	5	0,67
Circular Supplies	14	0,40
Upcycling	10	0,56
New Technology	1	1,00

FIGURE 14 EXAMPLE OF RANKING CIRCULAR BUSINESS MODELS

In order to clarify the meaning of all cells in a row in the RA-Tool design, Figure 15 explains the important aspects of each row and the differences between the white and green cells. These green cells are only shown to create a difference between cells that require calculation and cells that do not. Each supply chain position has a different list of statements. However, the calculation method for ranking the CBMs remains the same.

When the answer is 'False' the green cells receive the pre-calculated points for the ranking of CBMs

The letters A to O are the CBMs, whereas the total sum of numbers in each column is used to calculate the ranking

Statement	Answer [True/False]	A	B	C	D	E	F	G	H	I	J	K	L	M	N
No material is used in excess, product is totally dematerialised	False	0,00	0,00	0,00	0,00	0,17	0,17	0,17	0,00	0,00	0,14	0,17	0,20	0,06	0,00
Materials are highly eco-efficient (low energy and carbon emissions to produce)	True	0	0,00	0,00	0,00	0	0,00	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

The respondent answers each CRA-statement with 'True' or 'False'

When the answer is 'True', the green cells do not get any points that influence the ranking of CBMs

The white cells do not play a role for the statement and do not influence the ranking of CBMS

FIGURE 15 EXAMPLE OF STATEMENTS IN RA-TOOL

5. Interviews & Analysis

This chapter is about interviewing companies from the Lithium-Ion Battery [LIB] Industry to validate the RA-Tool, which clarifies step 8 in the research steps of Appendix I. Before this step the RA-Tool is developed and after this step it is possible to draw conclusions from the research.
The first section starts with an overview of the approach to conduct interviews and determine the objectives of the interviews. Following this, the selection criteria that determine the type of companies suitable for the interviews will be discussed. Once the selection of interviewees is completed, the preparation of the interviews can start. To optimise the interviews and the desired results, important questions and expectations of the interviews are determined. After conducting the interviewees, an analysis method is selected to rank the results from the interviews and ultimately draw a conclusion. The analysis method uses open, axial and selective coding. The coding phases help to interpret the data of the interviews. Finally, the outcomes of the interpretations are discussed.

5.1 Objective of Interview

The interviews will help to validate the RA-Tool. Prior to the start of the interviews, professionals within LIB companies will answer the statements. After that, an interview will be held to acquire information. The information focuses on the opinions of the interviewees regarding the following topics with regards to the RA-Tool;

- Outcomes
- Expectations
- Usefulness
- Missing topic
- Usability

The interview will be a semi-structured interview, which allows new insights being brought up, but the focus remains on the initial subject. By preparing questions regarding the RA-Tool, it will be possible to compare findings and reactions of the interviewees (Edwards & Holland, 2013). This information from the interviewees is critical to validate the RA-Tool. The advantage with a semi-structured interview is that there is flexibility in answering the statements. This is a valuable characteristic for the purpose of validating the RA-Tool. Moreover, it is easier to express opinions and explain expectations when conducting such a semi-structured interview.
The semi-structured interview is used in researches that are in the early stages of an exploratory research (Bernard, 2012). The collected data is descriptive, because there is no quantitative data available regarding the result of the RA-Tool. Semi-structured interviews stimulate the pace of the innovation process by gaining more valuable insights.

During the interview, predetermined topics must be discussed to determine differences and similarities between interviewees their opinions. A requirement is that the results of the different interviews are comparable (Verschuren et al., 2010).

5.2 Criteria for Selecting Interviewees

Criteria to select suitable companies for this research help to approach specific companies. Not only the type of companies is important, but also the professional within the company that will be interviewed. The differences in opinion amongst the professionals will help to validate the RA-Tool. The opinions of various companies help to indicate whether the RA-Tool is useful or not and for what kind of companies within the LIB Industry the tool is useful.

Therefore, the following selection criteria were created to diversify the companies for conducting interviews:

- Companies with different positions in supply chain
- Number of interviews: At least two companies per supply chain position
- Communication method: Interview can be via telecommunication or face-to-face
- Individual professional within a company
- Location of the company: Worldwide
- Size of the companies: Variation of small-, medium- and large-sized companies
- Professional within company has knowledge regarding product manufacturing and product specifications

These selection criteria determine the companies to approach for this research. Deviations are possible when there are difficulties when selecting suitable companies that do not match selection criteria.

Moreover, some company selection problems may arise due to the low number of companies in the LIB Industry, more specific there is a low number of LIB companies in Europe.

5.3 Selection of Interviewees

The goal of this section is to select companies in the LIB Industry to validate the RA-Tool by interviewing professionals within these companies. Most companies in the LIB Industry are positioned in Asia, a few in the United States and a few in Europe. As the statements require someone close to the production process and with the knowledge regarding product specifications, it is necessary to interview professionals within the LIB Industry.

