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# Circular economy for a rock and ore transportation equipment manufacturer

## A step towards changes in the business model?

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# Abstract

Moving towards circular economy is considered as a fundamental way to achieve sustainable development, but practices and tools that can support businesses in implementing this concept are still underdeveloped. Moreover, there is uncertainty about the impact that the adoption of circularity has on the current way of working of a company. With the adoption of aspects of action research on a rock and ore transportation equipment manufacturer, this thesis defines a methodology that could be used to support a firms in implementing circular economy and to delineate the changes needed to adopt it. For the case investigated, it was discovered that circularity is already present, consciously or unconsciously, in several aspects of the way of making business of the company and that opportunities of improvement can bring significant economic and environmental benefits. The implementation of these additional circular actions can be both easy and difficult, therefore minor and incremental changes are needed as well as radical and complex ones. In any case, modifications on the current business model are needed in order to move towards circularity. Despite the limitations of the adopted methodology, it may still be considered as a good starting point for the firm and for practitioners who want to support companies in adopting circular economy. It may also be valuable to academia that can gather some useful data about the real life implementation of this concept.


**Keywords:** circular economy, circular business model, business model innovation, mining industry

# Executive Summary

In a world where the economic system is founded on linear business models that, based on the take-make-dispose resource flow, are causing resource scarcity and environmental degradation, circular economy (CE) represents a way to overcome these issues. CE, in fact, is a concept that implies the creation of a regenerative system where the value of the resources used stays within it by extending, closing and narrowing resource loops. This is obtained via creating products that require less raw materials, harmful and scarce substances, and are designed for duration, life extension, recycling and to ease circular activities. This system is capable of preventing environmental degradation while improving the competitiveness and profitability of a company. For these reasons, circular economy has become a fundamental component to achieve sustainable development.

CE implementation depends not only on policy makers but also on firms and their ability to adopt this concept in their way of making business. However, it is unclear whether circularity is influencing the current business model of a company and, considering the sustainability benefits that CE can provide to a firm, it is important to assess the magnitude of the potential changes required to implement it. Moreover, there is a general lack of research, tools and methodologies to support a company in adopting circular economy.

This thesis therefore aims to shed a light over the real life implementation of circularity. Via the collaboration with a Sandvik's division, which is manufacturing rock and ore transportation equipment for the mining and construction industries, it was possible to assess the impact that circular economy may have on the way of working of a company and develop a methodology that can support a firm in adopting this concept.

In order to achieve these objectives, information was gathered about the current status of implementation of this concept in the division, the opportunities of improvement and their influence on the economic and environmental performances. Then, these additional circular actions have been analyzed to define their impact on the division's current business model. Finally, the applied methodology was critically analyzed in order to understand if it was able to support the company in adopting circular economy.

Therefore, this thesis adopts the rock and ore transportation equipment division as a case study to research on the implementation of CE and its impact on a company business model. Aspects of action research are also contained in the thesis because the author worked in close relationship with Sandvik's personnel in two workshops to define the current and future implementation of circularity.

It was discovered that the division is already implementing, consciously or unconsciously, several aspects of circular economy. It is characterized by a good level of energy and resource efficiency, an effort to minimize the used of toxic substances, a well-organized waste management system, several life extension practices (repair, maintenance and rebuilt), and it is sometimes providing their machines as a service and take them back. This is performed with the support of a good ICT system and partnership with external actors, e.g. suppliers and logistic companies.

In accordance with the current implementation of circular economy, some additional circular economy opportunities have been identified with the cooperation of the division's personnel. Design improvements for circularity, the use of more sustainable resource, a better cooperation with internal and external actors, the improvement of the rebuilt practices, the adoption of a

product service system (PSS) and the development of a better and more circular electric fleet are examples of activities that the division could potentially adopt. These actions could provide several benefits from an economic and environmental perspective and could support the division in meeting its sustainability ambitions.

These opportunities of additional implementation of CE were analyzed using the prioritization framework developed by the author. The 3 considered by the division to have the highest priority were improving the rebuilt practices, the interaction with suppliers and the product design. Cooperation with internal and external actors was identified as a fundamental enabler of circular economy and considered as an action that would allow a proper implementation of the 3 ones mentioned above.

The impact of these actions on the current business model was assessed using the circular economy implementation impact framework, once again developed by the author. Moreover, the influence of the greater adoption of circular economy was evaluated using PSS as an example.

It was discovered that implementing CE requires both soft and hard modifications. In certain cases, adopting circularity is more a matter of building up on existent capacities and knowledge rather than developing new ones, such as for the rebuilt and suppliers activities. However, other actions require substantial modifications and their implementation is challenging, for instance in the case of the design improvements for circularity and PSS. We can therefore deduce that the adoption of circular economy can be both easy and difficult. It is not always needed to drastically change the way of working but it is possible to further develop already present capacities to enable the implementation of circularity. However, the ease of implementation is context specific, according to the features of a company it could be easier to implement certain aspects of CE rather than others. In any case, the adoption of circular economy requires changes in the current way of making business.

In regards to the methodology, overall it can be considered successful in achieving its aim. It allowed creating an understanding of the context in which the division is operating and the current application of circular economy, to define the potentials of improvement and their economic and environmental impacts, and to delineate the one with the highest priority. The circular economy implementation impact framework also provided a visualization of the influence that the adoption of circularity has on the current business models and delineate the changes needed to adopt it. However, the methodology adopted presents some limitations and some of the parts of the research could have been conducted with a better and more structured approach. The author recognizes these facts and suggests ways of improvement.

Therefore, this thesis provides data that can fill the gaps related to the influence of circular economy on the way of making business of a company and the scarcity of methodologies to promote the implementation of this concept in a firm. The outcome of the thesis is may be useful not only for Sandvik and for other enterprises that want to adopt circularity, but also for academia. More research, however, needs to be performed to offer an appropriate support to companies in adopting circular economy.

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# Abbreviations

CE: Circular Economy

BM: Business Model

CBM: Circular Business Model

BMI: Business Model Innovation

CBMI: Circular Business Model Innovation

EOL: End-of-Life

EU: European Union

R&D: Research and Development

PSS: Product Service System

UNEP: United Nation Environment Program

IS: Industrial Symbiosis

TCO: Total Cost of Ownership

ICT: Information and Communication Technologies

LCA: Life Cycle Assessment

EV: Electric Vehicles

OEM: Original Equipment Manufacturers

RQ: Research Question

EHS: Environment, Health and Safety

PPT: PowerPoint

W1: First Workshop/Workshop 1

W2: Second Workshop/Workshop 2

IIIEE: International Institute for Industrial Environmental Economics

EMF: Ellen MacArthur Foundation

Int.: Interview

A/C: Air Conditioning

ISO: International Organization for Standardization

# 1 Introduction

The industrial revolution of the 17th century initiated the process on industrialization. In the following decades, the rapid development of the industry and technology brought increased wellness to our society and an unprecedented level of development and growth (Evans & Bocken, 2013; Prieto-Sandoval, Jaca, & Ormazabal, 2018).

However, the economic system was based on linear business models, founded on the *take-make-dispose* resource flow, which relies on huge amounts of cheap and easily accessible resource and energy that are discarded at the end-of-life of goods (EMF, 2015; Evans & Bocken, 2013). Technological innovation and scientific progress, in fact, were not keeping into consideration the limits of the environment. This phenomenon did not only lead to resource scarcity and volatility of their prices, but also to environmental degradation caused by resource overexploitation, waste generation and pollutants emissions (Antikainen & Valkokari, 2016; Prieto-Sandoval et al., 2018).

According to the United Nation Environment Program (UNEP) (2011) the amount of resource usage from 2011 to 2050 is going to triple, mainly because of increased population and welfare. This situation is no longer sustainable and humankind is facing the need to manage energy and resources in a smarter way and decouple economic growth from resources overexploitation and environmental damages (Evans & Bocken, 2013; Mendoza, Sharmina, Gallego-Schmid, Heyes, & Azapagic, 2017; Pinheiro et al., 2019).

Circular economy (CE) appears as a solution to these issues. It aims at overcoming the problems of a linear economy and promoting economic prosperity while preserving the quality of the environment and achieve social equity (Kirchherr, Reike, & Hekkert, 2017; Pinheiro et al., 2019). CE, in fact, prescribes a more cyclical way of running our economy with the aim of creating value keeping into consideration that we are living within our planetary boundaries where there is a limited amount of resources (Blomsma & Brennan, 2017; Manninen et al., 2018). Therefore, circular economy has the final objective of decoupling economic growth from finite resource consumption and environmental degradation (EMF, 2015).

CE describes an economic system where resources are transformed into goods that are then distributed to the customers. However, once the good reaches the end of life (EOL), it is recovered and its parts and materials are reused and/or recycled in order to retain the intrinsic value of resources by constantly cycle them back in the system (Prieto-Sandoval et al., 2018). In this way, CE increases resource and energy efficiency, and diminishes waste production and virgin raw materials extraction, reducing the pressure on the environment while promoting economic development (Manninen et al., 2018).

Therefore, CE may be a good tool to achieve sustainable development, provide economic growth and social benefits, and reduce our environmental footprint and the effects on climate change (Jain, Jain, & Metri, 2018; Kirchherr et al., 2017; Lewandowski, 2016). According to Bocken et al. (2016) CE has also the potential to create new jobs and move the society towards industrial symbiosis and zero-waste. In addition, circular economy can promote sustainable innovation and support the economic performances of a company and create competitive advantage (Antikainen & Valkokari, 2016; Mendoza et al., 2017). For this reasons, it is important to move our society and economy away from liner business model and change towards circularity.

The implementation of CE is depending not only on policy makers but also on firms and their ability to adopt circular practices in their business models (Lewandowski, 2016). However, implementing circular economy is challenging (N. Bocken, Strupeit, Whalen, & Nußholz, 2019). The adoption of this concept requires a multi-dimensional changes and the way of making business need to be modified (Jain et al., 2018; Pinheiro et al., 2019). New business models, redesign of products to favour circularity and a supply chain that goes to clients and back to the company may need to be developed (Jain et al., 2018; Pinheiro et al., 2019). These examples of actions required to implement CE depict that the modifications are significant compared to a linear way of making business. Thus, companies need guidance and support in order to implement this concept in an appropriate way (Bocken et al., 2019; Pinheiro et al., 2019).

## 1.1 Background and problem definition

Implementing circular economy is not an easy task. It is challenging for businesses to implement CE because it requires to change the paradigms of business, the structure of their value chain and the way they are creating and delivering value via their business model (BM) (Bocken et al., 2019; Lüdeke-Freund, Gold, & Bocken, 2019). In some cases it can also negatively impact the performances of companies, and undermine their current capabilities, network and business models (Antikainen & Valkokari, 2016).

Innovation and changes are therefore required in order to move toward circularity (Antikainen & Valkokari, 2016) and business model innovation (BMI) is often needed to support a company in implementing CE (Antikainen & Valkokari, 2016; Nußholz, 2018a). In fact, circular business models (CBM) are considered as fundamental enables of circular economy because they are capable of supporting the implementation of circular practices and collect all the economic, social and environmental benefits that CE can potentially provide (Bocken, Short, Rana, & Evans, 2014; Kirchherr et al., 2017; Nußholz, 2018). Also, according to Roos (2014) business model innovation can have a greater impact on profitability than any kind of innovation.

However, there is not always the need to create a new business model but it is possible to reconfigure the current BM towards circularity (Nußholz, 2018a). For this reason, it is important to understand if and how CE implementation is influencing the way of making business of a company. Moreover, according to the sustainability benefits that circularity can potentially provide (Kirchherr et al., 2017; Pinheiro et al., 2019), it is valuable to understand what kind of modifications a company needs to undertake to implement this concept.

To promote the adoption circular economy, it is also important to support businesses and provide them with tools to appropriately manage the change (Antikainen & Valkokari, 2016). Nevertheless, there is a general lack of capacities about how to implement CE and how to develop circular business models (Guldmann, Bocken, & Brezet, 2019; Lewandowski, 2016). This can undermine the possibility to capture the triple bottom line benefits that circular economy can provide.

There is some research done in this direction but it still not exhaustive. There are companies that have already implemented CE but more knowledge and guidelines are required in order to drive a systematic change towards circularity. This include providing a methodology on how to create a CBM and how to manage the change in companies and their value chains (Guldmann et al., 2019; Bocken et al., 2019).

Therefore, there is the need to create tools, frameworks and methodologies that could support businesses in their transition towards CE (Bocken et al., 2019; Lewandowski, 2016). More research needs to be performed to move firms away from the liner economy path and make them follow the circular and potentially more sustainable one.

This thesis aims at tackling the issue related to the uncertainty about the implementation of circular economy. The objective is therefore twofold.

The first goal is to understand how the adoption of CE is affecting the current business model of a firm in order to define if the application of circularity is influencing its way of working and, in case, what changes are required to implement this concept.

Secondly, this thesis aims at developing a methodology that can be used in order to support the implementation of circular economy in a company.

In order to achieve these objectives a Sandvik's division, which is manufacturing machines to handle and transport rocks and ore at a mining and/or construction site, is going to be analyzed. This company is going to be used as a case study to comprehend if and how circular economy is impacting the business model of a firm and to test the methodology developed to support the adoption of this concept.

Sandvik is a global company active in the sectors of machining tools, material technology, and mining and construction equipment. The company is willing to improve its circular performances and take advantage of the benefits that this concept can potentially provide. Circular economy, in fact, is one of the main pillar of its 2030 sustainability ambition. Sandvik has the aim of manufacturing products that are 90% circular via creating machines that are designed for circularity and life extension, maximize resource efficiency, minimize waste production, and use recycled and reused materials in their manufacturing processes (Sandvik, N.A.c, N.A.d, N.A.a, N.A.b). In addition, they are asking their suppliers to aim at the same circular targets to extend the adoption of CE also in their supply chain (Sandvik, N.A.c, N.A.d, N.A.a, N.A.b). These facts made Sandvik ask the author to support one of its divisions in implementing circularity in order to bring developments towards this direction.

## 1.2 Research questions

As we can understand from the thesis background, the two main research objectives are understanding if and how circular economy is influencing the current business model of a company and assess if the used methodology is effective in supporting the implementation of this concept.

In relation to the first goal, it is important to understand what the current status of implementation of CE in the division is in order to define what are the potentials of improvement. Then, an assessment of the economic and environmental benefits and drawbacks of the additional circular actions is going to be provided to understand if a wider adoption of this concept can provide benefits to the company and the environment. Once the circular economy opportunities are going to be defined, an evaluation of their impact on the current business model is going to be provided with the aim of assessing if modifications are needed and, in case, what changes are required to implement them.

The second objective prescribes a critical analysis of the applied methodology, used to support the adoption of CE in the division, to understand if it was effective in achieving its aim and if it can be used in other circumstances.

Therefore, the research questions (RQs) are the following:

*RQ 1: How is circular economy implementation influencing the division's current business model?*

The aim of this question is understanding how the adoption of circular economy is influencing the current way of working of the division and, in particular, if and how it is impacting its business model.

*RQ 1.1: What is the current status of implementation of circular economy in the division?*

The first step to address the main question is to grasp the current way of working of the division and if it has already adopted circular economy practices.

*RQ 1.2: What additional circular actions could be performed by the division to favour the adoption of circularity?*

The current way of working and the potentials of improvement are going to support the definition of future circular actions that could be performed by the division.

*RQ 1.3: What is the economic and environmental value of the selected circular economy opportunities?*

The additional circular actions have the aim of bringing economic and environmental benefits to the division and support the achievement of the sustainability goals. For this reason, it is important to assess if they are providing improvements in this direction.

*RQ 2: Is the selected methodology able to promote the implementation of circular economy?*

According to the fact that implementing circular economy is not an easy task, an assessment of the ability of the used methodology is going to be performed to comprehend if it was capable of supporting the division in moving towards circularity.

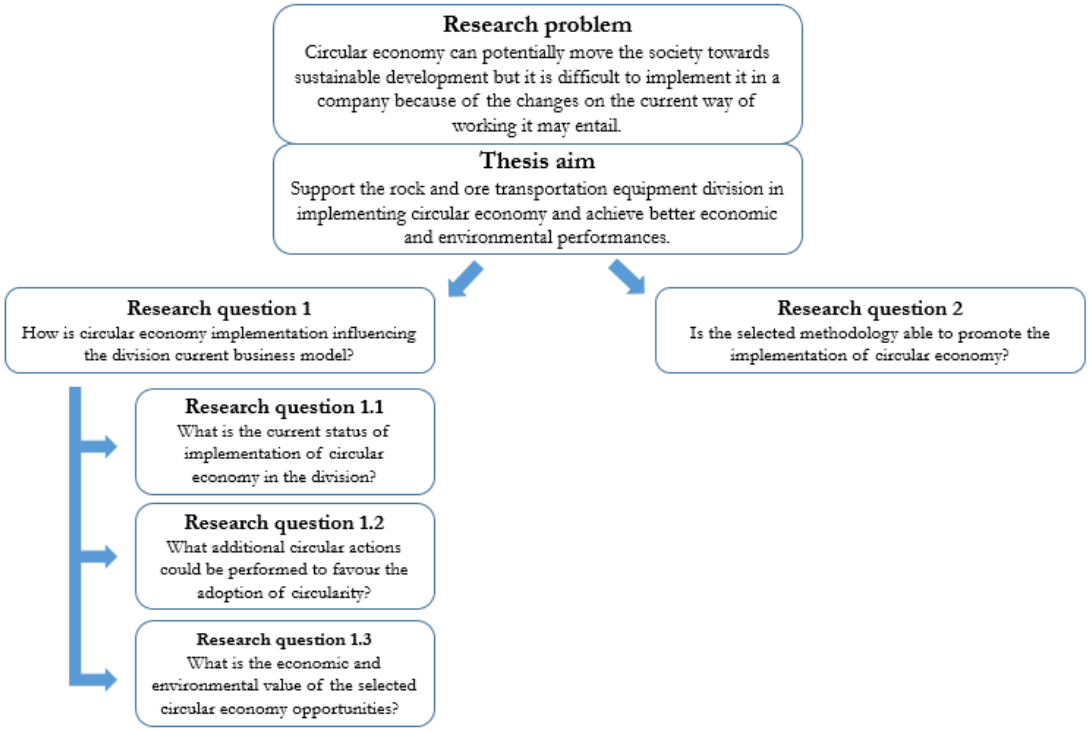


*Figure 1-1. Overview of thesis aim and research questions.*

*Source: Author.*

## 1.3 Scope and limitations

The thesis' scope is the Sandvik division that is manufacturing rock and ore transportation machines. As a consequence, the focus is going to be on micro-level of circular economy implementation because just the company environment is going to be analyzed (Ghisellini, Cialani, & Ulgiati, 2016).

As expected in such a case study research, the generalizability of the results is going to be negatively impacted (Verschuren, Doorewaard, & Mellion, 2010). However, if the methodology applied to assess the current and future implementation of circular economy is going to be proven as successful, it could be used in other divisions of the company or in other firms to support the adoption of CE.

Another limitation is the absence of interviews with customers. The lack of the point of view of this fundamental external stakeholder constitute a barrier towards the getting a complete understanding of the CE implementation impact. This assessment was conducted using the data provided by the other interviews and the theoretical knowledge gathered during the literature review, and thus it might be biased and imperfect.

Furthermore, the thesis is not going to provide an in depth environmental and economic assessment of the proposed circular actions. The economic and environmental impacts are going to be presented on a high level without deep dive into the marginal benefits and drawbacks of the suggested circular activities.

A final limitation is related to the fact that the social impact of the implementation of circular economy is not going to be addressed. The main reason is because this aspect received little attention in the research and there is a general lack of knowledge about the social benefits or shortcomings of CE. In addition, there is still little evidence that circular economy can provide a greater societal well-being and therefore is complicated to give a correct and fair assessment of the social impact (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Kirchherr et al., 2017).

## 1.4 Ethical consideration

The ethical consideration arise from the cooperation with the division that is manufacturing rock and ore transportation equipment.

The data gathered during the qualitative research are treated according to a confidentiality and non-disclosure agreement. Sensible information was omitted from the thesis because of the issue related to making them publicly available. In addition, the data gathered were protected from the access of third parties and no information about the way of working of the division was provided to actors outside the company and academic environment.

In addition, the people interviewed decided to participate voluntary, were informed about the risk and procedure of being involved in a thesis research, and their anonymity was granted. When interviews were conducted with people outside Sandvik, such as suppliers or customers, no questions or information that could undermine the relationship with the division were asked or provided.

During the two stays at the division production site an appropriate behavior was adopted in order to act professionally, avoid putting myself or other people in danger and to prevent the leakage of sensible information.

## 1.5 Audience

The thesis is the final assessed element of the Master's program in Environmental Management and Policy at the International Institute for Industrial Environmental Economics (IIIEE) of Lund University. It aims at supporting the Sandvik's division in implementing circular economy and filling the gap related to the lack of methodologies about how to do that.

Therefore, the first audience is Sandvik and the rock and ore transportation equipment division. In fact, the outcome of the research is going to support the future implementation of circular economy in the division and promote an improvement of the sustainability performance of the company. In addition, other Sandvik's divisions and/or companies could adopt the methodology used during the thesis in order to facilitate the adoption of circular economy.

The other audience of the thesis is academia that could gather valuable information about the implementation of circular economy and develop better strategies and tools to support companies in moving toward circularity.

## 1.6 Disposition

The thesis begins with an introduction, *Chapter 1*, which depicts the background of the research and defines the problem under analysis and the scope of the study.

The paper then continues with a literature review, *Chapter 2*, to present the most important concepts used and the knowledge adopted to run the research. In this section, the framework used to assess the impact of the implementation of circular economy on the division's current business is also introduced.

*Chapter 3* contains information about the research design, the methodology used to collect and analyze the data, and the division's case study.

The findings of the research are presented in *Chapter 4*. First, the current business model is introduced, then the present implementation of circular economy is provided followed by the opportunities of improvement.

*Chapter 5* contains the discussion. In this section, the impact of the implementation of CE on the current business model is provided. Then, the methodology used to promote the adoption of circularity is critically analyzed to assess its effectiveness.

Finally, *Chapter 6* illustrates the concluding remarks, the contribution of the thesis to research and practices, and suggestions for further research.

# 2 Literature Review

Circular economy could potentially provide benefits from a sustainability point of view (Jain et al., 2018; Kirchherr et al., 2017; Lewandowski, 2016) and can enhance the economic performance and the competitiveness of a company (Antikainen & Valkokari, 2016; Mendoza et al., 2017). The literature review is going to explore this concept and its application into business models to support Sandvik and the rock and ore transportation equipment division in developing towards circularity.

## 2.1 Circular economy

Before applying circular economy to the Sandvik case study, a better understanding of this concept, its components and the reasons why it is considered such an important way to achieve sustainability and enhance business competitiveness need to be provided.

The Ellen MacArthur Foundation (EMF) defines circular economy as "an economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows." (EMF, 2015, p. 5).

According to Manninen et al. (2018), CE is a concept where inputs, waste and emissions are minimized by closing, slowing, narrowing material and energy loops via reusing, reducing, recycling, maintain, repair, remanufacturing. Circular economy aims at increasing resource and energy efficiency, and therefore tries to find a better harmony between the environment, society and economy.

Kirchherr et al. (2017) describe CE as an economic system where at the end of life waste is reduced and products are reused, recycled and materials are recovered. The application of this concept has the final objective of creating sustainable development, and therefore economic prosperity, while preserving the quality of the environment and achieve social equity, in order to provide benefits to the present and future generations.

Another contribution to the definition of circular economy comes from Geissdoerfer et al. (2017) who describe the concept as a regenerative system where resource and energy usage, and waste production are minimized by narrowing, slowing and closing resource and energy loops. This is achieved via design for duration, maintenance repair, reuse, remanufacturing, refurbishing and recycling.

According to the nature of the research problem and the aim of the thesis, the following definition of CE was developed:

*Circular economy is a concept that implies the creation of a regenerative system where the value of the resources used stays within it by extending, closing and narrowing resource loops. This is obtained via creating products that require less raw materials, harmful and scarce substances, and are designed for duration, life extension, recycling and to ease circular activities. This system is capable of preventing environmental degradation while improving the competitiveness and profitability of a company.*

From this definition we can understand that circular economy uses nature as inspiration, where nutrients and chemicals are constantly cycled back in the system and no waste is really created (Miller & Spoolman, 2012; Prieto-Sandoval et al., 2018). In fact, CE aims at maximizing the

number of consecutive cycles that materials can do by constantly circulating products, their components and materials. In this way, the value of the resources and energy embedded in the goods we produce are preserved. Consequently, waste creation is precluded because, in a closed loop material cycle, all the output of production processes are recovered in order to maximize the retention of the intrinsic value of the resources used and minimize the amount of energy needed (EMF, 2015).

CE keeps into consideration that we are dealing with scarce resources and it aims at preserving the natural capital by managing in a wise and sustainable way the flow of finite resources and taking advantages of the renewable one (Manninen et al., 2018). In this manner, human kind can preserve the natural capital and thrive in the future (Prieto-Sandoval et al., 2018).

In order to achieve these aims, circular economy is founded on three main pillars (Bocken et al., 2016):

- *Slowing Resource Loops*: extending a product, its components and materials lifetime by using and reusing them for as long as possible (EMF, 2015).
- *Closing Resource Loops*: cycle the resources back in the system, from customers back to producers, in order to favour their reuse and recycle and retain the embedded value of the resources and energy used (Schenkel, Caniëls, Krikke, & van der Laan, 2015).
- *Narrowing Resource Flows*: use as little materials as possible and avoid using hazardous and harmful substances (Ghisellini et al., 2016).

The following sections depict how the three fundamental pillars of circular economy are translated into actions that a company can do to implement circular economy.

### 2.1.1 Slowing resource loop

With the purpose of slowing resource loop, products are designed for long lasting and to favor life extension practices.

In the first case, the utilization period needs to be as long and possible. Therefore, goods can be stressed for a long time without breaking down and are designed in a way that, if used according to the instruction of the producer, they can last for a specified period of time without failing (Bocken et al., 2016).

In the second one, products are designed for maintenance and repair to allow retaining the functionality of the product or restore it to working condition after damage (de Jesus & Mendonça, 2018). Modularity is an additional aspect that can favor extending the lifespan because the single modules can be substituted, repaired or upgraded without the need to act on the entire unit (Sianesi & Brandolese, 2016). The design for modularity, together with the one for dis and reassembly, which assure that the product can easily be separated into parts and can be assemble again, are considered as two fundamental aspects that can facilitate the lifespan extension practices (Bocken et al., 2016; Ghisellini et al., 2016; Schenkel et al., 2015). Also the design for upgradability, a process that permit to upgrade the product to the latest functionality and performance to continue using it, is considered as an important factor to make a product last for another lifecycle (Blomsma & Brennan, 2017; Bocken et al., 2016). Finally, designing for standardization and compatibility, that entails creating the product's parts in a way that can fit with other products' one, is fundamental to support life extension and to enable the design for upgradability and modularity (Blomsma & Brennan, 2017; EMF, 2015).

A good business model is also fundamental for the adoption of slowing resource loop practices (Bocken et al., 2016). A company can adopt a classic long life model where products are designed for duration and it can then provide all the services needed to assure the extension of their lifespan (Bocken et al., 2016). In alternative, the firm can offer functionality rather than ownership to its customers in a business model called product service system (PSS), presented in section 2.2 (e.g. de Jesus & Mendonça, 2018; EMF, 2015; Ghisellini et al., 2016).

### 2.1.2 Closing resource loop

Closing resource loop entails cycling the resources back in the system to promote their reuse and recycle, and preserve the embedded value of the resources and energy used (Schenkel et al., 2015).

A take-back system, where the products are returned to the producer to reuse, remanufacture (bring back a product to its original functionality) and/or recycle them and/or their components, enables to retain the embedded value of the resources (EMF, 2015). In this way, a company is capable of decreasing the materials leakage out of the system, support the design for circularity and maintain the intrinsic value of resources or exploiting the residual one (Bocken et al., 2016). However, implementing a take-back system is challenging not only because of the need of creating an appropriate infrastructure, but also because it implies the integration of the supply chain forward to the customers and the reverse one, and thus it can deeply influence the organizational structure and the original supply chain characteristics (de Jesus & Mendonça, 2018; Schenkel et al., 2015).

To ease closing loop practices, products design is important too. Designing products for technological cycle, to make the products recyclable, and for dis and reassembly, to allow separating the various parts and substances in an easy and effective way before recycling, are favoring the creation of a closed loop (Bocken et al., 2016; Evans & Bocken, 2013).

### 2.1.3 Narrowing resource flow

Circular economy implies manufacturing products using as little materials as possible and avoiding using hazardous substances (Bocken et al., 2016). Also their packaging should be designed to use less materials, in a way that it is not toxic and to make it reusable and/or recyclable (Ghisellini et al., 2016). A constant development and research about innovative and sustainable materials and the usage of better technologies, such as 3D printing, could favor this process. Also the design for manufacturing criteria, that allows to find useful application to waste and by-products, can favor narrowing resource flow practices (EMF, 2015).

With regards to operations, cleaner production should be applied to create more environmental friendly products, processes and services (de Jesus & Mendonça, 2018; Ghisellini et al., 2016). Energy and resource efficiency should be constantly improved to avoid their unnecessary usage and prevent leakages (de Jesus & Mendonça, 2018) and renewable energy should be preferred to the limited and highly polluting fossil fuels (EMF, 2015; Ghisellini et al., 2016).

Waste reduction and removal is another important aspect of narrowing the resource loop. Practices such as sufficiency, reusing, recycling and industrial symbiosis (IS), which aims turn the waste or by-products of a process into the input of another one, are enablers of waste minimization (Bocken et al., 2016; EMF, 2015). Additionally, the emissions to air soil and water should be reduced and properly managed (Ghisellini et al., 2016).

### 2.1.4 How to implement circular economy

As we can understand from the description of the 3 pillars, the main areas of improvement in order to effectively adopt CE are product design, operations and stakeholders involvement.

The adoption of circular economy starts with product design (EMF, 2015). Appropriately designed products can favor narrowing, closing and extending resource loops practices (Jain et al., 2018). In addition, a careful product design allows to reduce their environmental impact throughout their life cycle and assure a greater economic beneficial impact (Ghisellini et al., 2016). However, when designing a product for circularity, the performances and functionality should not be negatively impacted (EMF, 2015). Also, it is important to carefully plan the lifespan of a product. An appropriate duration can satisfy the needs of the customers of having a good for a fair amount of time but, at the same time, prevent the cannibalization of sale of new products or a negative impact on their quality and functionality (Blomsma & Brennan, 2017).

The design itself, however, is not sufficient to promote a good implementation of circular economy. The company's operations should be aligned to circularity too. The aim is to constantly improve resource and energy efficiency, minimize waste production and the adoption of harmful substances. These practices can allow to create products and/or services, and manufacturing processes that are more economic efficient and reduce the harm to the environment and society (de Jesus & Mendonça, 2018; EMF, 2015; Ghisellini et al., 2016). A good circular business model is therefore important to align all these actions to the company strategy (Kirchherr et al., 2017). However, a new business model is not always needed but it is possible to reconfigure the current one towards circularity (Nußholz, 2018).

Without the support of the various actors involved in the value chain, it is very difficult to implement circularity appropriately (Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). Customer cooperation is, for instance, a fundamental enabler of circular economy (Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). Consumers should be made willing to buy more sustainable products and remanufactured or used ones. Clients also need to take part in the circular process and change the way they are using and disposing the products at the end of life (EOL) (Ghisellini et al., 2016; de Jesus & Mendonça, 2018). It is important, in fact to exhort and educate them on how to use products in an appropriate way and to favor the take back process. In this way, it would be easier for a company to have products and components in good conditions that can be reused or remanufactured (Prieto-Sandoval et al., 2018). Once the product has irreversibly reached the EOL, clients have the fundamental role of recycling them correctly and avoid improper disposal practices (Ghisellini et al., 2016).

The support of a good information and communication technologies (ITC) systems, automation and big data is also a good enabler of circular economy because it can provide real time information support a better management of the supply chain, customer relationship and the products lifecycle (Schenkel et al., 2015).

### 2.1.5 The potential benefits of circular economy

Applying CE does not mean to achieve sustainable development but it is one of the most advanced way to move in that direction (Prieto-Sandoval et al., 2018). Therefore, the adoption of circularity can potentially bring economic, environmental and social improvements.

The economic aspects are the one that gain the most benefits from circular economy (Geissdoerfer et al., 2017). New revenues streams can be created through circular activities such as maintaining, repair, remanufacturing and recycling, selling second-hand and refurbished products, and long-lasting products at a higher price (Nußholz, 2017; Prieto-Sandoval et al.,

2018). Costs are reduced mainly via a better resource and energy efficiency in the manufacturing processes, and by designing products for extending lifetime because it can reduce the need for new raw materials and energy (EMF, 2015; Prieto-Sandoval et al., 2018). Savings can be achieved also thanks to a better waste management system and a lower amount of waste that needs to be disposed or landfilled (Ghisellini et al., 2016; Nußholz, 2017). In addition, purchasing used or recycled materials and components allows a company to save money, be less dependent on suppliers and thus be less effected by resource price volatility and supply risk (Blomsma & Brennan, 2017; Nußholz, 2018a). Lower costs of purchasing can be realized via the adoption of industrial symbiosis (IS) practices with neighbors companies too (Evans & Bocken, 2013; Ghisellini et al., 2016). These cost reductions also allow the company to provide cheaper products to its customers and enhance its competitiveness (Nußholz, 2017).

Moreover, CE is capable of boosting innovation by designing products for circularity and defining a better reverse logistic system (EMF, 2015). Additional developments could be achieved thanks to the creation of better technologies to enhance energy and resource efficiency, of innovative and more sustainable materials and of new opportunities to create profits for companies (Kalmykova, Sadagopan, & Rosado, 2018).

Circular economy allows having better control and greater amount of data about the entire lifecycle of the products. Therefore, a firm can have a better knowledge and understanding of its goods, the way they are performing and the customers' behavior. These facts can help companies in continuously improving their products and operational processes, and reduce the downtime for maintenance and repair operation, and consequently better satisfy their clients (Linder & Williander, 2017; Nußholz, 2017; Schenkel et al., 2015).

In regards to the environmental benefits, CE aims at decupling economy development to finite resource exploitation and environmental degradation by reducing virgin raw materials consumption (Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). In fact, circular economy favors the optimization of resources and energy usage, reuse and recycling of goods and their materials and components, reduce the production of waste and emissions, and thus decrease the environmental harm (Lewandowski, 2016). Thanks to that, companies can brand themselves as more sustainable and appeal customers that are concerned about this (EMF, 2015; Linder & Williander, 2017; Prieto-Sandoval et al., 2018).

Societal benefits are still uncertain. Little research has been done in this direction and there is little evidence that the application of this concept can provide a greater societal well-being (Geissdoerfer et al., 2017; Manninen et al., 2018). The main benefits could potentially come from a reduced externalities, with a positive impact on human health, higher job opportunities and fairer taxation (Ghisellini et al., 2016; Kalmykova et al., 2018). In addition, prices of goods are expected to decrease giving people a greater disposable income (EMF, 2015).

### 2.1.6 Problems with the application of circular economy

The implementation of circular economy presents challenges and barriers that can increase the risk of innovating towards circularity and can preclude a company from exploring the possibility of moving towards this direction.

The uncertainty about the reliability and predictability of the flow of used products and/or parts can cause problems with planning and executing the (re)manufacturing activities (Bocken, Schuit, & Kraaijenhagen, 2018). Also these practices requires technological expertise and are labor intensive, thus they can not only be costly for a company, but also cause problem of saturation and availability of the work force (Linder & Williander, 2017).

There is also the concern about the quality of the returned products. Customer may believe that the remanufactured products are not as good as the new one and want a discount for them. The quality of the collected materials needs to be good enough to allow recycling and also the materials are subject to quality degradation that limit their recyclability over a certain number of times (Nußholz, 2017). Quality and safety concerns shall therefore be considered when working with used and recycled materials (Bocken et al., 2018).

When implementing circular economy, the company could create a rebound effect because using secondary materials does not necessary lead to a reduction of the production of new good and prevent the use of virgin raw materials. Thus the company may not be able to create environmental benefits and save money (Nußholz, 2017).

It may also be costly to switch to recycled or more sustainable materials and technological limitation can prevent a company from improving energy and resource efficiency (Linder & Williander, 2017).

## 2.2 Product service system

Several experts in the field consider product service system (PSS) as a fundamental enabler of circular economy (Blomsma & Brennan, 2017; de Jesus & Mendonça, 2018; EMF, 2015; Ghisellini et al., 2016).

PSS is a business model that provides a combination of products, services and supporting network and infrastructure that can satisfy a customer need while enhancing competitiveness and sustainability performances of a company, compared to a traditional business model (Annarelli, Battistella, & Nonino, 2016; Mont, 2004).

There are mainly 3 kinds of PSS (Reim, Parida, & Örtqvist, 2015; Tukker, 2015):

- *Product-oriented*: where the firm sells the product to customers and provides all the services related to that, e.g. insurance, maintenance, advisory and consultancy.
- *Use-oriented*: the producer retains the ownership of the product, and thus is not selling it to the clients, but it makes it available via different forms such as renting (use by a single user) renting/sharing (used my multiple users) pooling (simultaneous use by multiple users).
- *Result-oriented*: where the producer provides a certain outcome to the customer rather than a product or a service.

The scope of the argumentation is going to be on the last two kind of PSS because they are considered as a better application of circular economy (Reim et al., 2015; Tukker, 2015). In this cases, in fact, all the materials used become cost factors for the producer that therefore wants to maximize resource and energy efficiency, and create long lasting products (Reim et al., 2015; Tukker, 2015).

### 2.2.1 The features of PSS

In a product service system the manufacturer is retaining the ownership and this business model works best with goods characterized by a high market value because, in this circumstance, it is worth to take stewardship over the product lifecycle (Xing & Ness, 2016). The customers are therefore turned from consumers into users (EMF, 2015).

Adopting a product service system model requires changes in the value chain, structure, culture and skills of a company mainly because of the focus is shifted from product production to

clients availability and needs (Adrodegari, Saccani, & Kowalkowski, 2016; Reim et al., 2015; Tukker, 2015). Therefore, the way of making business is radically different and consequently the value creation logic is also changing (Annarelli et al., 2016; Mont, 2004).

The product and processes also needs to be modified. To favor the adoption of a PSS, goods are designed for long lasting, modularity and dis and re assembly in order to favor reuse, remanufacture and recovery of materials and components, and facilitate the upgrading practices (Xing & Ness, 2016). A proper takeback system is thus created in order to enable these activities and allow the producer to provide the same products to multiple customers (Xing & Ness, 2016). Additionally, products require to have a minimal footprint, to be resource efficient and to require less toxic materials, energy, water and other production inputs to make the manufacturer save on production costs and prevent environmental damages (Reim et al., 2015). However, businesses need to realize that improvement in design and manufacturing practices are not a source of competitive advantage but that offering integrated solutions or experiences is a better way to attract customers. The products and processes design therefore are just a way to facilitate the company task of providing the service and make PSS more profitable, but what the customers really want is an effective and efficient service (Tukker, 2015).

### 2.2.2 Benefits of PSS

Despite the big changes required to implement PSS, this business model can provide 5 main benefits to a company.

First of all, by providing a service, a firm is differentiating itself from its competitors and from mass production, creating a unique offering to its customers and obtain a greater competitiveness (Annarelli et al., 2016).

Secondly, PSS aims at improving energy and resource efficiency via extending the lifespan of products, favor operation that can prolong the lifecycle and promote the reuse of products and components, e.g. remanufacturing and reuse. Also, a company is incentivized in creating products that are durable and require less intervention throughout their lifecycle. These facts, make a company save money in the production and after sale phase and improve profitability (Reim et al., 2015; Tukker, 2015).

Third, a more efficient use of resources and practices such as reuse and recycle of components, decrease the purchasing costs, making a company less reliant on suppliers and reducing the supply risk (Mont, 2004).

Fourth, the improved resource efficiency, reuse and recycling can have a good impact on the environment because of the less pressure on the resources it provides. Moreover, retaining the ownership assure that the product is going to be disposed correctly at the EOL. Thus, a company can brand itself as more environmental friendly and improve its image (Annarelli et al., 2016; Mont, 2004; Tukker, 2015).

Finally, a product service system can improve the relationship with clients and their satisfaction. Thanks to the higher amount of interactions with customers, PSS can allow a company to get to know them better and satisfy in a more appropriate way their needs (EMF, 2015). The company can also provide them a more flexible service that can better fit their needs and make them avoid an initial high investment for having a product and reduce the total cost of ownership (Mont, 2004).

### 2.2.3 Risks of PSS

There are some difficulties in implementing a product service system. These are mainly related to the changes compared to the current way of making business, the involvement of the stakeholders required to implement this BM, the resources needed to make a PSS work, the financial risk of retaining the ownership and the legislative context.

The drastic changes in the organizational structure required to implement PSS may be difficult to realize and therefore can constitute a barrier for a correct implementation of the business model (Tukker, 2015).

It may also be difficult to establish partnerships and find a good network of stakeholders that can support a good implementation of PSS (Mont, 2004). In particular, it is difficult to make customers see the value in purchasing functionality rather than ownership (Lieder, Asif, & Rashid, 2017). Clients like to have the control over their things and do not want to have any behavioral limitation (Mont, 2004; Tukker, 2015). In fact, if a customer does not own a product it tends to use it less carefully, making it more subject to wear and tear and thus of additional intervention for repair, maintenance or it is going to be returned earlier (Tukker, 2015). As a consequence the need of spare parts and intervention is going to increase influencing negatively the profitability of the business model and its ability to provide a beneficial environmental impact (Reim et al., 2015). Moreover, in case of an inappropriate user behavior it may be difficult to maintain a high functionality and safety, and this can negatively affect the customer satisfaction (Mont, 2004). Clients therefore need to change the way they are using and conceiving products (Annarelli et al., 2016). A good marketing strategy can make customers more familiar with purchasing functionality and show them the advantages and value that this concept can bring them (Lieder et al., 2017).

PSS requires a company to have personnel with a different set of skills and knowledge about service design, management and development, which may be difficult to acquire (Annarelli et al., 2016; Tukker, 2015). Moreover, this BM, especially the result-oriented one, requires higher usage of labor to allow products to keep performing their functionality. In case the cost of labor is high, this can negatively impact the profitability of the BM (Mont, 2004; Tukker, 2015).

In case a company is not able to effectively adopt a higher resource and energy efficiency, and to manage the second hand resources in an appropriate way, the PSS business model is not going to be capable of providing environmental benefits (Reim et al., 2015; Annarelli et al., 2016).

Final barriers are related to the fact that the firm is exposed to the financial risk of retaining the ownership of the products and the risk of liability in case of problems with the good (Linder & Williander, 2017). Furthermore, the local legislative context cannot allow a company to retain the ownership of the products and provide a service (Annarelli et al., 2016; Mont, 2004).

## 2.3 Business model

The way a firm compete is defined by a strategy. A strategy aims at creating superior value for a firm's customers and capture more value than the competitors. A business model allows to define the actions that are going to be performed to provide value to the customers, achieve competitive advantage and capture the intended share of value that the company needs to survive and thrive (Bocken et al., 2014; Richardson, 2008).

According to Osterwalder & Pigneur (2010, p. 14), "a business model describes the rationale of how an organization creates, deliver and capture value". Therefore, when speaking about

business model (BM) we have to consider the value creation architecture or logic (Osterwalder & Pigneur, 2010; J. Richardson, 2008). The sections below depict a summary of the value creation logic.

### 2.3.1 Value proposition

The value proposition is what the firm provides to its customers, why they should be willing to pay for the company's products and how it builds its competitive advantage (Richardson, 2017). The value proposition is composed of the following elements (Osterwalder & Pigneur, 2010):

- *Value proposition*: Is the kind of products or services that a company provides to the customers making them willing to choose a certain firm rather than its competitor.
- *Customer segments*: The different clients the company seeks to serve and the strategy needed to do that. Selling products allows a company to make profits and therefore the clients need to be divided into groups according to their needs and wants.
- *Customer relationship*: The kind of relationship that is established with customers in order to better provide them the value.

### 2.3.2 Value creation and delivery

Value creation and delivery describes how the firm creates and delivers value to its customers. For this reason, it is considered as a core in a business model because it entails all the activities that a firm performs to deliver the value (Bocken et al., 2014; Richardson, 2017). It is divided into the following elements (Osterwalder & Pigneur, 2010):

- *Key resources*: The assets (physical, financial, intellectual, or human) that are needed to create and deliver the value to customers.
- *Key activities*: The activities that a company needs to perform in order to realise the business model, create and deliver value.
- *Key partnerships*: It is the network of partners, suppliers and customers that allows a company to better implement its business model.
- *Channels*: How a company communicates, interacts and reaches its customers. In other words, how the company delivers value.

### 2.3.3 Value capture

Value capture depicts how the firm makes and spends money. A company needs to make money from the way it creates and provide value but it is also spending money to do that (Richardson, 2017). Therefore, it is composed of the following elements (Osterwalder & Pigneur, 2010):

- *Revenue streams*: How the company generates money from the interaction with the customers.
- *Cost structure*: Indicates the costs that a company needs to bear to make its BM work.

### 2.3.4 Critics to the original view of the business model

The definition of business model proposed by Osterwalder & Pigneur (2010) and Richardson (2017) focuses on creating value just for the customers and firms. Thus, there is the need to develop a more holistic vision to include sustainability aspects and consider the environment and society as stakeholders too (Bocken, Short, Rana, & Evans, 2013).

Bocken et al. (2018) and Bocken et al. (2013) provide some additional components that needs to be added to the value creation architecture in order to provide value on a triple bottom line (economic, environmental and social). They add to the value proposition the value provided to the environment and society, to value creation and delivery a multi-stakeholders approach to achieve sustainability and in the value capture selling functionality rather than ownership (Bocken et al., 2014; Bocken et al., 2018, 2013). In this way, a business model should be able to have a more holistic scope and consider the value on a triple bottom line. A circular business model (CBM) aims at achieving this objective, as presented in the following section.