Most of the companies are contacted via e-mail, contact forms and LinkedIn. The expectation is that LinkedIn has the highest chance of success. Because on this platform, it is possible to contact professionals within a company directly. One condition to have success in finding suitable interviewees on LinkedIn, is to search for professionals that have a high-level position within a company. Another condition is that the approached professional should have an academic background. Appendix XXI shows the approached companies, including the way of approaching, who is approached and his or her response.

The goal is to find two companies to interview per supply chain position, which makes in total six companies. However, the result is a total of five interviewees. For the supply chain positions LIB Manufacturer and Service Provider or Retailer, there are two interviewees per position. For the Component Manufacturer position, it was rather difficult to find suitable companies. One of the reasons is that most of the Component Manufacturers are located in Asia. These companies and professionals did not respond to requests or any questions.

Due to confidentiality reasons, all companies are mentioned anonymous. Company A represents the only company of supply chain position Component Manufacturer. Companies B and C are the LIB Manufacturers, while companies D and E are the Service Providers or Retailers.
To give an indication of the type of companies, Table 18 summarizes some company differences, which are the selection criteria of 5.2. This summary may help to detect and clarify differences in the results. A more extensive introduction of the selected companies and interviewees is described in Appendix XXII.
The distinction between the sizes of the companies are as follows: at a small company work less than 50 people, a medium-sized company work between 50 and 250 people and the large companies have more than 250 employees.

TABLE 18 COMPANY STATISTICS

	Size of company	Position in Market
Component Manufacturer		
Company A	Small	Innovator
LIB Manufacturer		
Company B	Medium	Top LIB producer Europe
Company C	Medium	Top LIB producer Europe
Service Provider or Retailer		
Company D	Large	Car Manufacturer
Company E	Small	Energy Storage System Provider

5.4 Interview Preparation

In order to determine what to obtain from the interviews for the research, the interviews require preparation. The reason for the interviews to be held, is because the RA-Tool requires feedback to decide whether the RA-Tool is useful and valuable for companies or not.

The questions throughout the interview focus on the following topics:

- Whether the outcomes meet the interviewees expectations
- If the interviewees agree with the outcomes
- If the interviewees value the RA-Tool as useful
- If any topics are missing or the RA-Tool requires clarifications
- If the interviewees would use the RA-Tool when it is available
- For whom the interviewees think the RA-Tool would be useful

Not only are the questions in the interviews important, but also the period while the interviewee completes the list of statements that are necessary to calculate the ranking. If an interviewee does not understand a statement, this is a credible sign of an unclear statement. The feedback from the interviewees while completing the statements can lead to possible design and formulation improvements.

To determine the credibility of the ranking, the comments from the interviewees during completion of the statements are valuable. With these comments, the interviewee provides detail of the current situation, or how they could improve the topic of the statement. These comments help to identify whether the ranking of Circular Business Models [CBMs] is credible in comparison to the comments of the interviewee.

Company A is a company that is currently developing their product and production process. Therefore, the statements answered are for the future production process and expected product specifications. The current testing phase of the company is in this case left out of scope.

For the Service Provider or Retailer supply chain position two approaches are chosen. The first company, Company D, is asked to complete the list of statements for the LIB in specific and not the end-product. The second company on the other hand, Company E, is asked to complete the statements for the entire product. This tactic is chosen, because at this moment it is unclear what the effects are when using one of these two possibilities. At the end of this chapter, after the coding analysis, one of the possibilities will be chosen.

5.5 Interview Analysis Method

This section describes how the quotes of the interviews are labelled and valued, which answer sub-question 7. The process of comparing the outcomes of the various interviews is a critical phase to validate the RA-Tool. Prior to comparing the outcomes, the first step is to transcribe the interviews at a high level of precision (Flick et al., 2004). For each interview, it is necessary to point out important aspects that have been said during the interview, especially the statements regarding the usability and experience of the RA-Tool.

To validate the RA-Tool, the five interviewees were asked to fill out the list of statements for their specific supply chain position. One of the five interviewees completed the list of statements in advance, the other four completed the list of statements during the interview. As discussed, the structure of the interview is a semi-structured interview, where it is important that the interviewees answer the same questions. However, the course of the conversation was not the same for all. This was due to several circumstances, such as:

- One of the five interviewees completed the statements upfront, which creates a different conversation from the start.
- One conversation was via Skype, one by phone and the other three face-to-face. This creates a different atmosphere and determines the grade of detailed answers.
- The interviewees have different educational & professional backgrounds and different knowledge on the relevant subjects. This provides a different view on the various statements.

After conducting all the interviews, the recorded interviews need to be transcribed. By transcribing the interviews, it becomes easier to select the relevant quotes. After the transcriptions are elaborated, the coding process starts. The coding process consists of three phases. The first phase is the open coding, in which each quote receives a code. This code describes the main theme of the specific fragment. This is done for all relevant quotes.