## 2.4 Circular business model

Contrary to a linear business model, where the resource flow *take-make-dispose* makes a company losing the intrinsic value of resources and damaging the environment, a circular one allows a company to capitalize on the embedded value of used products, and create value from an economic, environmental and social perspective (Guldmann et al., 2019; Linder & Williander, 2017; Roos, 2014).

A CBM implies to use circular economy strategies to create value (Nußholz, 2018). Therefore, the activities that creates, captures, and delivers value aim at improving resource efficiency, closing the materials flow and extending the lifecycle of products and their components (Nußholz, 2017).

### 2.4.1 Changes in the value creation architecture

A circular business model has a value creation logic designed to retain the value of the resources embedded in products (Guldmann et al., 2019; Linder & Williander, 2017). The value proposition, creation and delivery, and capture are therefore adjusted to ease the adoption of circular economy.

The value proposition is defined in a way that allows retaining the intrinsic value of the resources used in the products. This can be achieved, for instance, via designing durable products that can be repaired and maintained, or providing functionality rather than ownership to the customers (Nußholz, 2017).

This value is then created and delivered to customers. Clients who find the value in circular actions, and thus who are concerned about sustainability or that want to have long lasting products in order to decrease TCO, are the target (Bocken et al., 2018; Kirchherr et al., 2017; Nußholz, 2017). In this way, it is possible to establish a better relationship with them, remove the barriers to the take back system and favor the acceptance of used products and components (EMF, 2015; Evans & Bocken, 2013). A company is also creating appropriate activities, acquiring the right resources and forming useful partnerships to promote the adoption of CE practices in its BM (Nußholz, 2017). It is therefore establishing how to sell the products, directly or via PSS, how to handle the flow of used products, how to collaborate with customers and other stakeholders, how to handle reverse logistic and all the other actions needed to implement circular economy.

Finally, the company defines how circular activities can provide additional revenues streams and change the cost structure. Additional revenues can be generated for example via the after sale actions to prolong lifespan of products (repair and maintaining), via selling long-lasting products at a higher price, by selling second-hand or remanufactured products, and/or via product service system (Prieto-Sandoval et al., 2018). Cost savings can be realized by, for instance, lower use of resources and energy, by taking advantage of secondary materials that are coming from used

products and by reducing the cost of waste disposal (Blomsma & Brennan, 2017; Evans & Bocken, 2013; Ghisellini et al., 2016).

Therefore, big changes are required in the value proposition logic of a company and this fact can pose serious challenges and threats to the adoption of a CBM. However, these modifications can allow collecting all the potential benefits of CE and improving the profitability and competitiveness of a firm. The following section is presenting how to favor the implementation of a CBM.

### 2.4.2 How to implement a circular business model

Circular business models are one of the main enables of circular economy (Kirchherr et al., 2017). For this reason, it is important to understand how to implement them and what changes are required in order to create a good CBM.

One of the main enablers of a circular business model is product design (EMF, 2015). Therefore, the goods are designed for durability, for life extension practices (e.g. repair, maintaining, remanufacturing, reuse), dis and re assembly, modularity and upgradability, and to ease recycling when the end-of-life is eventually reached (Nußholz, 2017; Roos, 2014).

Companies are also creating a proper infrastructure and processes to enable life extension and closing the loop practices. They also aim to improve resource and energy efficiency, and develop new technologies that permit to use less input and are producing lower waste (Linder & Williander, 2017; Nußholz, 2018; Roos, 2014). The company establishes a good tack back system that allows collecting and reintegrating products and their parts into the value chain and retain their embedded value (Nußholz, 2018). This system can facilitate reuse and remanufacturing practices, avoid down cycling when EOL is irreversibly reached, and allow the company to reduce the need of virgin raw materials and energy intensive production methods (Linder & Williander, 2017; Nußholz, 2017). In this way, a firm can satisfy supplementary customers segments via additional sale of reused and refurbished products and parts, and after sale operations (Nußholz, 2018).

Implementing a circular business model requires extending the change outside the boundaries of the company and involving additional stakeholders such as customers and suppliers (Nußholz, 2017). CBM requires cooperation, collaboration and coordination with the various stakeholders involved and, in particular, customers need to take part in the circular process and change the way they are using the goods and disposing them at the end of life (Bocken et al., 2018; Kirchherr et al., 2017).

Finally, in order to implement CE, a company can move its business model towards a product service system one and sell functionality rather than ownership to its customers (Linder & Williander, 2017; Roos, 2014).

## 2.5 Circular business model innovation

The previous sections demonstrated how implementing circular economy and capture all its potential benefits require big changes compared to the traditional linear way of making business. A company, in fact, needs to modify the way it creates, delivers and captures value (Bocken et al., 2014; Bocken et al., 2019).

Therefore, innovation, and especially circular business model innovation (CBMI), is necessary (Antikainen & Valkokari, 2016; Prieto-Sandoval et al., 2018). Bocken et al., (2014) see business

model innovation (BMI) as key to achieve business success because without it is difficult to realize the changes and developments needed. For the scope of this thesis, sustainable business model innovation (SBMI) is required because, adopting circular economy entails that a company is creating value on a triple bottom line. In other words, a BM needs to profitable for the firm and, at the same time, provide value to customers and avoid harming the environment and society (Roos, 2014; Bocken et al., 2018). For this reasons, BMI is seen as a good way to support a company in implementing circularity because it can allow collecting all the economic and environmental benefits that this concept can provide. However, there is not always the need to create a new business model but it is possible to reconfigure the current one (Nußholz, 2018).

According to Antikainen & Valkokari (2016) and Bocken et al., (2019) there is currently a lack of frameworks to support CBMI. The following section aims at introducing a framework that can support companies in understanding how the implementation of circular economy is influencing their current business model and favor the future adoption of circular practices.

## 2.6 The circular economy implementation impact framework

The framework has been created to grasp how the current business model of a company is going to be impacted by the implementation of circular economy. In this way, it is possible to understand what changes are required to adopt certain circular actions and firms can have a guidance about how and where they can implement circularity.

The framework displays the current business model on the left side and the future ones are going to be placed in the columns on its right to get a visualization of how CE is impacting it. Visualizing the business model is a good way to communicate current business model and stimulate new ideas for its improvement (Nußholz, 2018; Osterwalder & Pigneur, 2010).

In circular business models, the way value is provided, created, delivered and captured by the company is changing. Thus, a visualization about how the circular activities are impacting the value creation architecture is useful to provide and understanding of how the current business model needs to be adjusted to allow an effective implementation of CE (Nußholz, 2018).

The framework, displayed in the table below, is based on the Business Model Canvas and value creation architecture created by Osterwalder & Pigneur (2010) and the definition of BM provided by Richardson (2008).

Supplementary components were added to make the framework more related to circular business model.

According to Lewandowski (2016), a CBM needs to include *adoption factors*, which hamper or limit the implementation of CE, and a *take-back system*, fundamental to extend, closing and narrowing resource loops. While the *take-back system* is considered as part of value creation and delivery, the *adoption factors* are not related to the value creation logic but are specific to the context in which a company is operating (Lewandowski, 2016). For this reason, this latter component was added to the top of the framework because it has an influence on the whole business model and application of CE.

Antikainen & Valkokari (2016) also worked on an improvement of the Business Model Canvas to adapt it to circularity. *Trends and drivers*, which characterize the environment in which the company is operating, were added together with the *impact*, both beneficial and negative, that a business model has on the environment. The first additional level is related to the context in which a firm is operating, and thus was added to the top of the framework, while the *environmental impacts* are specific to each single business model.

Joyce & Paquin (2016), Manninen et al. (2018) and Circulab (n.d.) researches on a business models' environmental impacts were adopted to better define the benefits and costs to the environment.

Finally, Antikainen & Valkokari (2016) prescribe a *constant reiteration of the circularity and sustainability performances* of the BM to continuously improve and update it, and check that it is providing the expected benefits on a triple bottom line.

*Table 2-1. The circular economy implementation impact framework.*

| **Trends and Drivers** | | | | |
|---|---|---|---|---|
| **Adoption factors (internal and external)** | | | | |
| | | | | |
| | **Current Business Model** | **Circular Business Model 1** | **…** | **Circular Business Model n** |
| ***VALUE PROPOSITION*** | | | | |
| **Value proposition** | | | | |
| **Customer segments** | | | | |
| **Customer relationship** | | | | |
| ***VALUE CREATION AND DELIVERY*** | | | | |
| **Take-back system** | | | | |
| **Key resources** | | | | |
| **Key activities** | | | | |
| **Key partnerships** | | | | |
| **Channels** | | | | |
| ***VALUE CAPTURE*** | | | | |
| **Revenues streams** | | | | |
| **Cost structure** | | | | |
| ***STAKEHOLDERS*** | | | | |
| **Stakeholders involvement** | | | | |
| ***ENVIRONMETAL IMPACT*** | | | | |
| **Environmental benefits** | | | | |
| **Environmental cost** | | | | |
| | | | | |
| **Constant reiteration of sustainability and circularity performances** | | | | |

*Source: Osterwalder & Pigneur, 2010; Richardson, 2008; Lewandowski, 2016; Antikainen & Valkokari, 2016; Joyce & Paquin, 2016; Manninen et al., 2018; Circulab, n.d.; Nußholz, 2018.*

The various components of the framework are described in the Appendix A.

In order to assess the good design of the tool, the work by Bocken et al. (2019) was adopted. These authors, in fact, created a checklist for creating a framework on circular business model innovation. The table below represents the criteria of the assessment tool and the analysis of the CE implementation impact framework based on them (Bocken et al., 2019, p. 13). Thanks to this checklist, it was possible to assess if the tool was appropriately created in order to stimulate CBMI.

*Table 2-2. Assessment of the framework.*

| **Criteria to assess the framework (Bocken et al., 2019, p. 13)** | **Analysis of the framework** |
|---|---|

| | |
|---|---|
| "The tool is purpose-made for CBMI." | The framework was created to stimulate CBMI because it aims to understand how the current business model is going to be impacted by the application of circular economy and what changes are required to adopt this concept. |
| "The tool is rigorously developed – from both literature and practice insights." | The tool was developed with the support of an in depth literature review about circular business model innovation. However, the framework was not created with the support of practice because it was tested the first time during the thesis process. |
| "The tool is iteratively developed and tested with potential users." | The tool is going to be tested for the first time during this research project, therefore it has not been developed with the support of application with potential users. |
| "The tool integrates relevant knowledge from different disciplines." | The structure of the framework was developed with knowledge about business model that was integrated with one about circular economy, sustainability issues and environmental impact assessment. |
| "The final tool version has then been used by practitioners, preferably multiple times, and an evaluation of this process is done to assess tool use and usefulness." | As mentioned before, the framework was tested for the first time during the thesis project. Therefore, the usefulness and applicability of the tool is not going to be assessed with a multiple application with practitioners. |
| "The tool provides a transparent procedure and guidance on how others can use the tool." | The section that describes the tool also presents the way the framework is supposed to be used. |
| "Circular economy or broader sustainability objectives and impact are firmly integrated into the tool and safeguarded when tool application is facilitated by others than the tool developer." | Circular economy and sustainability are integrated in the tool, as demonstrated by the inclusion of the environmental benefits and drawbacks dimensions, and the constant reiteration of sustainability performances. |
| "The tool is simple and not too time-consuming." | The tool was created in order to be simple and easy to apply. After the application this aspects are going to be better assessed in section 5.3. |
| "The tool inspires or triggers (business) change." | The framework was created to see how CE is affecting the current business model. In other words, it gives a visualization of how and where the BM is changing. Therefore, it can trigger and guide the change. |
| "The tool is adaptable to different (business) contexts." | The tool is applicable to different contexts because it considers the aspects of a business model that are common for various kinds of firms. |

*Source: Bocken et al., 2019, p. 13.*

As we can understand from table 2-2, the framework is performing good in almost all the requirements, apart from the one related to its development with the support of practice because it is going to be tested the first time during the thesis. Therefore, it can be considered as properly designed in order to support circular business model innovation. A further assessment of its usefulness and application is going to be provided in section 5.3.

# 3 Methodology

This section is presenting the methodology adopted during the research. It is fundamental for a thesis to be transparent about the way the research was conducted, how the data were collected and analyzed, and how the author arrived to his conclusions in order to assess the reliability of the study. It is of equal importance to accurately describe the methodology to assure the replicability of the findings and allow further researchers to adopt the same approach and attain to the same results (Walliman, 2006).

## 3.1 Research design

The research was conducted adopting a constructivist point of view. This school of philosophical worldview believes that individuals try to understand the world where they live by giving subjective meanings through their experiences. Therefore, the author tries to interpret the meaning that others have about the world and he does not start with a theory but it is constructing one via the interpretation of other people views about a certain aspect of the world (Creswell, 2014).

The implication is that the researcher has to use open-ended questions and tries to understand the situation by relying on the subjective view of people. Thus, the author keeps the conversation as general as possible and give importance to the fact that the social, historical and cultural aspects are influencing the view of the interviewed. The researcher is trying to comprehend the complexity of the picture and interpret the data collected in the field to generate meaning and he is conscious that his background and the context in which he is operating are influencing his interpretation (Creswell, 2014).

### 3.1.1 Action research and workshops

Aspects of action research were adopted in order to run this thesis.

According to Herr & Anderson (2005), action research is a kind of research that is performed with insiders of an organization and it is best done when there is a collaboration between the actors involved in the problem under investigation.

Action research also implies adopting a series of steps, in an iterative way, to improve the knowledge of the problem under analysis and define a solution (Herr & Anderson, 2005):

- *Plan* the actions that are going to be performed,
- *Act* to realise the plan,
- *Observe* the effect of the implementation of the actions in the context,
- *Reflect* of these effects and use the findings to plan further actions.

The thesis contains aspects of action research because two workshop were performed with the division's personnel. A workshop implies the involvement and cooperation of people in a social activity (Brem, 2019; Gabriel, Camargo, Monticolo, Boly, & Bourgault, 2016). In this case, the author is going to collaborate with the people inside the division in two workshops in order to define the current and future implementation of circular economy. Because of the interaction with the employees of the division during the workshops, which are going to be described in detail in the upcoming sections, this paper contains an aspect of action research.

Workshops can stimulate creativity and brainstorming, and therefore favor the creation of new ideas (Gabriel et al., 2016). Workshops planned in an appropriate manner, in fact, are a good

way to involve employees in supporting the creation of new and useful ideas, and promote innovation (Brem, 2019; Gabriel et al., 2016).

The decision of running two workshops was taken together with the company supervisor during the definition of the objectives and activities of the thesis.

The methodology defined to run the workshops, because of their relation with action research, is different from the one used in the rest of the thesis.

The participants of were selected according the characteristics of the workshop group defined by Brem (2019). This author explains that a workshop group needs to be homogeneous (people with characteristics in common) and heterogeneous (there should be different features in the group) (Brem, 2019).

Guldmann et al. (2019) propose a design thinking framework that allows to achieve CBMI. This tool presents the way of thinking that could be adopted in order to promote the creation of a circular business model (Guldmann et al., 2019). This framework was used to shape the flow of the two workshops because of its relevance in creating a useful mind-set towards circularity and business model innovation.

The first step is the *introductory space* where the concept of circular economy and CBM is presented (Guldmann et al., 2019). The first workshop (W1) started with an introduction to circular economy and business model in order to align the knowledge of the audience about these concepts.

Then there is the *exploratory space* where CBM opportunities are explored in relation to the context in which the company is working (Guldmann et al., 2019). In this case, the group work of the W1, the following discussion and the data analysis previous to the first workshop were used in order to identify CE opportunities.

After that there is the *alignment space* were CBMI and current strategy and aspiration of the company are merged in order to define a good way to implement circular economy (Guldmann et al., 2019). This was done during the data analysis after the first stay in Finland and the W1.

Then there is the *ideation space* where the circular activities are defined (Guldmann et al., 2019). This step was performed during data analysis after the first stay Finland and the second workshop (W2).

Finally, there is *prototyping and testing space* where the ideas are further developed and better defined (Guldmann et al., 2019). This task was executed during W2 and following data analysis.

Bringing together the Guldmann et al. (2019) framework and the iterative steps of action research, the following methodology was adopted to run the workshops.

The first workshop (W1) was planned with the objective of introducing people to the concept of circular economy, defining what the current status of implementation of circularity in the division was and delineating the opportunities for improvement. Then, the workshop was performed, and the reflection on its outcome and the collected feedback allowed planning the second one. In fact, the data about the current implementation of circular economy were used to define ideas about its further implementation in the division. These ideas were then tested during the second workshop (W2). An accurate planning of the W2 allowed presenting the circular activities to the participants and discussing about their importance, feasibility and

prioritization. The observation and reflection about the outcome of the workshop 2 supported the definition of the circular actions that were presented as suggestions to the division in the findings of the thesis.

The workshops were also designed and planned with the support of wikiHow, that provided some useful heads up about how to behave and engage people, and the Circular Economy Toolkit by Evans & Bocken (2013) that provided some valuable hints about how to run a workshop to stimulate the adoption of CE in a company.

### 3.1.2 Case study

A case study method of research was also applied to answer the research questions.

Yin (2014) claims that when a researcher is answering to a "how" question is appropriate to use a case study, thus this method of research is going to be applied to answer to the RQs. In fact, the aim is to understand a real-world and contemporary phenomenon, in this case the impact of the implementation of circular economy on the division's business model, because its understanding is involving contextual circumstances pertinent to my study (Yin, 2014). In addition, a case study approach was selected because the main data collection method is qualitative and, along the research, an in-depth study of the division case was performed (Verschuren et al., 2010).

Therefore, in this instance, the rock and ore moving equipment division is going to be used as a case study in order to assess if and how the implementation of circular economy is going to influence its business model. The description of the division is going to be provided in the following section.

One of the problem related to case study is the generalizability of the results because of the fact that just one case is analyzed and it may not represent a general trend (Yin, 2014; Verschuren et al., 2010).

### 3.1.3 Introduction to the rock and ore transportation equipment division

The rock and ore transportation equipment division is part of the Sandvik mining and rock technology business area (Sandvik, 2019). The division is producing loaders and trucks to transport the mining material within a mining site. It is creating high performant and safe machines with different dimensions and capacities. These vehicles are mainly powered by diesel engines but the division is also producing electric ones with a cable constantly connected to the grid, called in this thesis electric cable machines, and electric vehicles powered by batteries. The machines can be either standard or custom-made according to the needs of the clients (Sandvik, N.A.d, N.A.c).

The division is manufacturing the machines in three plants located respectively in Finland, China and South Africa and then it is selling the units all over the world mostly to underground hard rock mining sites. The division is mostly selling the machines directly to customers. However, in certain cases they are renting or leasing them, or define a pay-per-use or result oriented contract with their clients (Int. 13; Int. 15; Int. 24).

Sandvik has also workshop worldwide, normally close to the customers, that have the role of performing all the after sale operations such as repair, maintenance and rebuilt. There is another division, which is providing spare parts and after sale services, that is taking care of these

processes. Despite the fact that this division and the rock and ore transportation equipment one are closely related, the communication between the two is not very frequent (Int. 18).

The rock and ore transportation equipment division has very high sustainability objectives. It has to work towards the 2030 corporate goals that prescribe to halve the emission of CO2, create zero harm to people, both inside and outside Sandvik, and play fair by achieving high sustainability targets and avoid being associated with labor and human rights violation (Sandvik, N.A.a). In addition, Sandvik has the goal of reaching 90% circularity by 2030. In order to do that, the division has to improve its energy and resource efficiency towards the achievement of zero waste, improve the recycling and circularity for their customers, and make the suppliers aim to the same circular goals (Sandvik, N.A.a). The division has also its own sustainability ambition. In relation to circular economy, the division aims at creating long lasting products with the possibility to extend the lifespan, minimize material, energy and waste, adopt a closed loop supply chain, enhance reuse and recycle, create a proper take back system, perform remanufacturing and consider the opportunity to sell functionality rather than ownership (Sandvik, N.A.c).

For these reasons, Sandvik and the division are very interested in circular economy and the benefits it can potentially provide. Nevertheless, as demonstrated by the outcome of the interviews, the personnel is not fully knowledgeable about the concept of CE and the way it can be implemented. Therefore, they asked the support of the author because, thanks to its background, he may be able to bring improvements in this direction and favor the adoption of circular practices.

## 3.2 Data collection

This section provides an insight into the way the data were collected during the research project. The various steps that were undertaken to collect the various information are presented in a chronological order to systematically illustrate how the data collection process was performed.

Because of the nature of the research questions and objectives, qualitative data were collected via a desktop research, interviews, observation and workshops.

### 3.2.1 First part of the research

After defining the scope and objectives of the thesis project with the Sandvik's and university supervisors, information about the concept of circular economy and the context in which the division was operating were started to be collected. The goal was to answer to the research question 1.1, comprehend what the current status of implementation of CE in the division is.

In order to gather accurate data and get a holistic view of the context in which Sandvik and the rock and ore moving equipment division are operating, a triangulation of method and sources was applied. Verschuren et al. (2010) explain that when a single case study is used, is convenient to adopt triangulation. Interviews, document analysis and observation were therefore used to properly understand the context in which the division is operating and improve the reliability and validity of the information gathered (Yin, 2014; Verschuren et al., 2010).

#### *Interviews*

The process of interviewing was conducted using a semi-structured approach and it was organized as presented below.

The author started by interviewing the company supervisors. The Sandvik's supervisor, a global environment, health and safety (EHS) specialist, was initially questioned to get a general

understanding of the background of the company. Then the two division supervisors, respectively EHS manager and specialist, were interviewed to better comprehend the context in which the division is operating.

These interviews helped defining the people who could provide the author more detailed and precise information about the various operations. In order to get a holistic understanding of the situation, people from the various steps of the division's value chain were interviewed. The various steps of the value chain, and consequently the people who needed to be interviewed, were defined following the Porter's concept of value chain presented in the figure below (Porter, 2004).