The second phase is the axial coding phase. In this phase all open codes are linked to each other by using an axial umbrella code. In the process of axial coding, multiple axial umbrella codes will be formulated. These represent main categories to connect open codes with each other. Within these categories opinions may differ and can have different conclusions.

The final phase is selective coding. The task in this phase is to interpret the quotes and discover striking contrasts and similarities between quotes in an axial code. The interpretation of the quotes is done by comparing the quotes in a specific axial code.

5.6 Results of Interviews

The analysis of the interviews will create an overview of the results of the coding phases. The result of the analysis is the answer to sub-question 8. The goal is to identify valuable results, which can be derived from the combination of all interviews. By combining all valuable quotes of the interviews, it becomes possible to detect a general judgement or discrepancies.

The full list of transcribed interviews plus the results of the statements and ranking per company can be found starting from Appendix XXIII up to Appendix XXXII. This information serves as back-up information for the coding analysis. According to the coding phases, all quotes are listed. All quotes in the

list are categorized by performing the open coding phase and the axial coding phase. Due to the extensive number of quotes, these two phases can be found in Appendix XXXIII.
The axial coding creates multiple umbrella codes or in other words main categories. Within the categories the quotes can be positive and negative, as long as the main category of the quotes corresponds. The following axial umbrella codes are from the selection of quotes:

- Use of RA-Tool
- Matches with ranking
- Representative ranking
- Target group of RA-Tool
- Delete Circular Business Models
- Explanation of Circular Business Models
- Unclear statement
- Understanding ranking
- Use examples

The next step is the selective coding, where per axial code an interpretation analysis is given. Based on the combination of all quotes within an axial code, an interpretation is given for that specific axial code. In the following sections the quote numbers from Appendix XXXIII are mentioned as referrals. These quotes form the basis of the interpretation of the axial codes.

5.6.1 Usability Coding Analysis

The usability coding analysis are the most critical quotes of the research. These quotes relate to the usability of the RA-Tool, the match with the ranking of the RA-Tool, representativeness of the ranking and the suitable target group for using the RA-Tool.

Use of RA-Tool (Quotes Appendix XXXIII: 11, 29, 48, 67 and 82)
The answer to the question if the interviewees would use the RA-Tool is not specifically answered in all interviews. Company B states that the company might use the RA-Tool within their organisation. Whereas Company C states that the RA-Tool helps to understand the possibilities and the outcomes make sense. Company D explains that their organisation is too big to implement CBMs based on a tool. The interviewee of company E mentions that the RA-Tool is easy to use, but the interviewee does not answer specifically if the company would use it.

Despite the unclear answer on the question if the interviewees would use the tool, all interviewees agree that the RA-Tool is useful as such. However, they state that they do not have influence on the implementation of CBMs, for example because of the size of the company, like with Company D. All companies agree that the RA-Tool is helpful to establish priorities within the company and that it is useful for companies that are exploring new CBMs.

Matches with Ranking (Quotes Appendix XXXIII: 3, 5, 17, 18, 19, 22, 23, 24, 25, 26, 33, 34, 37, 38, 40, 57, 58, 59, 60, 62, 75, 76, 77, 78, 78)
The rankings of various companies show different outcomes and not all CBM positions in the ranking make sense. To determine if the CBMs in the ranking make sense, a comparison is made between the ranking and the quotes during the interviews. This section primarily focuses on specific CBMs that are not correctly displayed in the ranking. Appendix XXXIII gives an overview of the combination of the ranking of a specific CBM and quotes during the interview. A brief explanation helps to indicate if their explanation matches the ranking of the CBM.

When analysing all rankings in combination with the interviews, three positions of CBMs in the ranking do not correspond with the interviewees' story.
The first contradiction is during the interview with company A. The answered statements of company A focus on their future production process, because they are still developing the product. The company explains that Waste Reduction is a key aspect for their future production process while the CBM Waste Reduction is ranked ninth.
The expectation based on the company its quotes is that the Waste Reduction is top-ranked. This contradiction can be explained. The Company A explains they currently have a lot of waste during their current production process. However, the answered statements focus on the future production process of the company. Therefore, the current waste production does not represent the future, more optimal production process.
The second contradiction is in the interview with Company C, who explains that they already outsourced the necessary processes. And yet, Outsourcing CBM is ranked number 1. There is no clear explanation for this contradiction. This result could imply a fault in the ranking of Outsourcing, a misunderstanding of the statements, or an incorrect number of statements for each CBM. As shown in the simulation in Appendix XVII, the CBMs with a low number of statements have a higher chance to be top-ranked.

The last contradiction is in the ranking of Company D, where Maintenance & Repair is ranked first. However, the company already focuses on this CBM, since car manufacturers offer car reparation services for their cars. A possible explanation can be that the answers to the statements were focused on the LIBs and not on the entire product. If the interviewee answered the statements based on the end-product, the results would have been different. This interpretation is based on the comments made during the interview.

Two other ranked CBMs are unsure to be contradictions. These are described in the Appendix XXXIV. Based on the analysis of all interviews it shows that there are five CBMs that are not ranked as discussed or confirmed during the interview. These five rankings do not correspond with the discussions during the interviews. There were 52 CBMs ranked based on five rankings, of which five CBMs show inconsistencies. That means that 5 out of the 52 ranked CBMs are inconsistent, or in other words 90,38 percent is correct.

Representative Ranking (Quotes Appendix XXXIII: 6, 7, 30, 51, 61, 69, 74)
If the ranking of the RA-Tool is representative for companies, the RA-Tool adds value for the LIB Industry. The interviewees have different expectations of the RA-Tool and the ranking hereof.
Company A states that the RA-Tool can be followed as good advice, but in their opinion, it is more beneficial to elaborate on the results of the RA-Tool. The interviewee will therefore not use the RA-Tool when it is an online tool, because he prefers an extensive explanation of CBMs and the ranking. The company prefers a more personal approach, where an expert provides extensive information regarding the CBMs. When the topic of Waste Reduction was brought up during the interview, the interviewee reacts enlightened that their company should focus more on that. Their current process creates too much waste. The RA-Tool helps the company to recognize problems and advice the most suitable CBMs by ranking them.
Company B believes that in the LIB Industry major improvements are possible in each aspect of the industry. Because the industry is relatively young and rapidly developing, this results in more efficient and effective products. Nevertheless, the LIB companies lack attention towards CBMs, which is why it is not possible to state whether the ranking is representative or not.
Company C agrees with the ranking, but they state that these topics are known within the company without using the RA-Tool. Their remark does not imply that the RA-Tool is entirely useless, because Company C is currently busy with improving processes. The results of the RA-Tool match with Company C its vision of improving current processes.
Company D also agrees that the ranking of the RA-Tool is representative. The interviewee states that it shows the basics of the company, it helps as advice-tool and shows the possibilities a company can focus on.
Company E states that the ranking of the RA-Tool is representative and that it shows what opportunities there are for the company to focus on. The highest rankings show their current operations and opportunities they should and will focus on in the future.

To summarize, at least four companies agree with the ranking and Company B does not give a complete answer to the representativeness of the ranking. Based on the quotes of these companies it can be stated that the rankings are useful.

Target Group for the RA-Tool (Quotes Appendix XXXIII: 12, 13, 49, 52, 53, 68, 83, 85)

When the RA-Tool is available for use, it is necessary to determine how the RA-Tool will be used and in what type of situations. In order to do this, it is essential to determine the target group and for what purpose the RA-Tool is meant.

Company A and B explain that the RA-Tool is useful for a consultancy firm. Company A believes that a consultancy firm could use it for marketing or to propose and implement a new CBM when being located at a firm. In case the RA-Tool is used at a firm, it is possible to ask several employees to fill in the RA-Tool.

Company B states that if their company were to use the RA-Tool, they would hire a firm with more industry information and statistics. By using the RA-Tool, the company compares different CBMs and the industry average to see what CBMs require improvement to remain competitive in their industry.

Company D admits that their company is too big to use the RA-Tool. In case the company wants to use the RA-Tool, it has to be completed by someone with the authority to implement a new CBM. In the interviewee its opinion, the RA-Tool is more suitable for small companies that have more direct control and can react faster with the implementation of a new CBM.

Company E states that the RA-Tool is useful for managers to have a quick overview, while the RA-Tool is useful for different type of companies.

By connecting all these opinions, it can be interpreted that the target group is focused on small- and medium-sized enterprises. The people who can use the RA-Tool are professionals, who give advice to companies or have control within an organization, such as managers.

5.6.2 Design Aspects

Not only the opinions and expectations of the interviewees are crucial for the conclusions regarding the RA-Tool, but also the design aspects of the RA-Tool. If the RA-Tool is supposed to be used in the future, it is essential that it is useful and understandable at the same time. By dividing the design aspects into various topics, it becomes easier to determine what aspects of the RA-Tool need improvement.

Understanding of Ranking (Quotes Appendix XXXIII: 4, 10, 28, 43, 44, 45, 46, 47, 54, 66)

It is necessary that professionals within the LIB Industry understand the ranking of the CBMs. The objective is to achieve this without any personal explanations. After the interviewees complete the statements, they receive the ranking of the CBMs. The top-ranked CBMs indicate that these CBMs have the most potential in the company and that they should focus on these CBMs. During the interviews, the rankings were displayed as shown in Table 19. After these were shown to the interviewees, they were asked whether they understand the ranking of CBMs.

Company A suggests that the name of the 'Ranking' column should be changed into 'Priority'. He claims that such a change helps to clarify the meaning of the ranking in one word. The interviewee also suggests that the 'Relative Ranking' column should be named in a way that corresponds to the meaning of the numbers. Two suggestions were 'Linearity Index' or 'Circularity Index'. The preference for one of the suggestions depends on how the results are calculated. Company B agrees with Company A, that the ranking does not imply the meaning instantly.