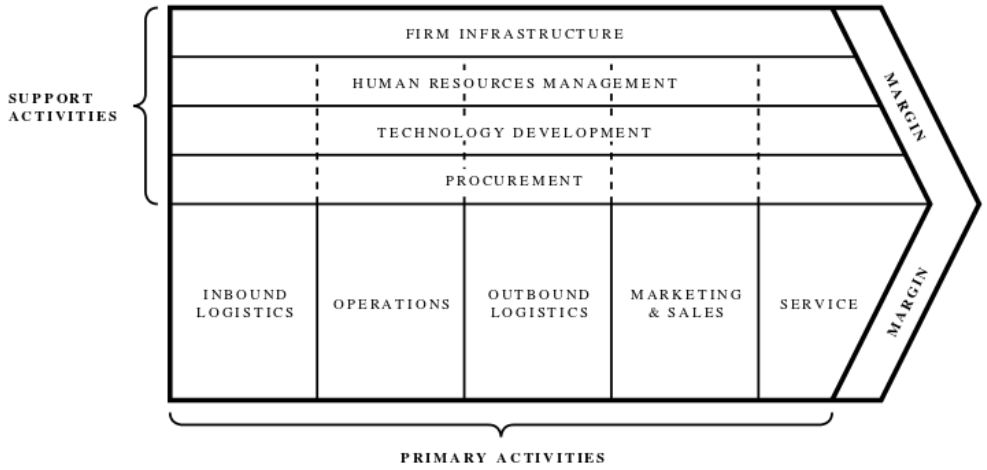


*Figure 3-1. The value chain.*

*Source: n.a.*

From the components of the value chain and from the understanding of the organizational structure of the company, these main steps of the value chain were defined and the following actors were interviewed:

*Table 3-1. Overview of the people interviewed.*

| **Product design** | **Supply** | **Manufacturing** | **Assembly** | **Sales** | **Logistic** | **After sale** | **Other** |
|---|---|---|---|---|---|---|---|
| Int. 1 – Product Sustainability<br><br>Int. 2 – Product Safety Manager | Int. 6 (follow-up questions) – Chief Procurement Officer | Int. 7 – Welding Manager<br><br>Int. 8 & Int. 9 (multiple interviews and follow-up questions) | Int. 11 (follow-up questions) – Assembly Manager<br><br>Int. 12 – Assembly Specialist | Int. 13 (follow-up questions) – Sales Support and Product Excellence Engineer | Int. 16 – Delivery Manager | Int. 17 – Product Line Manager Buckets<br><br>Int. 18 (follow-up questions) – Parts category | Int. 21 – American Supplier<br><br>Int.22 (Christina Hansson) – Global EHS Specialist |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Int. 3 (2 interviews) – Product Engineer manager<br><br>Int. 4 (follow-up questions) – Project Manager Electric Vehicles<br><br>Int. 5 – Life Cycle Manager | | – EHS Specialist & EHS Manager and Company Supervisors<br><br>Int. 10 (follow-up questions) – Area Supervisor & Team Leader test drive | | Int. 14 – Product Excellence Manager<br><br>Int. 15 (follow- up questions) – Sales support Engineer | | specialist, Rebuilt<br><br>Int. 19 – Warranty Manager<br><br>Int. 20 (follow-up questions) – Training Manager | and Thesis Supervisor<br><br>Int. 23 – Ex Employee |

*Source: Author.*

The outcome of the interviews was a comprehensive understanding of how the division is working and what kind of circular actions were already in place.

As table 3-1 depicts, interviews with multiple people from the same step of the value chain were realized to confirm the reliability and validity of the data, and the information collected were compared to observation and the one contained into documents. In addition, follow-up questions were asked via email or a new interview was scheduled in order to fill the gaps in the knowledge that the author identified when reviewing the interviews notes and/or listening to the recordings. In the interviews sometimes the snowball method was used because the next interview was selected on the basis of the findings obtained up to that point (Verschuren et al., 2010).

The interviews were conducted not only with actors internal to the company but also external ones were interrogated. One American and one Finnish supplier were interviewed to comprehend how the suppliers are going to be impacted by adoption of circular economy practices and if they would be willing to cooperate to facilitate the implementation of circular actions. An ex-employee was also interviewed to understand the company's background, what they were doing and better comprehend how to behave and approach the division's personnel.

### *Document review*

The document review started with studying the official website of the company followed by the documents that are publicly available, such as the sustainability and annual report. Specific documents related to the division and its operations were then provided by the supervisors, mainly as reports or PPT presentations, and allowed to better comprehend the way the division was working and in particular the characteristic of the operations, the organizational structure, the sustainability ambitions and the business performances.

In addition, some documents external to Sandvik were analyzed in order to do benchmarking and understand how the entire mining equipment industry is operating and what the general trends are. However, the accessible information were limited and could not be analyzed to

confirm their validity and reliability. The competitors' websites and public available documents were studied to comprehend what was their status of implementation of circular economy and to get some inspiration about what areas could the division improve and what were the threats and opportunities coming from the market. Mining industry associations were also analyzed to understand what the general trends that characterize the industry are, mainly in relation to circular economy and sustainability, and in what direction should Sandvik and the division move in the future.

### *Observation*

During the 2 weeks stay at the Finnish plant at the end of June and the 1 week one in mid-August, the author was able to observe the way the company was operating and how it was organized. A tour of the productions plants and the offices, organized by the supervisors, allowed to concretely understand how things are working in the Finnish headquarter and the behavior that the personnel has.

Despite the onsite visits were not recorded in any way because of confidentiality issues, they were still very relevant to better comprehend the context in with the division is operating.

### *Workshop 1*

The first stay in Finland terminated with a workshop with personnel from the rock and ore transportation machines division with the aim of further understanding the current status of implementation of circular economy.

There were 12 attenders to the workshop from different departments of the division:

1. EHS Manager
2. Delivery Manager
3. Assembly Manager
4. Product Development Manager
5. Category Manager Light Steel Fabrications & Machining
6. Logistic Manager
7. Training Manager
8. Product Line Manager, Large Loaders
9. EHS Specialist
10. Product Sustainability
11. Unit Sourcing Manager
12. Product Line Manager, Trucks

As we can understand from the roles of the participants, the group was homogeneous, because the attenders are working for the rock and ore transportation equipment division and are covering managerial roles, and heterogeneous, because they are coming from different departments, backgrounds and have different knowledge about different steps of the value chain (Brem, 2019).

The objective of the workshop was threefold.

The first aim was to introduce people to the concept of circular economy and its components. During the interviews, people were inquired about their knowledge of this concept and just in a few cases a good answer was provided. Therefore, a good and comprehensive introduction to circular economy was needed to provide them a solid knowledge about the concept. In this way,

the author was able to align the knowledge of the audience about circular economy and make them perform the group activity in a better and more efficient way.

The second goal was to understand the current status of implementation of circular economy in the division.

This leads consequently to the third objective, defining what potential actions could additionally be done.

In order to achieve these aims, 5 main activities were performed. Appendix B provides a more comprehensive overview of the actions performed.

1. Introduction to circular economy, its concepts and their economic and environmental benefits and risks, and the impact of the implementation of this concept on the corporate sustainability objectives and the ambition of the division. This activity had the aim of aligning the knowledge about CE of the audience.
2. Review of the definition of business model and introduction to the *value mapping tool* by Bocken et al. (2013) to define the way of thinking of the participants about the current and future implementation of CE.
3. Group work to delineate the current and future adoption of circularity in the division.
4. Discussion about the outcome of the group work where each team was presenting to the others its findings and the reasons behind them. The other groups were incentivized to ask questions and provide valuable feedback.
5. Presentation of the author's point of view and comparison with the outcome of the discussion.
6. Feedback about the workshop.

The outcome of the workshop was a list of circular activities currently performed by the rock and ore transportation equipment division and a one of additional potential application of circular economy. The data collected were added and compared to the findings of the qualitative analysis performed before and during the first stay at the Finnish plant. They allowed getting a more holistic and in depth view about the current implementation of circular economy in the division and therefore answering the RQ1.1.

### 3.2.2 Second part of the research

During the first stay in Finland the author, thanks to the support of the division's personnel, collected a great amount of information about the way the division is working and implementing circular economy, and it was able to understand what the potentials of improvements were and what their economic and environmental impacts are. This allowed answering to the RQs 1.2 and 1.3.

In order to elaborate of these additional circular actions in an appropriate and in depth way, an ad hoc literature review was performed. Furthermore, the circular economy implementation impact framework was developed and additional research was performed in this direction.

#### *Literature review about the future circular actions*

This section is presenting the literature review performed to elaborate on the potential additional circular actions.

The first suggestion for improvement towards circularity is related to creating products designed for circularity. Therefore, using Scopus and LUBsearch as search engines, the keywords

"circular design", "(design for) modularity", "design for upgradability", "design for recycling", "design for long-lasting", "design for life extension" were adopted. A small amount of literature that could fit the division's circumstance was found about these topics and the literature already collected about circular economy was used to elaborate about this recommendation too.

In order to elaborate about the take back system recommendation, sources about this concept were found using the search terms "take back system" and "closed loop supply chain" on LUBsearch and Scopus.

Another suggestion was to move the business model towards product service system (PSS). The same databases were used to find relevant articles using the key words "product service system", "product service system benefits/drawbacks", "product service system implementation", "product service system and customers".

The proposal about scale up the rebuilt practices was developed with the support of literature about remanufacturing, found using the key words "remanufacturing" and "refurbishing" on Scopus and LUBsearch, and the benchmarking about the competitors performed in the initial part of the research.

The suggestion about electric vehicles and battery end-of-life management was defined mainly via the interview with a division's project manager and the support of a thesis work of an alumnus of IIIEE. His thesis provided some references and key words, such as "electric vehicles battery disposal", "battery disposal management" and "battery secondary use", which were very useful to find articles and elaborate on this topic.

Other suggestions were about improving resource efficiency and sustainability, and about packaging recycling. The literature review already performed about circular economy and the qualitative data collected during and before the stay in Finland were very useful in developing these recommendations.

Finally, the suggestion about operations was created mainly via the interviews conducted with a Chinese EHS manger and the information collected during the workshop and previous interviews.

### *Literature review about the framework*

The circular economy implementation impact framework has the aim of comparing the current business model with the ones that are going to be developed because of the further adoption of circular economy. Therefore, this tool allows answering to the RQ1 because it permits to understand the magnitude of the impact that the implementation of CE has on the present division's BM.

Literature review about (circular) business model was used as basis for developing the framework. These articles were integrated with the one about implementation of circular economy. The search terms "circular economy implementation", "framework to implement circular economy" and "circular business model innovation" were used on Scopus and LUBserach to discover other frameworks and tools that have been developed by experts in the field to support the adoption of circular economy in a firm.

Several frameworks have been discovered but just a few were relevant to the research context and/or have been developed in an appropriate way that could have made them useful.

### Additional qualitative data collection

Other interviews have been conducted in order to collect more information about the operation. Interviews with a business line manager – surface drills and exploration (Int. 24), an EHS manager in the Chinese plant (Int. 25) and a Finnish supplier (Int. 26) were conducted. Valuable data about the selling process, about the Chinese factory and its way of working, and about the relation with suppliers and the impact on them of a greater implementation of CE were gathered and provided a more holistic picture about the current business model of the division.

### Workshop 2

During the second stay at the Finnish plant, a second workshop was conducted. The objective was to discuss about the suggested future circular actions and prioritize them. These CE opportunities were defined during the aforementioned research actions.

There were 14 attenders to the workshop from different departments of the division:

1. EHS Manager
2. Delivery Manager
3. Assembly Manager
4. Training Manager
5. EHS specialist
6. Product Sustainability
7. Unit sourcing Manager
8. Global EHS Specialist (Thesis supervisor)
9. VP Global EHS
10. Category Manager
11. Manufacturing Specialist
12. Product Safety Manager
13. Product Engineer Manager
14. Product line Manager, Trucks

The roles of the participants depict that once again the group was homogeneous and heterogeneous because of the same reasons of the W1 (Brem, 2019).

The second workshop had 3 objectives. The first one was to present the future circular economy opportunities and discuss about them. The second was to assess their importance and feasibility. Finally, the last goal was to prioritise these actions and define the 3 most important ones to make the author assess their impact on the current business model.

6 activities were organized to meet these objectives. An in-depth overview of the actions is provided in Appendix C.

1. Presentation of the circular economy opportunities, their benefits and risks. The author was also open to additional suggestions of implementation.
2. Presentation of the prioritisation framework, depicted in figure 3-2 and described in Appendix D.
3. Group work to prioritise the actions using the aforementioned framework.
4. Discussion about the outcome of the group work where each team was presenting the prioritisation of a certain actions and the others where commenting on that to define its final priority.

5. Decision of the 3 most important actions to allow the author to assess their impact on the current business model.
6. Feedback about the workshop.

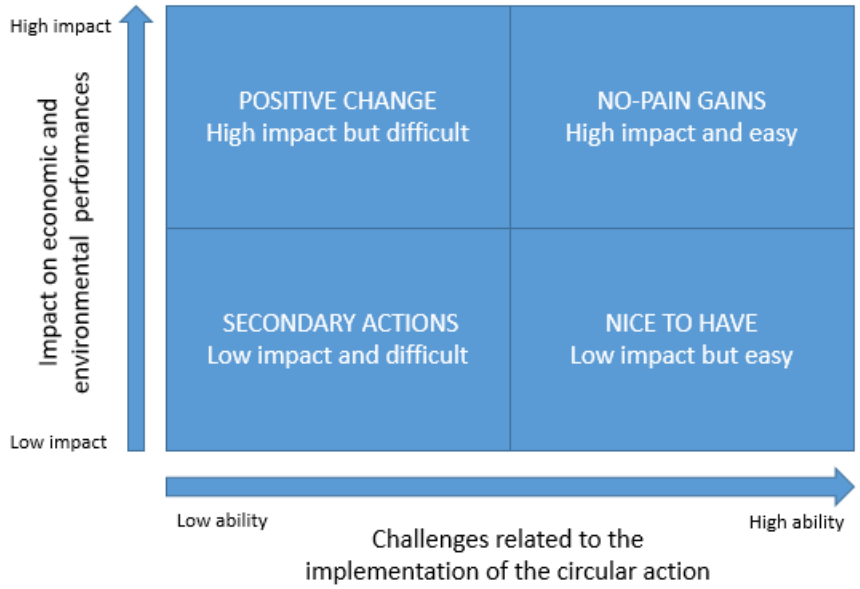


*Figure 3-2. Circular actions prioritisation framework.*

*Source: Author.*

The outcome of the workshop was a prioritisation of the suggested circular activities and the definition of the most relevant ones, presented in section 4.4.

## 3.3 Data analysis

The data collected were analyzed using the circular economy implementation impact framework. It allowed having a good description of the current business model and getting a visualization of the impact that the further adoption of circular economy has on the value creation architecture. The present BM was placed on the left and the changes required to implement the actions were recorded in the columns on the right, facilitating the comparison and therefore the definition of the magnitude of the variation. This visualization allowed also elaborating on the possible changes needed to implement the circular economy opportunities.

In the data analysis process no content analysis was performed. The great amount of interviews was the first barrier towards the adoption of this kind of research tool. The second motivation is related to the fact that the author was not knowing what kind of information he was going to get from the interviews. Diverse and various data were gathered during the interview process in order to get an holistic view of the way of working of the division and its current implementation of CE, therefore it would not have been useful to establish codes and themes. Instead, the author, with the consensus of the interviewed, recorded the interviews. The data were collected in a synthesis matrix were on the column there were the various steps of the value chain and on the rows the tasks performed by the department, the current situation of the operation, the objectives, the environmental and circular aspects considered, and potentials of improvement. This partition was selected to better comprehend what circular actions were already in place, using the information about the present way of running the business, and what could be the potentials of improvement, according to the objectives, environmental and circular aspects, and

the gap between the way CE should be theoretically applied and the way it was currently adopted.

## 3.4 Methodology and research questions

This section summarizes the way the methodology adopted allows to answer to the RQs.

The first part of research and the workshop 1 allowed getting a good understanding of the concept of circular economy and its current adoption in the division, and therefore answering to the research question 1.1.

The second part of the research made the author understand what were the potential of improvement, elaborate on them to understand how they are impacting the economic and environmental performances of a firm. The second workshop permitted to define the actions with the highest priority and further elaborate on them. In this way, the RQs 1.2 and 1.3 were answered.

The research question 1 was responded thanks to the development and application of the circular economy implementation impact on the current business model.

Finally, an overall assessment of the adopted methodology allowed answering to the RQ 2 and comprehending if it was able to promote the implementation of CE in the division.

The figure below provides a visualization of the relation between the various steps of the research (marked in blue) and the research questions (marked in orange).

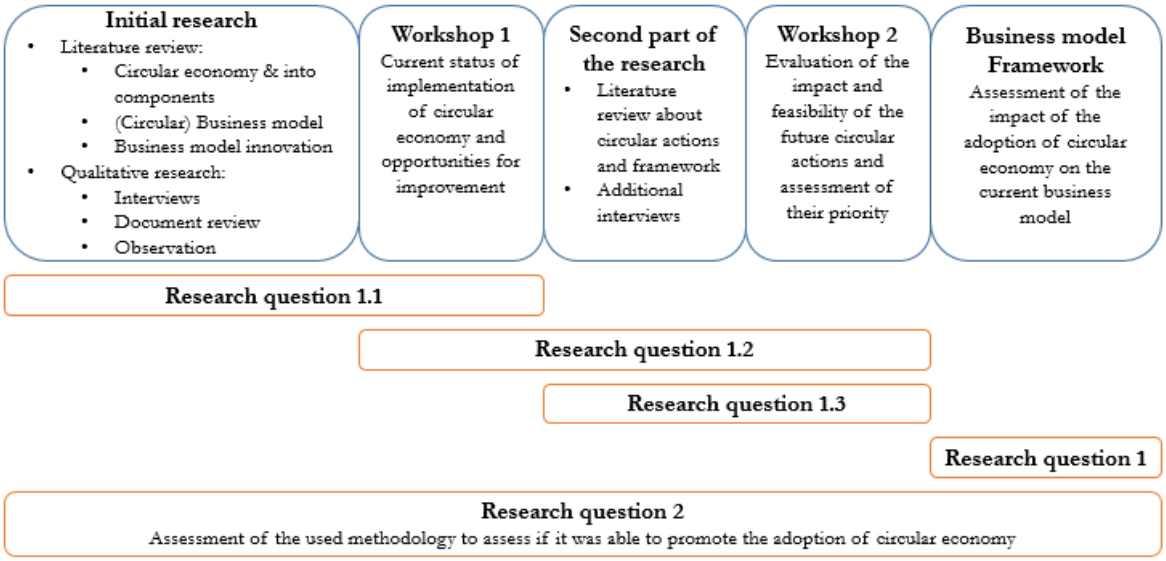


*Figure 3-3. Relation between RQs and research methodology.*

*Source: Author.*

# 4 Results

This chapter depicts the results of the qualitative research.

The triangulation between interviews, documents review and observation, integrated with the information collected during the first workshop, provided data about the context in which the Sandvik's division is operating, its business model and the current implementation of circular economy.

The information collected during the second part of research and the workshop 2 allowed the author to collect data about the future adoption of CE and the prioritized circular actions, and elaborate about them.

The following sections present these findings.

## 4.1 Current business model

Before introducing the circular actions performed by the division, we have to comprehend the context in which it is operating. Following the outline of the circular economy implementation impact framework, this section presents the current business model of the rock and ore transportation equipment division and the circular actions already in place.

The table below represents the current business model using the components of abovementioned framework, while table 5-1 represents the current business model in the framework.

*Table 4-1. The current business model of the division according to the components of the circular economy implementation impact framework.*

| **Framework components** | **Description** |
|---|---|
| Trends and drivers | The division is facing the current challenges and trends related to working in the mining industry.<br><br>In the In 2015, the EU created an Action Plan for circular economy and also the mining sector was influenced. According to Euromines, the European mining industry association, despite the increasing trends in reusing and recycling, the mining industry is supposed to keep supplying virgin raw materials in the upcoming years. The European mining industry aims at improving its resource and energy efficiency, and enhancing its sustainability performances. The implementation of circular economy is considered as a fundamental pillar to do achieve these aims.<br><br>Sandvik competitors have adopted several circular practices, such as takeback their products, reuse them or their parts, remanufacturing and recycling at the end-of-life, and one of them has also put in the market electric vehicles powered by batteries. Therefore, the entire industry is moving towards circular economy and electrification of the fleet. |
| Adoption factors | The division is characterized by a culture that embrace innovation and improvement. This is going to be a good driver for the adoption of circular economy. In addition, the implementation of CE is supported by the top management who made it one of the 4 main pillars of the 2030 sustainability ambition. Despite the adoption of circular practices is still in its early stages, the company has already adopted several CE actions, e.g. good resource and |

| | |
|---|---|
| | energy efficiency, remanufacturing and other product life extinction practices, which constitute a good starting point for a further application of the principles of circularity. However, the knowledge about circular economy and how it could be implemented is still underdeveloped.<br><br>The company is also in a good economic situation that allows not only to invest in innovation and development, but also to support its client by providing financial support in case of a leasing contract to purchase a unit.<br><br>The division has a wide network of workshops globally that are close to the customers and can efficiently provide life extension practices. However, the communication between upstream (designers, R&D and manufacturing) and forefront (workshops) actors is not very frequent. Therefore, the needs of the people who are maintaining, repairing, remanufacturing and recycling the machines are not well considered, with a consequent likely negative impact on the effectiveness and efficiency of these practices and the adoption of circular economy.<br><br>The division works in conformance with the safety and environmental regulation and it obtained several ISO certifications. However, operating globally presents several challenges because of the different legal system of the various countries. For instance, the machines working in the Middle-East are subject to the local law and not the Swedish one. Therefore, providing functionality rather than ownership in those territories is not possible because units cannot be subject to Swedish regulation. Additionally, some developing countries are characterized by an absence of a good recycling system and machines cannot be disposed correctly at the end-of-life (EOL).<br><br>Another challenge is related to serving a global range of customers. Some of them are willing to keep the machines for as long as possible and use them until the very end-of-life. Also, in some mines, in order to take out a unit, is necessary to stop the entire mining operations for several hours. Therefore, the machines are left inside the mining site because of the loss related to halt the various mining activities. The units are used in rough and dangerous conditions that expose them to fast worn out and accidents. Additionally, the operators are not always using the machines carefully and this can further improve the likelihood of a damage. These facts can hamper the adoption of take-back and consequently of narrowing and extending resource loop practices. |
| Value proposition | The division is providing high quality, safe and performant machines to its customers. Clients are also able to customize their machines and make them tailor made according to their needs. It is also possible to extend the life cycle of machines via maintaining, repair, rebuilt and upgrade.<br><br>Machines are available in an automated version and electric with cable or batteries. Customers can purchase them in different ways according to their needs. In fact, together with direct sale, there is the possibility to rent or lease them, or make a result oriented contract.<br><br>Finally, the division values sustainability issues and tries to run its business in a responsible and conformant manner. |
| Customer segments | The division is mainly serving underground hard rock mining sites. |
| Customer relationship | They have workshop distributed all over the world close to the mining sites of the clients. |