TABLE 19 EXAMPLE OF RANKING DURING INTERVIEW

Circular Business Model	Ranking	Relative Ranking
Energy Recovery	1	0,800
Produce on Demand	6	0,667
Waste reduction	9	0,571
Good Housekeeping, Lean Thinking, Fit Thinking	4	0,714
PSS: Activity management/Outsourcing	1	0,800
Recycling	7	0,625
Resource Recovery	4	0,714
Circular Supplies	10	0,200
Upcycling	7	0,625
New Technology	3	0,750

Company C has difficulties understanding the ranking right away. The reason for this is the lack of explanation and the colours of the cells in the ranking implicate two different meanings. Red cells in the ranking may indicate that these CBMs require more attention and therefore focus on these is necessary, whereas the green cells may indicate that the company scores higher on these CBMs and are relevant to implement.
Company D states that the colours help to clarify the ranking. Although, this can be questioned because there was an introduction given during the interview about the ranking of the RA-Tool.

Moreover, the understanding of the ranking shows some difficulties. It is not entirely clear what is meant with the numbers of the ranking. Three out of the five interviewees had comments on the ranking regarding the colour, name and explanation. Besides, that most people do not have sufficient knowledge regarding all of the CBMs. This implicates that the ranking requires changes that will help the respondent to fill out the RA-Tool to understand the ranking straight away.

Use Examples (Quotes Appendix XXXIII: 14, 15, 16, 50, 84)

The interviewees all agree to use examples for the CBMs. The examples will indicate what opportunities there are within a CBM. Company A and Company E mention that the examples of CBMs need to be linked to the industry where the RA-Tool is used.

Company B wants to see examples that are the state-of-the-art for each CBM. Next to this, the company wants to see the average score of other companies in the LIB Industry. This score will allow the RA-Tool to be used as a benchmark-tool to compare the results with competitor companies the LIB Industry.

Unclear Statements (Quotes Appendix XXXIII: 1, 2, 27, 32, 35, 36, 41, 55, 56, 63, 70, 72, 73, 80, 86)

Four of the five interviewees completed the list of statements during the interview. This creates an opportunity to assess the statements and evaluate whether these are clear to understand or not. When an interviewee asks for additional explanation or when they are questioning themselves, it is a sign of an unclear statement. Appendix XXXV shows the statements and why these require explanation or revision. A statement requires extra information or revision when an interviewee does not understand the statement.

Delete CBM (Quotes Appendix XXXIII: 8, 20, 21, 31, 42, 64, 81)

Another design aspect is concerning the exclusion of CBMs when certain statements are answered. The answer of certain statements implicates that specific CBMs are unsuitable for a company and exclusion of these CBMs is possible.

Four out of five interviewees respond that all of the CBMs should be included. Company B states that he has insufficient knowledge to determine the exclusion of CBMs. Another notable result is that Company C mentions that the CBMs: Good housekeeping, Fit thinking and Lean thinking should be excluded from the entire ranking, as quoted below.

"But, ok Good housekeeping, Lean thinking, Fit thinking you could use that in a sailing regatta or wherever to get a better result. I don't appreciate this point because it's like words that don't make sense." Quote Company C regarding the use of CBMs in ranking

Four of the five interviewees agree not to exclude CBMs based on specific answers to statements, while Company B admits not to have sufficient knowledge regarding the CBMs and its connecting relations.

5.6.3 Alternative Explanations of Results

Not all comments within the interviews relate to the coding analysis, where other results require explanations and clarifications where possible. This section focuses mainly on the discrepancies between the quotes of the interviewees and the results of the rankings. But before this, the first part discusses comparison of the ranking results of the supply chain position LIB Manufacturers and the results of the Normalized RA-Tool simulation.

By comparing the results of Company B and C with the results of the Normalized RA-Tool simulation, it is possible to see whether there are comparable results. As discussed, within the simulation there were CBMs that have a much higher chance to be top-ranked and sometimes bottom-ranked. If the results of both companies have similar results as the general trend in the simulation, it could be possible that the results are predictive and not unique.

Table 20 shows the ranking of CBMs from Company B and C. The cells with red marked text show similarities with the results of the simulation with normalized ranking method, as shown in Appendix XVII. It indicates where the matching rankings score extraordinary high in the simulation compared to the companies their ranking.

All red marked CBMs have a low number of statements. This may indicate that the number of statements highly affects the ranking. It can therefore be an option to have an equal number of statements for each CBM. The ranking of company B in combination with the number of statements, does not imply that the number of statements is highly influential, because the CBMs that have a lot of statements are ranked high as well. However, the ranking of Company C in combination with the number of statements, shows that all CBMs with a low number of statements are ranked higher than the CBMs with more statements.

TABLE 20 RANKINGS OF COMPANY B AND C

	Ranking		
Circular Business Model	Company B	Company C	Number of Statements
Energy Recovery	8	9	5
Next Life Sales	4	10	10
Upgrading	13	14	13
Hybrid model	11	13	13
Produce on Demand	12	6	6
Waste Reduction	5	4	6
Good Housekeeping, Lean Thinking, Fit Thinking	5	6	6
PSS: Activity management/Outsourcing	**2**	**1**	5
Remanufacture, Product Transformation	3	12	18
Recycling, Recycling 2.0	9	5	8
Resource Recovery	5	6	6
Circular Supplies	**14**	**1**	6
Upcycling	10	10	17
New Technology	**1**	**1**	4

The following sections focus on the discrepancies between the interview quotes and the ranking of the RA-Tool. Company A and Company C are not mentioned in these sections, because their ranking and quotes match.

Discrepancy Company B

Company B explains that they do not always use the most optimized process. The decision to use a less optimized process is based on the environmental effects of this process. However, by answering statements that relate to New Technologies, 'False', the company is being advised to implement New Technology. Although the company did not adopt new technologies based on environmental aspects, which is one of the foundational aspects of the Circular Economy.

Discrepancy Company C

During the interview, two comments were made regarding the recycling of the products. At first, the interviewee explains that they do not recycle any of the LIB, while in the second comment he states that they do focus a lot on recycling. This creates confusion in understanding the results, as the CBM Recycling has a medium-high score, placed sixth. After analysing the interview, it is assumed that the second comment is about the by-products of the production process. Therefore, it seems possible that this company recycles waste.

Company D discrepancies

Maintenance & Repair is something that Company D already provides. For car manufacturers, this task is in-line with the lifecycle of a car. Therefore, it is rather difficult to explain that Maintenance & Repair is ranked number 2. The rationale behind the RA-Tool design is that when a CBM is well developed in a company it is ranked low, so that there is less room for improvement.

Another CBM that is ranked high of Company D is the PSS: Product Renting, Sharing or Pooling. However, it is difficult to share batteries from a car with others unless there is some sort of docking system and such an operation is too complicated. On the other hand, the relative score for this PSS is low for a top-ranked CBM, when comparing it to other companies their rankings.

5.7 OUTCOMES

The results on the usability of the RA-Tool indicate that at least four out of five companies agree with the ranking. The other interviewee Company B, states that there is major room for improvements in the LIB Industry by adopting multiple CBMs. By combining the result of the rankings with the quotes of the interviews, it can be concluded that the rankings show a correctness of 90,38 percent.

All interviewees indicate that they do not have influence in determining the implementation of specific CBMs within their company. Company D indicates that their company is too big to use a tool like the RA-Tool.

The target group for using the RA-Tool is a combination of small- and medium-sized enterprises, with a focus on managers or consultancy firms. The consultancy firms can compare rankings completed by various employees of a company and have more knowledge regarding the CBMs and concept of Circular Economy. The knowledge of a consultant regarding CBMs can attribute to explain the usefulness of the RA-Tool. The RA-Tool is especially interesting for companies who want to explore CBMs and test what is most effective for their current company performances and processes.

The two companies of the supply chain position Service Provider or Retailer completed the list of statements different. Company D completed the statements with a focus on the LIB in the product, while Company E completed the statements with a focus on the entire end-product, so not only the LIBs in the product. Moreover, the ranking of company D shows discrepancies regarding the top-ranked CBMs.

Maintenance & Repair is ranked second, while the company already focuses on this aspect. Additionally, the third ranked CBM, PSS: Sharing, Renting or Pooling, is impossible to implement when focusing on LIBs only. The ranking of company E shows no abnormalities and the top-ranked CBMs are suitable for implementation in the company. It can therefore be stated that the list of statements has to be completed for the entire product and not only for the LIBs in the product.

The design and layout of the RA-Tool require adjustments when it is concluded that the tool is interesting for companies to use. Based on the interviews and user experiences the required adjustments for the RA-Tool are:

- The ranking of CBMs requires a new name and should include an explanation
- The colours of the ranking require a brief explanation
- Examples of each CBM for a specific industry is useful for inspiration and to show opportunities for a company
- The text to describe the relative numbers where the ranking is based on needs revision, which helps to understand the numbers instantly
- The statements that are considered unclear need rewriting or explanation

The discrepancies indicate that some of the quotes are not trustworthy and that some of the rankings of CBMs are incorrect. However, these problems are very limited to the total number of ranked CBMs. The wrong CBM positions in the ranking, though limited, is one of the reasons that the RA-Tool gives an indication and is an exploring-tool for companies, instead of giving a binding opinion. The RA-Tool results in an advice, which can help companies that are unfamiliar with CBMs. Another benefit to use the RA-Tool, is that it can be used as a support-tool to confirm the companies' assumptions in favour of a specific CBM. This section provides an answer on sub-question 8, whether the RA-Tool is usable for companies in the LIB Industry or what kind of improvements are necessary within companies.

6. Conclusion & Recommendations

The road towards answering the Research Question has led to various conclusions. Drawing conclusions is the last step, step 9, from Appendix I.