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| Take back | At present, the division has the policy of taking back machines that are not older than 5 years because of quality and functionality concerns. |
| Key resources | The company has 3 manufacturing and assembly plants respectively in Finland, China and South Africa. It also has workshop worldwide located close to customers' mining sites.<br><br>The division is also collecting data about the functioning of the machines, that are displayed real time to both Sandvik and customers, and allow providing quick and effective after sale services and constantly improving them.<br><br>The division can also count on skilled and qualified personnel. |
| Key activities | The main activities realized to provide good machines and after sales services are:<br><br>• Purchasing the raw materials and components from of suppliers selected according to the quality of their goods/service and responsibility.<br>• Manufacturing in efficient and well-organized manufacturing plants.<br>• Assembling the machines, and the maintaining and rebuilt kits.<br>• Maintenance and repair of machines.<br>• Rebuilt to make the units last for another lifecycle and upgrade them. |
| Key partnerships | The division has established long-lasting relationship with some suppliers of main components. Sandvik is also collaborating with logistic companies that are delivering its products and parts worldwide. The division is also working with recycling companies that are taking care of disposing its waste correctly. |
| Channels | The division has sales areas that are taking care of customers in the various regions of the world.<br><br>Sandvik has workshops with own personnel close to mining sites of customers.<br><br>There is a separate division that is taking care or delivering spare parts and performing the after sale activities. |
| Revenues streams | Sandvik is making money mainly via direct selling of its machines. However, it also adopts different kind of selling methods according to the needs and wants of its customers. Renting, leasing (with possibility to get financing from Sandvik) and result oriented contracts are the main additional selling strategies that are provided to the clients.<br><br>Another revenue stream are the after sale operations such as selling the parts and components and perform the activities required for the maintenance, repair and rebuilt operations. |
| Cost structure | One of the main cost incurred by the division is the one of personnel that is operating worldwide. Then, there is the cost of running 3 manufacturing plants and shipping the units all over the world. |
| Stakeholders involvement | Suppliers are the main stakeholder that are involved. Sandvik has the aim of making them 90% circular in order to extend the adoption of circular economy practices also along the supply chain.<br><br>Logistic companies are the second actor that is involved in order to deliver the machines and spare parts to customers and organize the take back activities. |

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| Environmental benefits | Sandvik is creating safe and high performance machines. This fact has indirect positive environmental impacts. For instance, using less steel in machines makes Sandvik save money in the manufacturing step and realize lighter units, allowing them to be faster and consume less fuel making the customer save on diesel and ventilation of the mining site. Using less raw materials has the indirect positive impact of preventing environmental degradation and make the machines use less fuel reducing consequently pollutants emission.<br><br>Moreover, during maintenance o repair operations, some of the components that are changed are repaired and used for future operations, and the company is also performing remanufacturing (called rebuilt). These two actions allow to extend the lifespan of machines and their components and reduce the use of virgin raw materials with a consequent positive environmental effect.<br><br>Sandvik is periodically checking its manufacturing plant(s) in order to identify and stop leakages and improve the overall resource and energy efficiency. The company also have a good waste management system thanks to the support of a recycling firm and the Finnish plant uses energy only from certified renewable sources. |
| Environmental costs | Sandvik is providing its customers with a machine manual that contains information about who to recycle it correctly at the EOL. However, the company is not checking if recycling is happening. An inappropriate disposal of the machines can cause serious damages to the environment and the ecosystems within it.<br><br>Despite the good waste management system in place and the partnership with a recycling company, plastic packaging coming from suppliers is not recycled and the one used to ship the spare parts to clients is not recyclable.<br><br>In the delivery operations, environmental concerns are of secondary importance. |
| Continuous reiteration of sustainability and circular performances | At present, the sustainability performances are checked but the circular ones are not characterized by the same attention. |

*Source: Euromines, 2011; Miller & Spoolman, 2012; Bourguignon, 2016; Nußholz, 2017; Kirchherr et al., 2017; Prieto-Sandoval et al., 2018; Euromines, n.d.; Caterpillar, 2018, n.d.; Epiroc, 2018, n.d.; Komatsu, n.d.; Nordmayer smag, n.d.; Sandvik, 2018, Sandvik, N.A.a; Sandvik, N.A.b; Sandvik n.d.-a; Sandvik, n.d.-b, Sandvik, n.d.-c; Int. 2; Int. 4; Int. 5; Int. 6; Int. 8; Int. 9; Int. 10; Int. 11; Int. 13; Int. 14; Int. 15; Int. 16; Int. 18; Int. 19; Int. 20; Int. 24; Int. 25; W1.*

## 4.2 Present application of circular economy

As the description of the current business model depicts, the division is already implementing certain aspects of circular economy. This subchapter is presenting them according to the three pillars of CE. Thus, this section is answering to the RQ 1.1 because it presents the current status of adoption of circular practices by the division.

### 4.2.1 Narrowing resource flow

Some units are created using a lighter but still robust steel that is allowing to use less materials and therefore decrease the weight of the machine, with a consequent beneficial impact on the

fuel efficiency, speed and tire wear (Sandvik, n.d.-b, n.d.-c; Int. 13; W1). Their metal supplier also provide them a steel that is 30% composed of recycled materials (Int. 1; Int. 7; Int. 26).

Sandvik also tries to use materials that are more environmental friendly and minimize the one of toxic substances (Int. 9; W1). The division, in the Finnish plant, uses soap for cleaning the machines that it is not harmful for the environment and the ecosystems within it and a paint equipment cleaner that is not using toxic chemicals. This is made first to safeguard personnel's health but also to protect the environment (Int. 9; Int. 25). The division is also using non-toxic paint and trying to avoid painting as much as they were doing before. In the past the units were repainted after every test drive, now they just repaint the parts that have been damaged during testing. In this way, they halved the use of paint (Int. 9).

When delivered to the customers, the machines manufactured in the Finnish plant are not packaged but sprayed with a protective and water based protective film to avoid using packaging (Int. 9; Int. 7; Int. 10). Moreover, components are not sent anymore to a central logistic facility in North Europe, unpackaged, repackaged and then shipped to customers but are delivered directly to customers saving energy and money as well as packaging resources (Int. 11; W1). Furthermore, for packaging spare parts they use standardized cardboard boxes instead of wooden ones. In this way, they use less material and make the process faster and more efficient (Int. 11).

During the test drive, the spilled oil that is leaking from the machines is collected in a tank below the testing area to prevent harmful spills to the environment (Int. 9). The division is also creating machines with separate oil tanks for the various hydraulic systems in order to reduce oil waste and the magnitude of the potential spills (Sandvik, n.d.-b, n.d.-c).

In the Finnish plant, they are also checking the manufacturing plant's leaks twice a year and once a year there is an external company that is coming auditing the plant energy efficiency (Int. 9). The Chinese plant is also subject to periodical check to constantly improve energy efficiency (Int. 25).

The division is substituting lights with LED ones and in Finland they are using certified renewable energy coming from bio and hydro energy (Int. 1; Int. 8; W1).

Sandvik is installing Swedish manufactured engines that are fuel efficient and allow low emissions. Additionally, they offer as an add-on to their clients a particulate filter that further reduces the emissions. The division also share info about product use in hard condition to allow the engine suppler to constantly improve its products (Sandvik, n.d.-b, n.d.-c; W1).

Finally, they adopt digitalization to make the more repetitive tasks performed by technology and let the people do the actions that are of added value to the customer. The adoption of digitalization also supports the optimization of processes and tasks (Int. 14).

### 4.2.2 Extending resource loop

The machines are designed for maintenance and repair in order to ease these practices and make this process safer for the personnel who is going to perform these activities (Sandvik, n.d.-b, n.d.-c; Int. 3).

The division tries to reduce the number of components and standardize the parts as much as possible to facilitate the production phase, the management of the stock and reduce waste. This fact facilitates the life extension practices too (W2).

The division is also taking advantage of a powerful ICT (information and communication technology) system that is using big data to provide real time information about the functioning of the machines to both Sandvik and its clients. In this way, it is possible to constantly check the units, understand if there is something that is not conformant with normal working and, in case, perform maintenance or repair (Int. 8; Int. 9; Int. 19; Int. 20).

The division is mainly selling their machines directly to customers and then it is providing after sale services to prolong the lifespan of machines. However, in some cases, it is adopting a product service system way of selling. Some of the machines, in fact, are rented, leased, with the possibility to get a financial aid by Sandvik, or provided as a service in a cost per ton of ore moved contact (Int. 20; Int. 24).

Another way of prolonging the lifecycle of the units is via rebuilt. Rebuilt is a practice inspired by the concept of remanufacturing where used machines are collected and restored to their original manufacturing specifications with also the possibility to upgrade them to the latest functionality. The rebuilt is performed by the workshops that the company has worldwide close to the main mining sites (Int. 11; Int. 18). In order to perform the rebuilt, the division is using new parts and components and it is only receiving the ones needed, and thus there is not waste. In some cases, the spare parts are delivered directly to the customers (Int. 11; Int. 12). At the moment the rebuilt kits are personalized according to the needs of the customer but in the future, with a likely higher amount of rebuilt to be performed, they are planning to create standardized rebuilt kits (Int. 18). The parts that are not used anymore after rebuilt are probably recycled (Int. 18).

Finally, in case a big part is breaking, such as an axel, converter, transmission, they are fixing it and use it later to repair another machine (Int. 19; W2).

### 4.2.3 Closing resource loop

The division is working with a recycling company that is handling its waste in an appropriate way (Int. 8; W1). They are recycling cardboard, metal and wood pallets (Int. 7; Int. 8; Int. 9).

Some of the pallets (made of metal or wood) are given back to the supplier using the same logistic trucks, while others are sold to other customers or reused (Int. 8; Int. 9; Int. 14).

Sandvik is also providing to its customers instructions on how to correctly dispose and recycle the machines at the end of their lifecycle. However, the lack of a proper recycling infrastructure in certain areas is hampering the proper disposal of the units (Int. 1; Int. 11; W1).

The division also wants to explore possibilities of cooperation with other companies for industrial symbiosis. They are planning to provide their wood waste to an East European furniture manufacturer to give a second life to their wood waste (W1).

## 4.3 Future potential circular actions

This section is presenting the potential actions that can be implemented by the division to further adopt circular economy. Here, the collected qualitative data are mixed with the one gathered during the literature review in order to get a more complete description of the CE actions. Therefore, this sub-chapter answers to the research question 1.2 and 1.3 because it presents the circular economy opportunities and their economic and environmental impact.

### 4.3.1 Design improvements for circularity

The machines design can ease the adoption of circular economy (Nußholz, 2018). The application of CE, in fact, starts with product design and the end of life management needs to be planned when designing the machines (EMF, 2015; Ghisellini et al., 2016; Jain et al., 2018).

#### *How the division is performing*

The machines are designed to be safe and performant, and they are already designed to facilitate maintenance and repair (Sandvik, n.d.-b, n.d.-c; Int. 3). There is also the aim to improve the modularity of machines but more concrete actions are needed to achieve this goal (Int. 3). However, other aspects of the design of circularity are not considered.

#### *Benchmark*

Some of the division's competitors have standardized the repair, maintenance and rebuilt kits to facilitate these practices (Caterpillar, 2018, n.d.; Epiroc, 2018, n.d.). Furthermore, one of the competitor is providing them to its clients in maximum 2 days (Komatsu, n.d.).

A Swedish competitor is also providing to its customers all the tools required to perform the after sales actions, creating new revenues streams (Epiroc, 2018, n.d.).

Modularity is a feature that allows an American competitor to remanufacture in an easy and fast way the machines and sell them as second hand. The same competitor is designing the machines, and especially their frames, for long-lasting (Caterpillar, 2018, n.d.). This characteristic allows creating machines that can last longer and provide more profitability and cost saving to the customers because of the longer time they can use the machines without buying a new one (W1). The durable and reliable machines are also sold as second-hand, making the company earning additional money (Caterpillar, 2018, n.d.).

#### *How the division can improve*

Contrary to repair and maintenance, the rebuilt is not included in the design of the machines (Int. 3). The rebuilt now works fine thanks to the experience of the personnel in the workshops and the low amount of rebuilt asked by the clients (Int. 18). The workshop are also supposed be able to handle a future higher amount of rebuilt because of the present low level of saturation (Int. 18). But, in order to facilitate this operation in the future, when the flow of units that need rebuilt is likely to rise, designing the machines for compatibility could facilitate this practice (Bocken et al., 2016). In this way, it would be easier to refurbish and upgrade the old machines using new parts and components (Bocken et al., 2016).

At the moment, the recyclability of the machines at the end of their lifecycle is not kept under consideration (Int. 3). Sandvik is providing information to the customers about how to dispose them correctly but they have no data about how complicated is to perform this task (Int. 1; Int. 11). For this reasons, there is the potential of improving recyclability of the machines. The design for recyclability can make the units easier to disassemble and facilitate the separation of the various components and materials. Moreover, this design strategy prescribes fewer or no materials combinations, to avoid being incapable of separating them, and a smaller amount of toxic materials, to prevent the need to dispose them correctly and to put the people who are performing recycling and the environment in danger (e.g. Blomsma & Brennan, 2017; EMF, 2015; Ghisellini et al., 2016).

In addition, the division recognized that its units could be more durable. The design for long-lasting can make the machines and their components last longer and better satisfy the customers' needs (Bocken et al., 2016; EMF, 2015; Schenkel et al.; Blomsma & Brennan, 2017).

In order to facilitate and improve the safety of the after sale operations, it is very useful also to design the units for dis and reassembly (Ghisellini et al., 2016). Design machines for modularity can deeply support the these practices too, for this reason it is considered as one of the best way to facilitate the implementation of a closed loop supply chain (Schenkel et al., 2015).

As Sandvik's competitors are doing, the division could standardize the repair, maintaining and rebuilt kits to make these actions faster and more efficient. In this way, it is also possible to deliver them within a smaller amount of time, reducing the downtime and better satisfy the customers. Furthermore, in case these practices are performed by other companies, the division could provide a container with all the tools and equipment needed to execute these tasks (Epiroc, 2018, n.d.).

Design improvements could also come thanks to a better interaction and communication with the division that is taking care of the spare parts and after sale services. This forefront division could provide useful ideas about how to improve the design of machines to ease the after sales practices (Int. 18). At present, the cooperation is not very frequent (Int. 18) and this can negatively influence the effectiveness of these services and a better implementation of circular economy.

### *Benefits and risks*

Design is a fundamental enabler of circular economy and can bring benefits to the division (EMF, 2015).

The design for compatibility allows speeding up the rebuilt process, making it more efficient and less costly, offering a faster, cheaper and high quality service to the customers.

Design for modularity facilitates the assembly and disassembly and therefore the manufacturing processes, and ease and speed up the repair and maintenance practices. Used modules can be removed, remanufactured and used for repair, maintenance, to create refurbished machines or, if their quality is good enough, in the rebuilt process. Also, it is possible to upgrade singles modules while leaving the rest of the unit as it is. Modularity also facilitates the customization because it is going to be possible to install different modules according to the customers' requests (Krikke, le Blanc, & van de Velde, 2004; Xing & Ness, 2016; Sianesi & Brandolese, 2016).

The division, by designing the machines for long-lasting, could sell the spare parts for maintenance and repair for a longer period of time and making more money. Designing for duration can also be good in case the division wants to adopt a product service system business model because machines last longer and are more reliable. Also durable machines reduce the need of manufacturing new ones and therefore the need of virgin resources, energy and the production of waste, with a positive effect on the economic and environmental performances of the company (Prieto-Sandoval et al., 2018).

Facilitating the recycling operation would also allow Sandvik to be able to recover as many materials as possible from used machines, sell the materials to recycling companies and earn money (Prieto-Sandoval et al., 2018). Moreover, the division can improve its image thanks to the positive impact on the environment because of the reduced environmental degradation caused by a smaller extraction of virgin raw materials (Ghisellini et al., 2016).

Furthermore, improving the communication with internal and external actors can bring feedback and suggestions that can support the continuous improvement of the design and processes (EMF, 2015).

There might be significant challenges and drawbacks in improving the design of products for circularity that can constitute a barrier to the implementation of CE (Roos, 2014).

The division pointed out some challenges related to design machines for compatibility and recyclability because it might negatively influence the cost of production, quality, safety, duration and performances of the machines (Int. 2; Int. 3). Sandvik cannot risk being liable for and accident and thus the machines need to be of high quality all the time (Int. 2).

Moreover, it is difficult to design products for modularity because of the low amount of units they are producing and the fact that at present the customers can heavily personalize the machines and also create tailor made ones. The modules are also complicated and bulky, and it might be complex to store them while waiting for being used (Int. 3; Int. 11).

The division also recognized that improving the design to make units more durable might require changing the materials used with a consequent negative impact on the cost structure of the company. Also, a machine with a long life span might require a different shape and major changes in the design that can negatively impact its production costs, performance and safety (Int. 3).

There is finally the potential problem that durable machines, with the possibility to further extend the life cycle, could cannibalize sales of new machines (Linder & Williander, 2017).

### 4.3.2 Resource efficiency and sustainability

Exploring new opportunities for materials improvements can support the division in creating more performant and sustainable units and bring benefits to the economic and environmental performances of the division (Bocken et al, 2016; EMF, 2015; Ghisellini et al, 2016; Kirchherr et al., 2017).

#### *How the division is performing*

There is the willingness to keep exploring the market looking for innovation in the field of material technology (W1).

Some units have been realized with fewer materials or new substances. This fact is making them lighter, more fuel-efficient and performant (W1).

Sandvik also aims at improving the amount of automated vehicles. The absence of the cabin in these units can drastically reduce the weight and improve the performances (Int. 3) and this can be another way to provide benefits to both the company, its clients and the environment.

The division is also exploring the possibility of cooperating with 3D printing manufacturers in order to have better and more sustainable products (W1). 3D printed materials are more resource and energy efficient and can bring benefits to the sustainable performance of the company (EMF, 2015), therefore it might be a good idea to explore the possibility to purchase these materials.

Finally, the division is planning to install reusable filters during the test drive instead of the current disposable one to avoid the unnecessary production of waste (W1).

### *How the division can improve*

The aforementioned materials developments brought to certain models could be transferred to the other ones to improve their sustainability performances and make them more appealing to customers.

Reducing the amount of toxic substances is another way to bring benefits to the firm (Bocken et al, 2016; EMF, 2015; Ghisellini et al, 2016). The division could use biodegradable oil in the hydraulic systems rather than the present toxic one. The proximity of the workshops to the customers, and the role they have in the maintenance of machines (Int. 18), could allow Sandvik to keep making the units running using bio oil (Int. 9; W1). In addition, they could change the liquid of the A/C system of the machines with a non-toxic one. However, the current one is not flammable and therefore it is suitable and safe in case of a fire. They could look in the market if there is one that can be used without negatively impact the flammability of the vehicle in case of a fire (W1).

Bio-diesel could be used during the test drive. A local bio-diesel producer can become supplier. The division is already supplying food waste to them and a partnership could be established to send the also the food waste coming from a close cafeteria and get discount on the fuel (Int. 9).

Another opportunity comes from substituting inputs that are not renewable or are difficult to recycle with ones that are (Linder & Williander, 2017).

Constantly looking for opportunities in the market could be a good way to adopt more sustainable resources (Mendoza et al., 2017). Cooperation with suppliers, in fact, is considered as an important enabler of circular economy (Pinheiro et al., 2019). The division can look for suppliers that are providing more sustainable materials and start purchasing the resources from them. Additionally, a better cooperation could be established with current suppliers to design the purchased raw materials in a circular way. In this manner, the resources could be made more durable, recyclable or in a way that can favor the after sale operations (Schenkel et al., 2015).

### *Benefits and risks*

Reducing toxic materials can avoid exposing people to danger and prevent damaging the environment. In this way, a better implementation of circular economy and a lower environmental footprint could be achieved (Ghisellini et al, 2016).

However, these more sustainable materials might be more costly and it might be challenging to bring these modifications to the units without compromising their performances and safety.

## 4.3.3 Packaging recycling

Despite the big effort done by the division in order to manage resources and waste in a sustainable way, there is still a big margin of improvement in relation to packaging (Int. 8; W1).

### *How the division is performing*

Sandvik is planning to buy a machine that cuts the cardboard packaging into chips that are then used to fill the boxes used to transport spare parts (W1).

### *How the division can improve*

At the moment, plastic packaging is not recycled at the Finnish plant (Int. 7; Int. 10; Int. 11). The consultancy of the recycling company can be very useful to comprehend how to better handle this waste and understanding what kind of plastic could be more easily recyclable. If it is not possible to recycle the plastic coming from suppliers the division could ask to adopt the

new and recyclable kind of plastic. A Finnish supplier, that is one of the main provider of the unrecyclable plastic, claims that it would be willing to switch the packaging into a more sustainable one (Int. 26).

Furthermore, the plastic that the division is using in Finland for packaging spare parts and components is not recyclable too. A new kind of plastic could be adopted to favor its recyclability (Int. 9) and the division could provide information to its customers about how to correctly dispose the packaging.

The Chinese plant is packaging the machines before shipping them to its clients (Int. 25). They could use the same film protection adopted in Finland for delivery (Int. 7; Int. 8; Int. 9). This can help the Chinese company in reducing the amount of packaging used, and consequently the costs, and be more responsible towards the environment. Moreover, the Chinese plant has the potential to adopt the same measures to favor recycling and reuse of the packaging from suppliers, and package the components with recyclable materials (Int. 8; Int. 9; Int. 25). The communication with the Finnish plant needs to improve to transfer these developments, share experiences and success stories, provide feedback and keep the company's plants performances aligned.

#### *Benefits and risks*

Adopting a more sustainable packaging and develop a better waste management can enhance the resource efficiency of the division, reduce the amount of waste produced, favor recycling and prevent virgin resource usage (Nußholz, 2017). Recycling brings positive impact to the environment thanks to the fact that it is possible to reduce extraction of virgin raw materials (Ghisellini et al, 2016). Favoring the recycling process would thus allow the division to brand itself as more sustainable and improve its image (Ghisellini et al, 2016).

However, recycling presents some limitations because plastic cannot be recycled more than a certain amount of times and the quality of the material needs to be high enough to enable the recycling process (Nußholz, 2017).

### 4.3.4 Take back system

Taking back the machines could provide several benefits to the division but the implementation of a good system is one of the biggest challenges because of the nature of the machines and the conditions in which they are used (Int. 22).

#### *How the division is performing*

Machines could potentially been taken back after use and there is the willingness to explore this practice (W1). At present Sandvik is sometimes taking back machines not older than 5 years, otherwise they are too worn out and not useful (Int. 24).

#### *Benchmark*

An American competitor is taking back used units and is selling them as second-hand (Caterpillar, 2018, n.d.). The same company is claiming that a constant maintenance of the machines can assure the good quality of the unit once it is taken back (Caterpillar, 2018, n.d.).

#### *How the division can improve*

A taken back unit can be reused for different purposes such as renting or PSS, substitution as a bridge unit, sold as second-hand or it can be stripped down to collect the parts that are still in good condition and reuse them. In this latter case, the used parts can be mainly used for

maintenance and repair or for rebuilt, even if it is more challenging because the machine has to last for another lifecycle and therefore the parts needs to be of high quality. In addition, second hand parts can be used for remanufacturing and selling the refurbished units for renting or substitution, or for creating a second-hand market where customers can buy spare parts and used or remanufactured units.

To enable take back, a good infrastructure needs to be created and the organizational structure needs to be changed to favor this process (de Jesus & Mendonça, 2018; Nußholz, 2018; Schenkel et al., 2015). An efficient take back procedure also needs to be developed. The machines can be taken back to the closest workshop, stripped down and the parts can then be reused or recycled.