The most widely accepted definition of Circular Economy is from the Ellen MacArthur Foundation. They state that the Circular Economy is *'restorative and regenerative by design and keep materials and products at their highest utility. It aims to redefine products and services to design waste out, while minimising negative impacts'* (EMF, June 2015, page 19). This corresponds with the researcher' expectations, as their definition covers multiple aspects and makes a distinction between various Circular Economy Loops. The Circular Business Models are divided by the actions: Regenerate, Share, Optimise, Loop, Virtualise and Exchange. This is a result of the referred definition of the Circular Economy. The indicators for the Circular Economy are derived from existing indicators for measuring sustainability.

The research uses three supply chain positions within the Lithium-Ion Battery Industry, by making three different lists of statements with matching Circular Business Models for each position. The three selected positions are: Component Manufacturers, Lithium-Ion Battery Manufacturers and Service Providers or Retailers.

Before this research was conducted, primarily three existing tools were available that focus on Business Models within the Circular Economy. The Circular Economy Assessment Tool, known as the Bocken-Tool, is determined to use as a starting point for the development of the RA-Tool, as the Bocken-Tool has useful aspects for the new RA-Tool design. These aspects focus on the statements from their questionnaire and the Circular Economy actions. These are transferred to Circular Business Model that are linked to the statements. The statements from the Bocken-Tool are adjusted before using in the RA-Tool. The number of statements that are linked to Circular Business Models is insufficient and therefore new statements are formulated based on Circular Economy indicators and characteristics of the Circular Business Models. Each supply chain position will have a suitable selection of statements and all statements are linked to the Circular Business Models.

To rank the Circular Business Models in the design of the RA-Tool it is necessary to select an analysis method that calculates the weights for each Circular Business Model. The analysis show that the Normalized method is most suitable analysis method to calculate the weights. The weight depends on the number of statements for a specific Circular Business Model.

By conducting interviews with five companies in the Lithium-Ion Battery Industry the RA-tool is validated. All interviews are analysed in three steps by using the Coding Analysis, which are: open-, axial- and selective-coding. The interviews indicate that the ranking results of the RA-Tool show representative results for the different companies in the Lithium-Ion Battery Industry.

The discussed subjects summarize the sub-questions. By connecting these answers, it is possible to draw a conclusion for the Research Question. A recap of the Research Question:

How to design a new Circular Business Model Assessment Tool to introduce the concept of Circular Economy to companies in the Lithium-Ion Battery Industry enabling them to explore the opportunities of Circular Business Models?

The RA-Tool proves that it is possible to design a new Assessment Tool to introduce the concept of Circular Economy to companies in the Lithium-Ion Battery Industry. The new design helps companies to explore the possibilities within the Circular Economy by indicating what kind of Circular Business Models fit in the operations of a company. After analysing the interviews, it can be stated that the RA-Tool serves as a catalyst, as it initiates discussions companies did not think of before. The new RA-Tool supports and advices companies by indicating future opportunities. Moreover, it is able to advice companies upfront before implementing a Circular Business Model, in which case the RA-Tool serves as a verification-tool. Throughout the conduction of interviews, it became clear that the ranking of Circular Business Models is representative for companies in the Lithium-Ion Battery Industry. In other words, it can be stated that the ranking of Circular Business Models shows representative results when comparing the results of these rankings to the interviewees' explanations of their current practices and future potentials.

An important aspect to draw a final conclusion, is whether the new RA-Tool is useful for companies in the Lithium-Ion Battery Industry. This is a more difficult aspect to answer. The opinions of the interviewees about the usefulness for their company are not unanimous, as one of them states that it is not useful. Other companies do not explicitly state whether they find it useful or not. However, it can be concluded from the interviews that the companies find the results interesting and are open to discuss the suitable Circular Business Models. The bottom-line is that it is unclear if the RA-Tool is useful for companies in the Lithium-Ion Battery Industry. This can be assigned to the interviewing questions, which is a result of the lack of experience of the interviewer, as the evaluation of the usefulness required more attention.

It can be concluded that the design and feedback on the RA-Tool require more attention. Not all predetermined expectations are achieved, as the target group remains unclear and the RA-Tool requires adjustments prior to implementing. It is more difficult than expected to design a fully understandable Assessment Tool for all companies in an industry. The result of analysing the interviews, is that the ranking of the RA-Tool can be stated as being representative. However, there are improvements necessary to define the RA-Tool if of use for giving advice and supporting companies in the Lithium-Ion Battery Industry. These improvements are mainly focused on the formulation and the design of the RA-Tool.

Generalization

After discussing the Research Question, the question arises whether the RA-Tool is usable in other industries. In order to generalize the RA-Tool, a few aspects of other industries have to match with that of the Lithium-Ion Battery Industry. This especially depends on the manufactured products, as this directly relates to the type of statements from the RA-Tool. The statements subjects focus on product usage, mechanical product specifications, energy usage and production process, so other industries need to be influenced by these aspects as well. The RA-Tool is expected to be suitable in industries where the core product is a mechanical product. Examples of suitable industries are: car manufacturers and electrical devices such as computers and smartphones.