Cooperation with various stakeholders therefore needs to be created in order to favor the creation of a closed loop supply chain (Nußholz, 2017). Customers, in particular, needs to be involved in this process because their cooperation is a fundamental enabler of a good take back system (Sinclair, Sheldrick, Moreno, & Dewberry, 2018; Prieto-Sandoval et al., 2018). They could be educated on and nudged toward how to best use the machines and favor the process of taking back (Lieder et al. 2017; Kirchherr et al., 2017). Clients need to be taught about the benefits of reusing materials and parts, and exhorted to buy remanufactured and second-hand parts and units via making them understand that used and refurbished products are of good quality and reliable (Ghisellini et al., 2016; Pinheiro et al., 2019). In this way, it is possible to get their support during the take back process and prevent them from the willingness to retain the units for as long as possible (Linder & Williander, 2017). In case the clients is not willing to give away its unit for free the division could buy it back (Lieder et al. 2017). Furthermore, to favor the take back process, a better cooperation with the division that is providing spare parts and after sale services to customers can be established. In this way, the division can collect useful data from these forefront actors and understand how to better design the machines to facilitate take back, how to organize the process and what kind of information they could provide to customers to make them willing to cooperate.

If the parts cannot be reused or the end-of-life is irreversibly reached, the materials are recycled and downcycling needs to be avoided (Nußholz, 2017; Nußholz, 2018). Especially in the case when a customer is not willing to give the unit back, it is important that Sandvik is assuring a good disposal of the machines. In case in the country where the unit is used there is a good recycling system, the division needs to verify that the recycling is happening correctly. However, in certain circumstances, there is not a correct waste management system and the division can take the responsibility of taking the machines back and disposing them correctly (EMF, 2015; Ghisellini et al., 2016; Kirchherr et al., 2017).

### *Benefits and risks*

The main benefit of a take back system are related to cost savings. The division could reduce the cost of manufacturing because it is going to use more second hand units and their parts and consequently reduce the need of virgin resources, energy and decrease waste production (Prieto-Sandoval et al., 2018). It is also possible to save on purchasing costs because of the smaller need of virgin raw materials and new parts (Ghisellini et al., 2016). The company can therefore make its products cheaper, and more appealing to customers, or just improve its margins (Linder & Williander, 2017; Nußholz, 2018).

While the division can become less reliant on suppliers and on volatility of price of resource, there is still the problem that a smaller dependence on the suppliers may negatively influence the relationship with them (Ghisellini et al., 2016). However, the interviews with the division's personnel and the two suppliers highlighted that if Sandvik is going to communicate this change

properly and the volume of supply is not going to decrease too much, the suppliers may still be willing to cooperate (Int. 6; Int. 21; Int. 26).

A take back system also allows establishing a better relationship with customers because of the higher amount of contacts and serving them better via a provision of cheaper but still reliable used products and components (Schenkel et al., 2015). Also, new revenues streams can be created via selling remanufactured and second-hand units and parts, and via providing materials to recycling companies (Prieto-Sandoval et al., 2018).

Adopting a taking back system can also allow the company to improve its environmental performances because of the smaller usage of virgin raw materials and a consequent lower environmental degradation. Sandvik can thus brand itself as more sustainable and improve its image and reputation (Evans & Bocken, 2013; Schenkel et al., 2015; Ghisellini et al., 2016; Linder & Williander, 2017; Blomsma & Brennan, 2017).

Moreover, the division can get a better knowledge of its machines thanks to the understanding of the parts that are still in good conditions and the one that are not, and thus constantly improve them (Schenkel et al., 2015; Nußholz, 2017; Nußholz, 2018).

However, according to the division's personnel it is difficult to reuse parts because the machines are seriously worn out after an entire lifecycle (Int. 11; Int. 2; Int. 15; Int. 18). For this reason, it might be impossible to recover secondary materials or, in case some of them can be reused, they can negatively influence the quality of the machines because of their bad conditions (Int. 11; Int. 2; Int. 15; Int. 18). In addition, it is difficult in some underground mines to take a machine out of the mining site because of the need to stop the entire mine and therefore lose money. For this reason, the machines are left inside the mine once they cannot be used anymore, preventing Sandvik from being able to taking them back (Int. 8; W1).

Furthermore, some of the customers may want to own the machine for as long as possible and using it until the end-of-life is irreversibly reached (Schenkel et al., 2015). These facts constitute a barrier to the reliability and predictability of the flow of used products/parts and cause problems with planning and executing the remanufacturing activities and the labor needs (Kirchherr et al., 2017).

In case take back is going to be adopted, the production using virgin raw materials needs to decrease otherwise there is not going to be any environmental benefit (Nußholz, 2017). However, there should be a balance between selling new products and taking back old ones. Selling of new products should not be cannibalized because this can prevent having a future flow of used products back (Roos, 2014).

### 4.3.5 Product service system

Product service system (PSS) is considered one of the most important enablers of circular economy (Bocken et al., 2014; Roos, 2014; EMF, 2015; Ghisellini et al., 2016). For this reason, the division can explore the possibility to further implement this kind of business model.

#### *How the division is performing*

The division is adopting this kind of business model in certain cases with good results. For instance, in India the division is adopting a PSS based on cost per hour because the customers do not want to be liable for the machines and find it more lucrative. Sandvik has seen this kind of business as profitable too because it assures a secure after sale market for 5/10 years and thus

maintain a good level of revenues. This safe and fixed business for several years also allows the division to create a proper infrastructure and hire a suitable number of people to assure an adequate provision of the service to its clients (Int. 20). Therefore, the division has already experience about providing service rather than ownership to its customer and can therefore build up on existing know-how rather than developing new skills and gather new resources.

### Benchmark

A Japanese competitor is offering to its customers support in relocating the machine to a new mining site and facilitate the process of selling the machine to another client and move it to the new location (Komatsu, n.d.).

### How the division can improve

The division could increase the adoption of a product service system. It can implement it via a use-oriented PSS, where the machines are going to be available to the clients via a renting, leasing or pooling contracts, or via a result-oriented one, where the division is going to provide a certain outcome to the customer (Reim et al., 2015; Tukker, 2015).

The rock and ore moving division can also provide additional services to its clients such as the relocation of the machines once the customers have finished using them and supporting the reselling process (Komatsu, n.d.).

### Benefits and risks

Adopting a product service system can provide several benefits to the division.

First, there are economic benefits. The division could create new revenues streams and get good margins via the provision of a service (Prieto-Sandoval et al., 2018). In addition, the division could reduce its cost because PSS stimulates energy and resource efficiency. The firm is going to be incentivized to create products that are long lasting, require less intervention and with a life cycle that can be extended via repair, maintenance, remanufacturing and reuse (Reim et al., 2015). Moreover, in the manufacturing operations the cost of the input are going to be reduced because of the adoption of secondary materials and a constant optimization of the materials and energy usage. Therefore, also the purchasing cost is going to decrease, making the division less subject to supply risk too (Mont, 2004; Tukker, 2015).

Secondly, there are environmental benefits related to the smaller use of virgin raw materials and energy, and the fact that retaining the ownership assure that the machines are going to be disposed correctly at the end-of-life. Thus the division can brand itself as more sustainable and further improve its image (Annarelli et al., 2016; Mont, 2004; Tukker, 2015).

Thirdly, PSS improves the relationship with customers because of the higher number of interactions with them and allow the division to provide a more flexible service that can better fit their needs (EMF, 2015). The division can also collect useful information about clients' behaviors and use them to provide a better service (Nußholz, 2017; Schenkel et al., 2015). Clients can also be pleased thanks to the avoidance of an initial high investment for having the machine and reduce the total cost of ownership (Mont, 2004).

Finally, retaining the ownership of the units facilitates the take back procedures and allows to get all the advantages that this circular action is carrying with it (Linder & Williander, 2017).

However, as depicted in the section on product service system, implementing this business model requires several changes in the current way of running the company. The changes related to the value creation architecture and the organizational structure may be significant and, if not

implemented correctly, may not provide all the potential benefits that characterize PSS (Adrodegari et al., 2016; Mont, 2004; Tukker, 2015).

In addition, the division needs to establish a good take back system and improve the design of its products, towards long lasting and life extension. Realizing these actions is very challenging and can drastically hamper the implementation of a good service based business model (de Jesus & Mendonça, 2018; Reim et al., 2015; Xing & Ness, 2016).

Another barrier is the fact that the local legislative context may be a barrier to retaining the ownership of the products and provide them as a service, such as it is happening in the Middle-East (Annarelli et al., 2016; Mont, 2004; Int. 24).

PSS normally requires a greater amount of labor force to allow the products to keep performing its functionality and, in case the cost of labor is high such as in Australia, this can negatively impact the profitability of this business model (Mont, 2004; Tukker, 2015; W1).

There is also the risk of the inappropriate machine usage behavior of the customers and the dangerous conditions in which the machines are working (Schenkel et al., 2015; Int. 17). These facts can negatively influence the duration of the units, increase the need of intervention and therefore the costs for the division, and also make maintaining a high functionality and safety very challenging (Mont, 2004; Tukker, 2015). Sandvik cannot risk to be liable for a problem with the machines (Int. 2). Thus, it is fundamental that the division is going to present to its customers all the advantages of this business model and educate them in using the equipment in an appropriate way (Lieder et al., 2017; Linder & Williander, 2017).

### 4.3.6 Rebuilt

Sandvik has recently introduced the rebuilt process for its products. The customer are satisfied about this practice mainly because it gives the possibility of making a unit last for another lifecycle, without the need of purchasing a new one, and because the cost of rebuilding a machines and the lead time are lower than buying a new one. Despite that, there is still a big margin of improvement to make this activity more efficient and effective, and further enhance the competitiveness of the division (Int. 18; W1).

#### *How the division is performing*

The rebuilt is a practice that aims at taking back old models, remanufacture and upgrade them to the latest functionality, and deliver them back to the same customer (Int. 18).

During the rebuilt new and more performant engines are installed making the machine more fuel efficient and less polluting, bringing consequently savings to the customer (Int. 11; Int. 12; Int. 18).

At the moment, customers have a big say about the rebuilt and can customize this practice according to their needs and wants (Int. 11; Int. 18). However, in the future, with a likely higher request for remanufactured machines, the rebuilt kits are probably going to be standardized to serve the clients in a better and faster way (Int. 18).

#### *Benchmark*

Some of Sandvik competitors offer standardized rebuilt kits to provide a faster and more efficient service to their customers (Epiroc, 2018, n.d.; Caterpillar, 2018, n.d.). Also the

competitors are providing different rebuilt kits according to the needs and the pockets of their clients (Epiroc, 2018, n.d.; Komatsu, n.d.).

A Swedish competitor is also offering upgrade kits to improve functionality of machines during its lifetime and not only once the first lifecycle is ended (Epiroc, 2018, n.d.).

Finally, while the machine is being rebuilt, a Japanese competitor is providing a substitute one, called bridge unit, to reduce the downtime (Komatsu, n.d.).

### How the division can improve

The rebuilt is a great application of circular economy because it allows to extend the lifespan of a machine for another lifecycle, thanks to remanufacturing and upgrading practices, and therefore retain the embedded value of the resources used (Bocken et al., 2016; EMF, 2015; Blomsma & Brennan, 2017; Kirchherr et al., 2017). Therefore, scaling up this solution can provide potential high benefits to the division (Nußholz, 2018).

The division could offer different kinds of rebuilt kits:

- *Basic kit*: restore the machine to same functionality. It is a cheap and fast way to provide customers with a working machine that can last for another lifecycle.
- *Upgrade kit*: rebuilt the machine and upgrade it to the latest functionality or to various levels of better functionality according to the budget and needs of the customer.
- *Upgrade kit Plus*: rebuilt and upgrade to the latest functionality plus making the vehicle automated.

The division can also explore the possibility of providing upgrading kits also during the lifespan of the unit to give the customer the chance of working always with the best available technology (Epiroc, 2018, n.d.).

The division could provide a bridge unit to prevent the client from being incapable of not working while the remanufacturing is happening (Komatsu, n.d.).

At the end of the lifespan of a rebuilt machine, probably no parts can be reused because the unit is too worn out (Int. 7; Int. 17; Int. 18; W1). At this point of time, the machine needs to be disposed correctly in order to recycle as many materials as possible and close the resource loop.

### Benefits and risks

The benefits for the division are related to the fact that it can create new revenues streams because the customers are paying for this service. Also, the division can use less resources and energy, and produce less waste because the smaller adoption of manufacturing processes, and therefore reduce its costs. This fact has also a positive impact from an environmental and economic point of view because of the smaller usage of virgin raw materials (Nußholz, 2017; Prieto-Sandoval et al., 2018).

The rebuilt practices are implying a take back of the machine. The data and knowledge developed about this process could be used to better plan the take back system and enhance the understanding of the needs and behavior of the customers.

However, there is the problem that remanufacturing can cannibalize sales of new machines (Linder & Williander, 2017).

Rebuilt is also a labor intensive activity that can increase the costs for the division (Mont, 2004; Tukker, 2015). On the other hand, remanufacturing normally takes less time than normal production and the company may have some savings also from the workforce perspective (Ghisellini et al., 2016).

### 4.3.7 Electrification

Mining companies have shown an interest for electric vehicles (EV) because of the benefits they can provide. The machines powered by batteries can reduce the emission at the mining site, facilitating a company in being compliant with legislation and allowing it to brand itself as more sustainable (Int. 4). There are also economic benefits in purchasing an electric fleet. A mining company can reduce the cost related to ventilation and avoid spending money in creating the infrastructure of channels needed to purify the air in the site. The client can save on fuels cost and reduce the repair and maintenance costs because an electric engine has fewer mechanical parts and it is more durable (Int. 4).

The market is therefore moving in this direction because of these benefits and it is important for Sandvik and for the division to further develop the electric fleet and to do it in a sustainable way (Int. 4; Int. 13; Int. 15). Applying circular economy to electrification can allow creating vehicles in a more responsible way and taking care of the batteries and their repurpose and/or disposal in an appropriate manner.

#### *How the division is performing*

The division is working hard to develop EVs as fast as possible. Sandvik has just bought a Californian company that is producing electric machines with batteries in order to get their knowledge and avoid having competitors ahead of them (Int. 4; Int. 14). Thanks to this acquisition, they have already placed some EVs on the market (Int. 4).

#### *Benchmark*

A Swedish competitor is also offering electric vehicles to its customers. This company is providing customers with a limited range of batteries, with different chemicals compositions, according to the features of the mining site. Moreover, its batteries can be easily disassembled and reassembled in the machines and can be charged both while the machine is moving and idle (Epiroc, 2018, n.d.).

There is also a Japanese competitor that is creating hybrid loaders that recharge the batteries, which are supporting the diesel engine, during breaking (Komatsu, n.d.).

A Swedish heavy duty vehicles original equipment manufacturers (OEM) decided to adopt a PSS business model to provide its electric trucks to its customers (IIIEE, 2016). This company has also created the charging infrastructure needed to make them work (IIIEE, 2016).

#### *How the division can improve*

The division aims at outsourcing the batteries but it is still trying to find the best suppliers (Int. 4). IIIEE (2016) suggests creating different batteries according to the needs of the customers, based on the energy-to-weight ratio, and in the future making them tailor made according to the client's requirement. The division could provide at the beginning a limited range of batteries choice to its customers in order to better satisfy their needs and in the long run allowing a higher degree of personalization. In addition, in order to reduce downtime, it could follow the example of the Swedish competitor and create batteries that are easy to dis and reassemble to substitute the out of power battery with a charged one (Epiroc, 2018, n.d.). The batteries could also be

made in a way that can be recharged both while the machine is working and when it is in idle, to further reduce the time when the unit is not working (Epiroc, 2018, n.d.).

Under the directive 2006/66/EC, on batteries and accumulators and waste batteries and accumulators, the producer who is putting the equipment in the market is responsible for taking care of the batteries disposal at the end-of-life (European Parliament, 2006). Therefore, Sandvik needs to take care of them at the EOL.

Batteries designed for easy recyclability can make the various materials easy to separate and recycle. They can also be designed to facilitate repurpose because used batteries still have 70/80% of their capacity and could be reused instead of being disposed immediately (Bloomberg, 2018). Jonsson Larsson (2015) claims that heavy-duty vehicles OEM, should not jump directly into repurposing the used batteries but they should just simply collect and provide them to a partner company that is going to find a second use for them. At the same time, they could keep a part of the batteries and run a pilot project to define how they could be reused and define the basis for a future business model (Jonsson Larsson, 2015). Jonsson Larsson (2015) also suggests that home energy storage systems seem to be an industry that are suitable for using second hand batteries in the upcoming years. Nevertheless, the high functionality requirements and the competition of batteries coming from electric cars may constitute a barrier to enter in this market. In alternative, electric ferries and mobile fast charger for EV would fit the features of the used heavy duty vehicles batteries and could provide opportunities for repurposing those kind of second-hand batteries (Bloomberg, 2018; Jonsson Larsson, 2015). Alternatively, the division's personnel suggested that batteries could be used to store electricity at the mining site to supply energy in the moments of need or to charge faster the electric fleet (W1). According to Lucas & Petit (2018), fast vehicles charging can positively influence the stability of the flux of electricity in the grid while assuring a fast and reliable charge of EV. This can be profitable for the mining site that not only can use the batteries to accumulate energy and use it for various purposes, but can also avoid experiencing problems with stability of electricity supply and charge its electric fleet in a fast and reliable way.

Sandvik could therefore cooperate with companies that are providing repurposed batteries to these industries in order to favor the life extension and therefore circularity and sustainability of their batteries. Meanwhile, the division could create a pilot project for using repurposed batteries at the mining sites.

Adopting a PSS business model for EV can be a good strategy to handle the life cycle of these machines, as demonstrated by the example of the Swedish heavy duty equipment manufacturer (IIIEE, 2016). The division could not only provide the electric equipment to move rocks and ore but also the infrastructure needed to charge and make it work (IIIEE, 2016). The division could collaborate with local energy providers to create the infrastructure and if possible supply the electricity from renewable sources in order to make the mining company even more sustainable. As an alternative, as suggested during the workshop 1, the division could support the installation of PV panels at the mining site, in case it is going to be used for a long time, and provide all the energy needed using solar radiation (W1). In this way, Sandvik could win the resistance of the mining companies related to the investment on purchasing expensive EVs and creating the charging infrastructure, and provide a more comprehensive and better service to its customers (IIIEE, 2016).

### *Benefits and risks*

Finding a second purpose for used batteries can be profitable for Sandvik and allow to further support the implementation of circular economy (Foster et al., 2017). Remanufacturing and repurposing batteries, in fact, is seen as a remunerative business in the future (Foster, Isely,

Standridge, & Hasan, 2014). However, the cost of repurposing batteries is very high and the process requires technical expertise. Therefore it is better to jump into this business step by step in order to avoid incurring in risky investments (Standridge & Hasan, 2015). There is also still uncertainty about the future application of used batteries. The lack of data about their performance once they are repurposed and the little amount of actors capable of remanufacturing and finding a new application for them are the two main sources of insecurity (Elkind, 2014; Reid & Julve, 2016; Jiao & Evans, 2016).

Adopting a PSS may make customers more willing to switch to an electric fleet because they do not need to purchase expensive EVs, which according to Int. 4 they could cost about 50% more than the diesel one, but just buy their functionality (Schenkel et al., 2015). Providing the units as a service also allows Sandvik to keep under control the batteries' end-of-life and find a suitable second use for them and, later on, dispose them correctly.

Sandvik could take advantage of the fact that EV require less maintenance (Int. 4) to reduce the cost of making the service available and make the PSS more profitable.

Finally, adopting a PSS could differentiate Sandvik from its competitors and make the firm obtain a greater competitiveness (Annarelli et al., 2016).

### 4.3.8 Operations

It is important for the division to constantly look for technologies that allow saving on production inputs and are producing lower waste (Roos, 2014).

#### *How the division is performing*

There are different projects that the division is likely to implement in the upcoming years to improve its operations.

The current manufacturing equipment is quite worn out and they are aiming to invest in better and more efficient machineries (Int. 1; Int. 8; Int. 9). They are also planning to collect the hot air coming from welding, put it into pipes, purify it and use it to heat the factory (Int. 1; Int. 7; Int. 9). They also want to collect the hot water (90°C) used for washing the units in tanks that are going to transfer the heat to the heating system of the factory (Int. 9). At the moment, they are letting the heat from the factory out to the environment. They could cycle it back into the factory to further heat it, and save energy and money while be more environmental friendly (W1). Finally, they are planning to send to the grid the energy generated during the test drive on the roller conveyers and they aim at developing electric cable machines that are recovering the energy from breaking and sending it to the electricity network (Int. 9; W1).

Sandvik wants to make its suppliers 90% circular as well (Sandvik, N.A.a). Now they are in the process of identification of key suppliers and they are going to develop a plan to make them more circular (Int. 6).

#### *How the division can improve*

The division needs to constantly look for opportunities to reduce waste and improve resource and energy efficiency, and the aforementioned project can be useful to achieve these aims (W1).

The communication between the various plants needs to be enhanced to share best practices, experiences and success stories, and continuously improve the overall performance of the company. An example of good practices that can be transferred from the Finnish to the Chinese

plant are the painting one. The Chinese factory is still using oil based paints and solvents for cleaning the equipment while in Finland they are using non-toxic substances for both painting the machines and cleaning the tools (Int. 9; Int. 25). These better technologies could be transferred to the plant in China in order to align the performance and make it more environmental friendly.

The plant in China is also working in an industrial park (Int. 25). It could explore the possibilities of establishing a cooperation with local companies to share waste, excess energy and/or by-products and create an industrial symbiosis.

Some parts of the engines are scrapped immediately after receiving them from the Swedish supplier. The division could ask them to avoid putting these pieces. But, the division has such little relevance to the supplier that they might not willing to change the way they are producing their engines (W1).

#### *Benefits and risks*

The company can improve its economic and environmental performances thanks to a higher resource and energy efficiency (Roos, 2014).

However, these investments may be very expensive and difficult to realize (Int. 9).

## 4.4 Circular actions with the highest priority

The outcome of the second workshop was a definition of the circular actions with the highest priority (W2), obtained via the adoption of the prioritisation framework:

1. Rebuilt and its further adoption and improvement.
2. The impact of the implementation of circular economy on suppliers with the packaging issue as a case study.
3. Design improvements towards circularity.

Cooperation with internal actors, other divisions and external stakeholders was also identified as a fundamental enabler of circular economy and considered as an action that would allow a proper implementation of the 3 abovementioned one.

These actions were chosen because of the fact that they were considered as the *positive changes* easier to realise (rebuilt and suppliers), the one with the highest impact and most challenging to realise (design) and the one that was marked as easier (packaging) (W2). The selected actions therefore include a high, medium and low level of feasibility, and they represent from a high to low impact on the economic and environmental performances of the division (W2).

The following sections are going to provide suggestions on how to favour their adoption in the division. These recommendations have been developed using the knowledge provided by the qualitative research and the outcome of the workshops. In the subchapter 4.3, the overall range of features related to the actions is presented, while here the characteristics of the activities are related to their real implementation in the division. Additionally, the discussion chapter is going to depict the assessment of their impact on the current business model using the circular economy implementation impact framework.