However, the RA-Tool cannot be used in all type of industries. Industries that can be excluded from using the RA-Tool are industries that do not match with the subjects of the current list of statements. Examples of excluded industries are: clothing industry, and food and beverage industry. For these industries the statements of the RA-Tool are impossible to answer.

Reflection on Results

The result of this thesis is the new developed RA-Tool, which is displayed in an Excel-sheet. If I were to do this research again, I would present the tool in a more professional layout. This would especially support me during the interviews and the same applies to the presentation of the ranking. Another aspect that relates to the presentation of the RA-Tool, is that I would test the statements and understanding of the ranking more deliberately before using the tool when conducting interviews. I underestimated the importance of this aspect, so therefore I would incorporate this in the planning.

The current RA-Tool makes use of three different supply chain positions. For future tool designs, I would combine the two manufacturing positions: Component Manufacturers and Lithium-Ion Battery Manufacturers. This will provide a manufacturer a more comprehensive overview of the Circular Business Models.

Reflection on Process

Writing this thesis was an informative experience. It helped me to become better in conducting academic research. It has been a very time-consuming process, where I inevitably learned to be more patient and had to accept that mistakes occur for the greater good.

In hindsight, I would have made a few different decisions regarding the research process. Firstly, I would have two different persons within a company fill out the RA-Tool, rather than one. This will create a better overview of the company and allow the results to be compared, rather than using one completed RA-Tool per company. I believe that a total of one interview per company will remain to be sufficient. In my opinion the number of interviews was sufficient, however next time I would try to validate less than three different lists of statements. By doing so, it will become more substantial to

validate the tool. It would also lower the threshold to find interviewees of different supply chain positions. Moreover, in this research it was difficult to find Component Manufacturers, because in Europe there are hardly any companies that produce components. Arranging the other interviews was rather easy and were conducted in a rapid paste.
One last point regarding the reflection of the research process, is that next time I would start the thesis by discussing the concept of Circular Economy with an expert. This will save time, as finding the suitable definitions was very time-consuming. I would invite the expert for a second conversation when the design of the RA-Tool is completed. This enables you to discuss your findings and verify whether your assumptions are correct. If this is not the case, you will still be able to make adjustments where needed.

Recommendations & Limitations
It requires several steps before using the RA-Tool in the Lithium-Ion Battery Industry. The first step is to apply adjustments to the RA-Tool design. These adjustments focus on:

- Providing examples for each Circular Business Model
- Giving the columns ‘Ranking’ and ‘Relative Number’ of the ranking table more clarifying definitions
- Including explanations for the ranking results and Circular Business Models
- Revising or explaining more extensively unclear statements

Future research could be to test the RA-Tool in other industries. This requires modification of the RA-Tool first. Thereafter it is possible to validate the RA-Tool in other industries. To test the usability of the RA-Tool in another industry requires validation by conducting interviews. A suggestion to test the RA-Tool in another industry could be another manufacturing industries, such as smartphone manufacturers.

As some of the interviewees mentioned the use of the RA-Tool by consultancy firms, it would also be interesting to collaborate with a consultancy firm, especially one that focuses on the Circular Economy. In the future, it is possible that the RA-Tool contributes to simplify the exploration phase and to gather knowledge and experiences from employees of a company. Based on the acquired information, it would be possible for a consultancy firm to draw a general view of the company by having the statements filled out by employees.

It would also be interesting to test the RA-Tool with various target groups to find out what the right target group is. This would add value to the ranking results. In order to assemble this information, the RA-Tool requires additional testing at consultancy firms, a new industry and managers of departments of Lithium-Ion Battery companies.

Another recommendation is to elaborate on a roadmap to implement a Circular Business Model within a company. The RA-Tool gives an indication of what Circular Business Models are suitable for a company but does not advise on next steps. By developing these steps, a roadmap towards implementation of Circular Business Models is created.

During the research, there were some obstacles, which is why the optimal result is not achieved. The first obstacle is the lack of experience by the interviewer. This makes it more difficult to select the most effective questions upfront and to acquire the optimal results from the interviews. An example is the unsatisfying answer to the target group. The opinions lie apart from each other. One of the reasons can be the lack of experience of the interviewer.
A second limitation is one interview that is missing. This is due to the location of all the Lithium-Ion Battery Component Manufacturers. This additional interview might have been useful to value the results more precise.
Another limitation is a missing expert-opinion that can provide feedback on the design of the RA-Tool and the selection of Circular Business Models. In this research, the findings from the literature review determined the use of definitions and the methodology to design the RA-Tool. Various professionals of the Lithium-Ion Battery Industry reviewed the RA-Tool and the results, although no expert in the field of Circular Economy. This limitation creates an opportunity for further research, to validate the RA-Tool with experts within the academic community.

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