### 4.4.1 Rebuilt improvements

Rebuilt is a suitable application of circular economy because it based on the concept of remanufacturing. This process allows to make a used machine last for another lifecycle for a

lower cost than purchasing a new machine. For this reason, it is very appealing for customers because they like the idea of having a machine for longer period of time without the need to purchase a new and costly one. The rebuilt also happens within a short amount of time preventing the clients from waiting for several weeks before receiving a new unit. The customers can also avoid paying customs because the remanufacturing normally happens within the same country where the mining site is and it is in line with a company policy of not buying new assets but rely on the present ones.

The rebuilt process has also benefits for Sandvik. This activity allows the division to use less resources and energy than producing a new machine. Therefore, it can reduce the costs for the division, decrease the pressure on the environment and prevent its degradation. Rebuilt is therefore a great source of competitive advance, earnings and environmental benefits. For this reasons, this circular action was marked as medium impact during the second workshop and it was also considered as not very challenging to implement.

According to the fact that the remanufacturing is performed by the division that is providing spare parts and after sale services to the customers, it is important to realise a better interaction with this division to perform this process in a better way and create machines that can facilitate the activities it entails. The personnel who is performing the rebuilt therefore needs to be involved in the process of product design and development. Their requests and suggestions can improve the present design of the units and make the rebuilt practices more efficient, effective and safer. The clients can thus be served in a faster way making them loose less time, and consequently money, and make them more willing to keep working using Sandvik's equipment. However, changing the design of the machines can be difficult and costly, and therefore not feasible from a practical and economic perspective. Moreover, it can negatively impact the performances, safety and functionality of the units making them losing the features that make them appealing to the customers.

The division could also provide different kinds of rebuilt to the clients. As presented in section 4.3.6, rebuilt may restore the machine to the same functionality, give the possibility to upgrade it and even turn it into an automated one. It is likely that with a greater range of choice the clients are going to be more inclined to perform this activity and provide Sandvik with all the economic and environmental benefits it entails.

The rebuilt process can be made even more efficient and faster if the rebuilt kits are standardised. Also, according to the fact that in the future it is likely that there is going to be a higher demand for remanufacturing, it is convenient for the division to have standardised kits to facilitate and speed up this process, and prevent being saturated and delayed by a high amount of requests. More the machines are taken back and rebuilt, more knowledge can be developed about the parts that are likely to worn out and therefore which are the components that can be introduced into the standardised kit. However, having standardised kits can negatively impact the capability of the division to provide a custom-made remanufacturing. Personalisation is a feature that make Sandvik very appealing to customers and it may be disadvantageous to lose this characteristic. The suggestion is therefore to understand which parts are more likely to be substituted during the rebuild are and pre-create the kits according to them and the 3 kinds of rebuilt that can be offered to the clients. Then, the components that allow personalisation are added to the kit before it is shipped to the workshop. In this way, it may be possible to speed up the process and provide a more efficient service to the clients.

The division can also provide bridge units while the rebuilt is performed to allow customers to work with the same amount of machines and do not lose productivity and thus money.

Acting like that can consequently make client more inclined to undertake the rebuilt process and be better satisfied by the service.

Finally, rebuilt entails taking back the machines. Thus, the data and know-how developed thanks to this practice could be used to understand if it is possible to adopt this fundamental aspect of circular economy and in case establish a take back system.

### 4.4.2 Suppliers involvement

Suppliers are considered as a fundamental enabler of circular economy because they allow to purchase more sustainable resources. These kind of raw materials can strongly improve the sustainability performance of the division. Sandvik also needs to constantly look for opportunities of materials improvement in the market and find the best available suppliers to better enable the adoption of circular economy.

Building strong relationship with suppliers is therefore important to assure a secure supply of all the resources needed and can enable the constant improvement of the purchased materials and components. It is important for the division to get the support of its suppliers to favour the implementation of circular economy. It can ask them to produce their products to make them more durable, lighter and more performant. Furthermore, the suppliers can make their products in a way that favour the after sale operations such as maintenance and remanufacturing. Their supports can also be asked to repair broken parts of the machines in order to further use them and reduce waste production. The suppliers can also be involved in designing materials for recyclability and additionally enhance the environmental performances of the division.

The interviews conducted with the suppliers demonstrated that the division has already established strong partnership with some of them and that cooperation for development have already been practiced. This kind of strategical behaviour can be extended to other suppliers in order to constantly improving the sustainability and circular performances.

Moreover, Sandvik's sustainability ambitions define that the same circularity goals needs to be extended to the supply chain. In fact, suppliers are asked to become 90% circular by 2030. Sandvik can establish goals and indicators in order to achieve this aim. The division can ask suppliers to reduce their amount of waste, improve resource and energy efficiency, and extend these requirements to their supply chain. A constant monitoring of their performances and cooperation are important to facilitate the achievement of these circular objectives and can also improve the relationship with them. In this way, the entire supply chain can be turned into a more sustainable and circular one.

In case the division is going to further adopt take back practices and start relying less on suppliers and more on second and materials and components, it needs to properly communicate this change to them. A better communication and cooperation is fundamental to avoid undermining long lasting and strong relationship and reduce the supply risk. The suppliers in the interviews expressed their intention to keep working with the division despite a lower demand of virgin raw materials.

Plastic packaging represents an example of cooperation with suppliers in order to further enable the adoption of circular economy. As presented before, the plastic currently used by certain suppliers is not recyclable. However, during one of the interview, a Finnish supplier presented its willingness to use a different kind of plastic to allow the division to recycle it. Therefore, Sandvik can cooperate with them to switch to a more sustainable plastic and improve the environmental performances of its operation and supply chain.

A similar kind of plastic can also be adopted for the packing of the spare parts that the division is shipping to its customers. Sandvik can ask the current supplier to provide them a recyclable kind of plastic or look for a different company to purchase it.

Despite the sustainability benefits of these packaging solutions and their relatively high feasibility, it might be costly to switch to a different kind of plastic and challenging to find a different supplier.

### 4.4.3 Design improvement towards circularity

Product design is considered as one of the most effective way of implementing circular economy. In fact, it was labelled as the action with the highest impact during the workshop 2. However, the division recognised the challenges related to improve the design of the machines towards circularity and therefore, it was considered also as the most difficult one to implement.

Compatibility can be seen as the most accessible way of supporting the adoption of circular economy because it can favour the personalisation of the machines, and thus better satisfy the customers' needs, and the rebuilt process because of the fact that old machines and their parts are compatible with the newer ones.

Design for recyclability is another manageable way of improving product design towards circularity. It may not be extremely challenging to design the machines for easy dis and re assembly in order to favour the separation and consequently recycling of the machines and their components at the end-of-life. The division or the final user can perform these actions in a faster and more efficient way, saving on labour costs while closing the materials loop and bringing benefits to the environment.

On the other hand, designing the units for modularity is considered very challenging. Despite the fact that it can facilitate repair, maintenance, remanufacturing and upgradability, as depicted in section 4.3.1, the division encountered several barriers while it was exploring this strategy. The bulkiness and complexity of the modules can cause problems in manufacturing and storing them. Moreover, having a fixed amount of models can hamper the high level of customisation that characterise the way of making business of the division.

Also designing for long lasting make the division incur in some challenges. It is complicated to modify the design of the various parts and/or change the materials used. It may be costly to change the machines' features and using more performant materials. It may also be needed to find a different supplier who can provide these materials, and it is difficult to do that and establish a new cooperation. Moreover, more durable machines can cannibalise the sale of new units and negatively impact the economic performances of the division. Nevertheless, long lasting machines can better serve the customer needs, better adapt the though condition of underground mines and can allow the division to sell spare parts for a longer period of time and increase the earnings.

All these design strategies, despite their benefits, can be costly to implement and can negatively impact the performances, functionality and safety of the machines. The division cannot incur in such risks because it will lose completive advantage. The design developments therefore need to be carefully studied before their adoption. Pilot projects and incremental improvements could favour the adoption of design for circularity while preventing the division from realising radical and risky changes.

# 5 Discussion

This chapter is presenting an assessment of the impact that the circular actions marked with the highest priority during the second workshop have on the current business model. Moreover, the impact of a greater adoption of circular economy is provided. The circular economy implementation impact framework is adopted to run these evaluations and understand if and how CE has an impact on the preset way of making business. Then, a critical assessment of the methodology used is provided in order to understand if it was able to promote the adoption of circular economy practices in the division.

## 5.1 Impact of the high priority circular actions on the current business model

This subchapter is presenting the impact that the before mentioned circular actions have on the current business model of the division. The table below depicts this influence, using the circular economy implementation impact framework, and the following sections are describing it.

In this way, it is possible to response to the research question 1 because here the impact of the further adoption of CE on the present BM is analyzed. Moreover, the RQs 1.2 and 1.3 can be better answered because of the improved definition of the features of the actions with the highest priority and a further assessment of their economic and environmental impact.

*Table 5-1. Influence of the adoption of the circular actions on the current business model using the circular economy implementation impact framework.*

| **Trends and Drivers** |
|---|
| The European mining industry is willing to move towards circularity and improve its sustainability performances.<br>EU action plan for CE.<br>Willingness to improve sustainability performance.<br>Mining industry is facing the competition of recycled and reused resources.<br>Competitors are adopting several circular practices.<br>Market is moving towards electrification. |
| **Adoption factors (internal and external)** |
| INTERNAL:<br>Willingness to implement circular economy, a fundamental aspect of the 2030 sustainability goals of the division.<br>Support of the top management.<br>Company culture towards constant innovation and improvement.<br>CE practices already in place.<br>Possibility of financing clients for leasing.<br>Workshops present worldwide to promote lifecycle extension practices.<br>General lack of knowledge about CE.<br>Scarce communication between upstream (designers) and downstream (forefront) actors.<br><br>EXTERNAL:<br>In line with regulation about safety and environmental issues.<br>Operating globally makes the company subject to different regulations according to countries. For instance, in Middle-East countries Sweden cannot be the owner of machines operating in those territories and cannot implement PSS.<br>Lack of recycling infrastructure in developing countries.<br>Some clients prefer to keep the machine until the end of lifecycle.<br>Machines are used in rough and dangerous conditions that expose them to fast worn out and accidents. Possible careless use of the units by the operators. After 5 years of use, Sandvik do not want to take machines back anymore.<br>Difficult in some mines to take out machines because you need to stop the entire mine site.<br>A competitor is also selling battery electric vehicles. The market is moving slowly in that direction. |

| | Current Business Model | Rebuilt | Suppliers | Design |
|---|---|---|---|---|
| ***VALUE PROPOSITION*** | | | | |
| **Value proposition** | High quality and performant machines with possibility of rebuilt.<br>High level of customization.<br>Safe units.<br>Automated vehicles.<br>Good lifecycle services: easy to maintain and repair.<br>Rebuilt and upgrade to make it last for a second lifecycle.<br>Different contracts to satisfy customers' needs (direct sale, leasing, pay per use).<br>Sustainability concerns. | Better customer satisfaction thanks to a provision of a faster and more efficient service.<br>Possibility to personalize the rebuilt according to the needs. | Provision of more sustainable and performant products thanks to the supply of better raw materials. | Better customization and rebuilt.<br>Facilitate recycling.<br>Ease repair, maintenance, remanufacturing and upgradability.<br>More durable machines.<br>Customization challenges. |
| **Customer segments** | Focus on hard rock underground mining companies. | Same type of customers. | Same type of customers. | Same type of customers. |
| **Customer relationship** | Workshop operating worldwide to support lifecycle extension practices. | Improved relationship because of the higher amount of contacts with them thanks to the provision of the rebuilt service. | Same kind of relationship. | Same kind of relationship. |
| ***VALUE CREATION AND DELIVERY*** | | | | |
| **Take-back system** | Take back within 5 years. | Provide useful information about how to establish a take back system. | No difference. | No difference. |
| **Key resources** | 3 manufacturing facilities.<br>Workshops worldwide.<br>Info about machines.<br>Skilled personnel. | Knowledge of parts that are subject to faster worn out.<br>Know-how about how to provide different kind of rebuilt. | No difference. | Knowledge about how to implement the design improvements.<br>New and more performant materials. |
| **Key activities** | Manufacturing.<br>Assembly.<br>Delivery.<br>Repair and maintain.<br>Rebuilt. | Design improvement.<br>Pre-creation of the rebuilt kits.<br>Different kinds of rebuilt. | Cooperation and communication with suppliers. | Pilot project and incremental improvement of design. |
| **Key partnerships** | Logistic companies.<br>Long relation with suppliers. | Better cooperation with the spare parts and after sale services division. | Establishment of partnership with suppliers to reduce supply risk and constantly improve | Possible new cooperation with suppliers. |

| | | | | |
|---|---|---|---|---|
| | | | the sustainability performances of the machines.<br>Cooperation with the suppliers to improve their circularity performances. | |
| **Channels** | Sales areas worldwide.<br>Workshops worldwide. | Same as before. | Same as before. | Same as before. |
| ***VALUE CAPTURE*** | | | | |
| **Revenues streams** | Revenues from different contracts (direct sale, leasing/renting, result oriented).<br>After sale services (maintenance and repair).<br>Rebuilt. | Higher amount of rebuilt. | Same as before. | Higher revenues from recycled materials.<br>Greater sale of spare parts. |
| **Cost structure** | Cost of personnel operating worldwide.<br>Cost of running 3 manufacturing plans.<br>Shipping units and their parts worldwide. | Possible higher labor cost. | Sustainable materials and/or switching suppliers can be costly.<br>Investment in establishing and maintain good relationships. | Reduction of labor costs.<br>Higher cost for running design improvement projects.<br>Possible higher cost of more performant materials. |
| ***STAKEHOLDERS*** | | | | |
| **Stakeholders involvement** | Suppliers (make them 90% circular)<br>Logistic companies. | Better cooperation with the spare parts and after sale services division.<br>Better communication with customers to understand their needs. | Greater involvement of the suppliers in the achievement of the circularity goals. | Same as before. |
| ***ENVIRONMETAL IMPACT*** | | | | |
| **Environmental benefits** | Indirect benefits coming from increased safety and performances of machines (reduce weight, efficient engines and small use of toxic substances …).<br>Constant improvement of resource and energy efficiency, and pollution emission in the manufacturing plants.<br>Good waste management system.<br>Only renewable energy in Finland. | Reduced usage of resources and energy. | Usage of more sustainable products and production of more environmental friendly machines.<br>Improved recyclability.<br>Environmental performance improvement in the entire supply chain.<br>Plastic recycling. | Improved recyclability.<br>Favor machines life extension practices with therefore less need of energy and resources. |

| | | | | |
|---|---|---|---|---|
| | Remanufacturing of machines and repair of components. | | | |
| **Environmental costs** | Uncertainty about machines recycling at the EOL.<br>Wide usage of hydrocarbons for fuel and lubricants.<br>Delivery consider environmental aspects of secondary importance.<br>No plastic recycling. | Not any major environmental drawbacks. | Not any major environmental drawbacks. | Non-used modules represent a waste. |
| | | | | |
| **Constant reiteration of sustainability and circularity performances**<br>Constantly optimize and improve the business model.<br>Use LCA and main components of CE to understand the areas of improvement. | | | | |

*Source: Author.*

### 5.1.1 Rebuilt

The division is going to improve its value proposition, and thus the customer satisfaction, because of a provision of a faster and more efficient service, and the possibility to maintain the personalization of the rebuilt according to the clients' needs. The relationships with customers are also going to improve because of the higher amount of contacts with them thanks to the provision of the rebuilt service. In this way, it is also possible to better understand and satisfy their needs.

The division needs to develop new knowledge about the parts that are subject to faster worn out and know-how about how to provide different kinds of rebuilt. Also, because of the greater cooperation with the division that is providing spare parts and after sales services, it may need to improve the design of the products with all the challenges that this activity is carrying with it.

The division needs to create new activities such as the pre-creation of the rebuilt kits and the provision of different kinds of remanufacturing. However, it could collect useful information about the take back process that can be used to assess its feasibility on a larger scale and, in case, implement it.

New revenues streams can be created thanks to a higher amount of rebuilt, also thanks to a better customer satisfaction. However, this activity can increase the costs because remanufacturing is a labour intensive process.

Finally, rebuilt can bring a positive environmental impact, because of the retention of the value of the resources used in the machines, without having any major drawbacks.

The impact on the business model of this circular activity is mainly related to the new knowledge and activities that need to be developed and performed. It is going to be challenging to implement these actions but the economic and environmental benefits that the division could gain from it may worth the effort. In addition, the division can collect valuable data that can favour the establishment of a take back system. A special attention needs to be placed to the possible higher labour cost. A careful management of the rebuilt process is important to avoid to negatively influence the profitability of the division.

### 5.1.2 Suppliers

Supply better materials and components can allow the division to provide more sustainable and performant products to the customers.

The establishment of partnership with suppliers and a better communication and cooperation with them are fundamental to reduce supply risk and constantly improve the sustainability performances of the machines. This enhanced cooperation is also an enabler of the extension of the circularity performances in the entire supply chain. Anyway, the establishment and conservation of these relationship may require effort and investments from the division. Furthermore, the adoption of more sustainable raw materials or switching to a new and better supplier can be costly and therefore reduce the profitability of the business model.

However, supplying more sustainable materials and components allows to improve the environmental performances of the division and the supply chain. In fact, the high objectives in terms of circularity can turn the entire supply chain into a more sustainable one. Moreover, the division can manufacture more environmental friendly machines because of the kind of substances they are made of and/or they are using, or because they are for instance lighter and thus require less fuel. The division can also enhance recyclability, by purchasing recyclable plastic and providing a similar one to its clients, and improve its environmental performances.

Therefore, the main changes in the current business model are related to the adoption of better a cooperation and communication with the suppliers, and the establishment of valuable partnerships with them. It might be challenging to realise that but the improved environmental performances and value proposition can have a high beneficial effect on the competitiveness and sustainability of the division.

### 5.1.3 Design

The value provided to customers is going to be enhanced by the implementation of circular design strategies. The clients can receive a faster and more efficient rebuilt service. Moreover, the after sale services, such as repair, maintenance, remanufacturing and upgradability, can be better provided in case of the adoption of the design for modularity. Customers can also count of long lasting machines that can better deal with the hard condition of their mining sites. However, the level of customization can be negatively impacted in case the various parts of the machines are turned into modules.

There are not big changes on the way the value is delivered to customers but an enhanced circular design can require new resources and activities. New knowledge about how to create machines to favor the adoption of CE needs to be developed and new and more performant materials may need to be supplied. Pilot projects and incremental changes are the main additional activities that the division needs to undertake in order to promote the adoption a circular design.

The division can capture value via increasing the revenues streams because the design for long lasting allows selling spare parts for a longer period. New earnings can also be created from selling recyclable materials to recycling companies. Other economic benefits come from the lower labor cost because of the fact that the machines are easier to dis and re assemble. However, changing the design of the units and purchasing more performant materials can be costly. Higher costs can also come from storing the bulky modules.

The environmental benefits are related to an increased recyclability of the resources and the facilitation of life extension practices. These activates allow to decrease the need of virgin resources and energy and therefore reduce the pressure of the environment and the resources

it provides. However, in case modules are produced but not used, they constitute a waste and thus an unnecessary use of resources and energy.

The adoption of a design for circularity has therefore a deep impact on the current business model. The way the value is provided, created and captured is changing. Despite the benefits that a better design can provide and the fact that it is a fundamental enable of circular economy, it is a very risky activity that, if not carefully implemented, can negatively affect the competitiveness of the division.

## 5.2 Impact of a greater implementation of circularity on the present way of making business

This subchapter is presenting the impact that a greater implementation of circular economy has on the current business model. The focus is on the product service system business model because it represents one of the greatest examples of implementation of this concept. Another reason is that this action was marked as a *secondary action* in the second workshop despite the potential economic and environmental benefits it could provide.

Table 5.2 is placing the PSS action in the circular economy implementation impact framework in order to understand its effects on the present BM and the changes needed to adopt this circular activity. A description of the influence on the current way of making business is provided below.

*Table 5-2. Impact of product service system on the current business model using the circular economy implementation impact framework.*

| | Current Business Model | PSS |
|---|---|---|
| ***VALUE PROPOSITION*** | | |
| **Value proposition** | High quality and performant machines with possibility of rebuilt.<br>High level of customization.<br>Safe units.<br>Automated vehicles.<br>Good lifecycle services: easy to maintain and repair. Rebuilt and upgrade to make it last for a second lifecycle.<br>Different contracts to satisfy customers' needs (direct sale, leasing, pay per use).<br>Sustainability concerns. | The firm is providing a service to the customers and the product is not sold directly anymore. The value proposition consists of the portfolio of different services sold to the clients to deliver the expected functionality or result. |
| **Customer segments** | Focus on hard rock underground mining companies. | Same type of customers plus the cheaper ones and/or the one that want the units for a limited amount of time |
| **Customer relationship** | Workshop operating worldwide to support lifecycle extension practices. | Improved relationship because of the higher amount of contacts with them. |
| ***VALUE CREATION AND DELIVERY*** | | |
| **Take-back system** | Take back within 5 years. | Machines are taken back to provide them to other customers or to be used for other purposes. |
| **Key resources** | 3 manufacturing facilities.<br>Workshops worldwide.<br>Info about machines.<br>Skilled personnel. | Support of top management and champions.<br>People with knowledge and skills about service provision, management and development.<br>Financial resources to retain the ownership.<br>Good ICT system. |
| **Key activities** | Manufacturing. | Designing products to favor PSS. |

| | | |
|---|---|---|
| | Assembly.<br>Delivery.<br>Repair and maintain.<br>Rebuilt. | Product production and provision of the services. |
| **Key partnerships** | Logistic companies.<br>Long relation suppliers. | Enhanced cooperation with suppliers, logistic companies and customers. |
| **Channels** | Sales areas worldwide.<br>Workshops worldwide. | Creation of channels to provide the service. |
| ***VALUE CAPTURE*** | | |
| **Revenues streams** | Revenues from different contracts (direct sale, pay per use, leasing/renting).<br>After sale services (maintenance and repair).<br>Rebuilt. | Money comes for the amount and quality of the service. |
| **Cost structure** | Cost of personnel operating worldwide.<br>Cost of running 3 manufacturing plans.<br>Shipping units and their parts worldwide. | Reduction of production costs because of the better resource and energy efficiency.<br>Lower purchasing costs because of the adoption of second and units and parts.<br>An inappropriate use of the products can make the division incur in higher costs.<br>Labor costs can be high. |
| ***STAKEHOLDERS*** | | |
| **Stakeholders involvement** | Suppliers (make them 90% circular)<br>Logistic companies. | Potential better relationship with suppliers, logistic companies and customers. |
| ***ENVIRONMETAL IMPACT*** | | |
| **Environmental benefits** | Indirect benefits coming from increased safety and performances of machines (reduce weight, efficient engines and small use of toxic substances …).<br>Constant improvement of manufacturing plant resource and energy efficiency and pollution emission.<br>Good waste management system.<br>Only renewable energy in the Finnish plant.<br>Remanufacturing of machines and repair of components. | Better resource and energy efficiency can reduce the pressure on the environment.<br>Correct disposal of the machines at EOL. |
| **Environmental costs** | Uncertainty about machines recycled at the EOL.<br>Wide usage of hydrocarbons for fuel and lubricants.<br>Delivery consider environmental aspects of secondary importance.<br>No plastic recycling. | An inappropriate use of the products can increase the need of virgin raw materials.<br>Missed environmental benefits in case of better resource and energy efficiency is not realized. |

*Source: Author.*

As we can understand from the framework, the current business model is deeply influenced.

The division is just going to deliver services the customers and the value proposition consist of the portfolio of the different services it provides. Sandvik could acquire a higher amount of customers because it could potentially serve the ones who cannot afford or do not want to buy new machines, and the clients interested in having the units for a limited amount of time. Moreover, Sandvik could improve the relationship with them thanks to the higher amount of contacts because of the provision of the services.

In order to implement PSS the support from the top management and/or a champion both in the producer and client firms is required to favor the acceptance of the service provision. Moreover, several new actions need to be undertaken. People with knowledge and skills about

service provision, management and development needs to be hired or these capacities need to be developed. An efficient take back system and infrastructure needs to be implemented too, with all the challenges that this activity is carrying with it (see section 4.3.4). Is also important that the division has sufficient financial resources to retain the ownership of the product and that the ICT system is adequately updated to constantly monitor the firm's products, provide a better service and develop the offering. Products need to be designed to favor the adoption of PSS, thus for instance to be durable, easy to dis and re assemble and modular, and produced using both virgin and used raw materials. The division also needs to develop proper channels to provide the service and establish partnerships with key stakeholders such as suppliers, to purchase proper components and spare parts, logistic companies, to move the products back and forth to the company, and customers, to sell the service to and to favor machines take back.

The revenues are coming from the quality and amount of the services provided. The cost structure is influenced because the better resource and energy efficiency, the higher adoption of used components and materials, and remanufacturing could sensibly reduce the expenses. These facts are also lowering the purchasing costs. However, there might be higher labor costs because the provision of a service requires more personnel. Greater expenses could potentially come from an inappropriate customers' usage of the units that can increase the need of intervention.

The environmental benefits generated from a higher resource and energy efficiency could not be achieved in case PSS is not properly implemented. Moreover, an inappropriate use of the products can increase the need of intervention and thus the need of virgin raw materials and consequently cause environmental degradation.

Therefore, the value creation logic is profoundly influenced. It is also difficult to make the customers want to purchase a service, deprive them from the ownership of the product and change the way they are using the units to make them last longer and keep a low level of intervention. For this reasons, this action was marked as high challenge during the workshop 2. Moreover, the division considered PSS as low impactful despite the substantial benefits it could potentially provide. A sensible cost reduction, new revenues streams, lower environmental degradation because of the higher resource and energy efficiency, the possibility of serving a wider range of clients and more information about the performance of the machines and customers needs that can favor the improvement of the service, are examples of the positive impacts of the adoption of PSS. Thus, the division seems to be characterized by low level of readiness to implement more radical changes that, despite the challenges they entail, could provide significant economic and environmental improvements and a better implementation of circular economy.

## 5.3 Overall impact of the implementation of circular economy

As we can understand from the two previous subchapters, implementing circular economy requires changes in the current way of making business.

These modifications can be both soft and hard. In fact, the implementation of the *rebuilt* and *suppliers* circular actions is based on building up on existing capacities rather than developing new ones. Thus, they require incremental changes instead of radical ones and they can still provide significant environmental and economic benefits to the division, which can support the achievement of the sustainability ambitions. On the other hand, the *design* and *PSS* activities are more complicated to realize and require more radical and complex modifications to the current business model. In fact, the adoption of these two actions have a deep impact on the entire value creation logic. Despite the substantial sustainability improvements they can provide, their implementation is risky and may not provide all their potential benefits.

Therefore, we can deduce that there are aspects of circular economy that are easy to implement and others that require significant changes on the business model. The ease of implementation seems to be very context specific and based on the characteristics of the company that is adopting a certain action. For instance, if the division had not already had a good experience about rebuilt it would have probably been very complicated to implement this action from scratch. For this reason, the adoption of circular economy, according to the circumstance, may just require soft and incremental changes as well as more radical and complex ones.

However, the 3 high priority actions have some common aspects. They are connected by the fact that they require a better cooperation with internal and external stakeholders, design improvements and the supply of more circular and sustainable materials. Consequently, the division could consider the idea of implementing them together. A special attention needs to be placed to these common aspects in order to be sure that their adoption is beneficial for each of the action and for the overall implementation of circular economy. In this way, the division could create a more comprehensive and effective strategy to apply circularity in its business model.

Regardless to this fact, implementing circular economy requires changes on the current business model. These modifications can be characterized by different levels of complexity and can provide diverse beneficial impacts, but they still have an impact on the current way of working of a company.

## 5.4 Assessment of the methodology

This section is presenting an evaluation of the methodology used to run the thesis and support the implementation of circular economy in the division. The assessment is conducted via a critical reflection on the method used to collect and analyze data, and the way the workshops and interactions with the company were realized. Therefore, the research question 2 is answered here.

### 5.4.1 Critical reflection and criteria

Critical reflection is considered as a fundamental tool to assess the validity and reliability of a study and can change the way of knowing of the author (Liamputtong & Rumbold, 2008). According to Fook (1996) critical reflection can help the researcher getting rid of biased and restrictive way of thinking and indicate options for change and improvement. Critical reflection is also a tool that fits with action research and therefore can be useful in the context of this thesis (Liamputtong & Rumbold, 2008).

The methodology was developed to support the implementation of circular economy in the division and answer to the research questions. In particular, it had two different aims, investigate the current and future adoption of circularity and the economic and environmental benefits it can provide, and assess the impact of CE on the way of making business of the company. Consequently, it is important to comprehend if it was able to:

- Create a solid knowledge of circular economy and (circular) business model.
- Understanding the context in which the division is operating.
- Define the current status of implementation of circular economy.
- Understand the opportunities of improvement.
- Delineate their economic and environmental impact.
- Give priority to the suggested actions and assess the quality of the prioritisation framework.

- Assess the influence of these action on the current business model and critically reflect of the circular economy implementation impact framework.

Thus, it is fundamental to comprehend how well the information were gathered in order to evaluate if the researcher was able to collect valuable and sufficient data. The assessment of the data collection method not only permits to recognize if the author developed a solid knowledge about circular economy and the context in which the division is operating, but also it allows answering to the research question 1.1 about the definition of the current implementation of circular economy.

Then, it is important to understand how well the circular economy opportunities were developed, if they were relevant and valuable for the division, and define their economic and environmental impact. In this way, it is possible to understand if the author and his research methodology were able to answer to the research questions 1.2 and 1.3. For this purpose, it is also relevant to critically reflect on the workshops, the prioritization framework and the way it was created.

It is also needed to define the quality of the methodology used to assess the impact of the additional circular actions on the current business model in order to understand if the author was able to answer to the RQ1 appropriately. In this direction, it is important to critically analyze the circular economy implementation impact framework.

### 5.4.2 The evaluation

The data collection method has proven to be successful.

The extensive literature review about circular economy, its concepts, benefits and risks and the one about circular business model and BM innovation permitted the author to create a solid knowledge about the topic under analysis and be able to argue about it and defend its thoughts.

The researcher, thanks to the triangulation method, was also able to collect a great amount of valuable information that provided a good understanding of the way the division is working and of the context in which it is operating. The positive feedback received from the company supervisors about the understanding of the context are demonstrating this fact.

The interviews with various actors from each step of the value chain allowed gathering a good overview of the current way of working and the present status of implementation of circular economy. The questions, in fact, were aimed not only at understanding the role of the interviewed and the way the division was operating in a certain step of the value chain, but also at comprehending if certain circular actions were already in place by applying the knowledge about this concept to the specific department.

Furthermore, the first workshop was very useful to gather a more holistic view of the current implementation of CE. The view of the author, in fact, could have been biased or limited by the fact that most of the data were collected during interviews and documents review. But, thanks to the fact that the participants are more knowledgeable and expert about what is happening in the division, the author was able to gather a better and more comprehensive knowledge about the division and the way it was currently implementing circular economy. The 7 people who answered the feedback of the workshop 1 were satisfied about the way the workshop was handled and about its length. They said that it helped in improving their knowledge about CE and its current status of implementation in the division, and stimulated the brainstorming about

opportunities of improvement. Nevertheless, the 58% (7/12) of the participants' opinions may not be representative of the overall view of the attenders and the feedback may not be reliable.

The interviews with external actors were valuable as well. Understanding the point of view of suppliers was essential to comprehend how they could be impacted by the implementation of circular economy and their willingness to cooperate in order to favor the division in implementing this concept. However, the incapability of interviewing customers and other external actors prevented the author from comprehending their inclination to cooperate and how the relation with them would have been influenced by the further adoption of CE. These facts were therefore assessed only via theoretical knowledge and information provided by the division's personnel. This understanding is thus incomplete and biased, and may not correctly represent what is happening in reality.

The second part of the research, aimed at elaborating on the further implementation of circular economy, allowed to define the CE opportunities that could be implemented by the division and properly argue about them.

The literature review about these opportunities allowed delineating their features, their economic and environmental impact and properly presenting the potential benefits and risks related to them. The benchmark completed the definition of these additional circular actions via including the way of working of the competitors and the market trends.

The workshop 2 was performed with the objective of presenting and prioritizing these circular actions. The 7 feedback collected, despite non representative of the view of all the attenders, said that the participants were overall satisfied about the proposed additional circular actions and the 71.5% of them were happy with their prioritization. All of the participants considered the prioritization framework as useful and well designed to reach the aim of prioritizing the actions. However, most of them found difficulties in assessing the economic and environmental impact together.

The literature review performed in the previous steps of the research permitted to elaborate of the actions with the highest priority and provide suggestions on how to implement them in the division. However, none of the recommended action was marked as *no-pain gains* during the second workshop. Therefore, the methodology did not allow the author to properly define easy implementable circular activities that could be immediately adopted by the division to obtain high economic and environmental benefits.

The circular economy implementation impact framework was useful to get an easy visualization of the current business model and the changes required to implement the circular actions. The fact that the various components of the value creation logic of the present BM are placed right next to the ones of the additional circular activities allows to easily understand where the changes are located and what kind of modification are required. The framework also permits to understand the additional economic and environmental benefits and costs related to the various actions and therefore comprehend their impact on these two fundamental aspects of the division's performance.

This tool is going to be useful for the division because it facilitates the understanding of what kind of modifications are required to implement the circular actions, the magnitude of the change and its impact. Thus, it can provide a guidance about how to adopt the actions.

While the author recognizes its utility in assessing the influence of a further adoption of CE, the feedback of the company cannot be collected. The division is going to assess the usefulness of

the framework once it is going to try to implement the circular actions and understand if the tool was suitable to define what kind of changes need to be undertaken and how to perform them. Until that moment, which will come after the end of the thesis period, it is impossible to speculate about its real value for a company.

### 5.4.3 Opportunities for improvement

The author recognizes the limits of the methodology and understands that there are possibilities of improvement to make it more effective.

First, the point of view of customers should have been included to get a better understanding of the impact of circular economy on the entire range of stakeholders of the division.

Secondly, the author should have tried to improve the amount of feedback of the workshops. Despite the reminders, he was not able to gather an amount of responses that are representative of the entire group of participants. A better strategy to make the attenders fill the feedback should have been adopted. Perhaps, making the participants fill the feedback as last activity of the workshop, in other words while they were still in the room, could have provided a higher rate of response.

A third improvement is related to the prioritization framework. The inclusion of the economic and environmental impact in the assessment of the importance of the circular actions created problems among the participants in defining a proper impact. Maybe a scoreboard could have been used to rank the economic and environmental aspects separately and then compare the results to define the overall impact. Otherwise, the two impact could have been kept separate and a different methodology to assess the impact could have been developed.

Finally, the suggested actions to further implement circular economy were never considered by the division's personnel as high impactful and easily implementable. Despite the positive feedback about the understanding of the current way of working, more time and attention could have been dedicated to gain a better knowledge of the division's background to identify the low-hanging fruit.

Overall, the methodology can be considered successful in achieving its aim. It allowed the author to understand the context in which the division is operating, the current application of circular economy, the potentials of improvement and their economic and environmental impact, define the ones with the highest priority and their influence on the present business model. For this reason, it can be considered as a good starting point for Sandvik in order to extend the implementation of CE to other divisions or for other firms to facilitate the adoption of this concept. Companies can thus build up on the adopted methodology, adapt it to their specific context and constantly improve it to increase its effectiveness.

# 6 Conclusion

Circular economy is considered as a useful tool to move our society towards sustainable development. The implementation of this concept depends not only on policy makers but also on firms and their ability to adopt circularity in their way of making business. However, we are unsure about the impact that CE has on a company way of working and there is a lack solid and working methodologies on how to drive companies toward CE. Therefore, businesses are struggling in moving towards circularity. Some research has been performed but it is still at its early stages and cannot provide firms with the guidance they need.

This thesis aims at assessing if and how the implementation of this concept is influencing the current business model of a firm and at filling the gap about the lack of tools and practices to implement circularity by defining a methodology that could support companies in adopting circular economy.

Via using the rock and ore moving division of Sandvik as a case study and adopting aspects of action research, it was possible to create an understanding of the current status of implementation of CE in the company, define the opportunities of improvement and assess their impact on the economic and environmental performances. Once the main future circular actions were defined with the support of the division's personnel, their impact on the present business model was studied in order to understand what changes on the current way of working are needed to adopt them. The methodology used was then critically analyzed with the objective of recognizing if it was useful, valid and effective in achieving its aim.

Through using this method, it was found that the division is already implementing, consciously or unconsciously several aspects of circular economy. In fact, it is characterized by a good level of energy and resource efficiency, it has a well-organized waste management system, it is performing several life extension practices such as repair, maintenance and rebuilt, and it is sometimes providing their machines as a service and taking them back. All of that is performed with the support of a good ICT system and partnership with external actors, for example suppliers and logistic companies.

Therefore, for certain aspects, the further adoption of circular economy is more a matter of building up on existent capacities and knowledge rather than developing new ones. For instance, the *suppliers* and *rebuilt* actions require incremental changes rather than radical ones and still provide significant benefits from an economic and environmental point of view. This fact is putting the division on the right path because it can allow Sandvik to improve its sustainability performances and achieve its ambitions without drastically change its current way of working. However, other actions require substantial modifications and their adoption is challenging. The circular activities related to *design* and *PSS* need significant changes on the value creation architecture to be implemented and to collect all the economic and environmental benefits they can potentially provide.

Consequently, we can deduce that the implementation of circular economy can be both easy and difficult. In fact, it is not always needed to drastically change the way of working and undertake a change at the corporate level to enable the implementation of circularity. There are some aspects of this concept that, in certain contexts, can be considered as low hanging fruit or incremental changes and therefore are easy to implement and can provide significant sustainability improvements. However, other components of circular economy are more complicated to embrace. While their sustainability benefits may be more significant, substantial changes need to be undertaken with all the risks that this process is carrying with it.

Implementing circular economy therefore requires changes on the current way of working. These modifications, according to the circumstance, can have a different magnitude and can provide different levels of improvement but they still have an impact on the business model.

Change can be scary and difficult, and may not provide all the expected benefits. The division seemed to have the tendency of preferring the aspect of circular economy that are easier to implement and do not require drastic changes in the current way of working. This is totally understandable and it is probably the correct strategy to approach the adoption of circular economy. However, the division did not appear to have a level of readiness high enough to undertake more radical changes, such as implementing a pure PSS. It is also true that the conditions in which the machines are used can severely hamper the implementation of this action but, according to the substantial sustainability benefits it and other more complex circular activities could provide, it may be worthy to explore these more complicated circular actions.

In any case, as depicted in the last row of the circular economy implementation impact framework, it is important for the division, and thus for other firms, to constantly reiterate their sustainability and circular performances. In this way, it is possible to continually improve the various business activities and keep the BM updated to the latest and more beneficial trends. The knowledge about CE provided in this thesis can constitute a valuable starting point to keep the circular performances monitored and improve them.

Another useful aspect of this thesis is the presentation of all the circular economy opportunities that the division can potentially implement, represented in the result section. An overview of all these actions can inspire the personnel in finding new ways of implementing CE and constitute a good basis for a future greater adoption of this concept. The circular economy implementation impact framework, despite the need of further testing and improvement, can support the assessment of the impact of these additional actions and the changes required to implement them. Moreover, the discussion about the circular activities with the highest priority and the identification of the changes needed to implement them can support their adoption in the near future.

In addition, Sandvik can build up on the adopted research methodology to extend the implementation of CE to other divisions. The company can further assess its effectiveness and constantly improve it to increase its usefulness. Other firms could use this methodology, with some developments and adaptations to their specific context, in order to understand their present status of implementation of circular economy and define opportunities of improvement. Therefore, despite its limitations and the need of improvement, the methodology used can still be considered a good starting point for practitioners who want to favor the adoption of circular economy in a firm.

This research and the adopted methodology can also be valuable to academia because they provide some real life and practical data about the implementation of circular economy that can be useful to develop tools and practices to support companies in adopting this concept and move towards sustainability.

Another contribution to the academic field comes from the use of the circular economy implementation impact framework. This tool brings together the thoughts of several important actors in the field of (circular) business model and defines a more comprehensive way to assess the influence of the adoption of circular economy. This framework can therefore be used by academics as a starting point to do develop an appropriate methodology to support firms in developing a CBM and define the changes required to move towards circularity.

The two workshops and the way they were organized can also be a source of inspiration for practitioners who want to develop a practical and engaging approach to understand a company and its way of working, and promote an additional implementation of circular economy. Researchers can also build up on the prioritization framework to develop an appropriate tool to assess the importance and feasibility of the circular actions and support firms in understanding to what aspects of CE they should give the priority.

Therefore, this thesis can support filling the gap in the literature related to the lack of methodologies to promote the adoption of CE in an industrial environment. More research, however, need to be performed in order to provide adequate support to firms to move towards circularity.

The author believes that, because circular economy is a concept, its implementation depends on the specific circumstance in which we want to apply it. Thus, approaches that are more practical could be developed to support firms in the real life. In this way, the adoption of circular economy is going to be defined together with the people who are working in an enterprise, that have a better understanding of the context in which they are operating, and therefore it is possible to develop proper circular actions that can fit the specific situation.

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# Appendix A: The components of the circular economy implementation impact framework

The table below is presenting the list of the framework's components and a brief description of each of them.

*Table 0-1. Description of the components of the framework.*

| **Components** | **Description** |
|---|---|
| Trends and drivers | The environment in which the business is operating and the trends that characterize the industry. |
| Adoption factors | The factors that are supporting and preventing the implementation of CE. There are both internal factors, related to a business capability of implementing CE such as culture, team motivation, knowledge and change management, and external factors, which concern the political, economic, technological and social context in which the company is operating. |
| Value proposition | The products/services that create value to customers, satisfy the needs of a particular customer segment and differentiate a firm from its competitors. |
| Customer segments | The way a company divides its customer and the one that it aim to serve and how. |
| Customer relationship | The kind of relationship that a company establishes with its customer segments. Customer relationship have the aim to acquire customers, retain them or boosting sales. |
| Take-back system | All the activities related to the reverse logistic that allow recovering, returning, reusing and recycling used products. |
| Key resources | The most important resources required to make a BM work, in order words to create value proposition, serve customers and earn money. |
| Key activities | The activities that a company needs to do to make its BM work. |
| Key partnerships | The network that a company creates to improve the performance of its BM. Partnerships involve suppliers, customers or other actors that are relevant to make the BM work. |

| | |
|---|---|
| Channels | How a company communicate and reaches its customer segments. |
| Revenue streams | How a company is making money. Each way of creating revenues streams may have different price mechanisms. |
| Cost structure | Describes the main costs incurred by a company in order to execute its business model (get resources, do key activities, maintain partnership and customers relations, make and sell products…). |
| Stakeholders involvement | The main actors that need to be involved. |
| Environmental benefits | They are related to environmental impact reduction, environmental positive effects and environmental restoration. |
| Environmental costs | The damages or negative impacts that a company has on the environment. |
| Constant reiteration of sustainability and circularity performances | Constantly optimize and improve the business model using, for instance, LCA and the components of CE to identify the areas of improvement. |

*Source: Osterwalder & Pigneur, 2010; Richardson, 2008; Lewandowski, 2016; Antikainen & Valkokari, 2016; Joyce & Paquin, 2016; Manninen et al., 2018; Circulab, n.d.; Nußholz, 2018.*

# Appendix B: The activities of the workshop 1

This section provides an in-depth overview of the activities performed during the workshop 1.

The first was a 30 minutes introduction to circular economy. A video about Ellen MacArthur Foundation (EMF) was shown to provide a general understanding of the concept and its importance for our economy, environment and society. Then, the main components of circular economy were defined and presented together with their benefits and drawbacks, and a success story of their implementation (e.g. Evans & Bocken, 2013; EMF, 2015; Schenkel et al., 2015; Ghisellini et al., 2016; Bocken et al., 2016; Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). In addition, an assessment of the impact that CE can have on the sustainability ambitions of the division was provided to highlight on which objectives CE implementation is going to have an impact (Sandvik, N.A.a, N.A.b).

The second activity was a 10 minutes review of the business model concept and an introduction to the *Value Mapping Tool* (Bocken et al., 2013). Every time we are working on BM during a workshop is important to introduce or refresh the knowledge about this concept in order to be aligned on what a BM actually is, what are its components and provide a simple but understandable definition (Osterwalder & Pigneur, 2010). The review was defined with the support of the work of the following authors Bocken et al. (2014), Osterwalder & Pigneur (2010) and Richardson (2017) and had the objective of making the audience considering the value they could provide to the company and its internal and external stakeholders while they were thinking about the future circular economy actions. The *Value Mapping Tool* by Bocken et al. (2013) was used in order to define the participants' way of thinking about the current and future implementation of CE. The tool is supporting the improvement of the sustainable performance of a company by making its personnel think about their current value proposition, the value that they are destroying or missing and the opportunities that can be further explored (Bocken et al., 2013). The aim, in fact, was to make the attenders realize what they have already done in relation to circularity (current value proposition), what they are not doing (value missed or destroyed) and what additional circular actions could be done (value opportunities).

Thirdly, there was a 1 hour group work. The participants were divided into 3 groups of 4 people each and they had to define the current and potential future circular actions performed by the division. In order to do so, they were exhorted to review the various components of circular economy introduced during the first activity, and understand what actions were already in place, which one they were not performing and the one that could be done in the future. A poster was provided in order to write down the present and future circular activities and to allow them to have their outcome written down in two lists that could be effectively presented to the other groups.

The fourth group activity was a discussion where each team was asked to present its findings to the others in about 15 minutes. During the presentation follow up questions about their circular actions and the reasons behind them were asked in order to stimulate the discussion. Moreover, each of the other two groups was asked to choose one present and one future action that they considered as the most relevant or interesting and explain their motivation to further incentivize the discussion and the brainstorming.

Finally, the author's point of view about the current and future implementation of circular economy was presented to the audience. This was created via the analysis of the qualitative

data collected during and before the stay in Finland, and the literature review about circular economy and circular business models. The aim was to show the author's findings about the first analysis of the current situation of the division, compare them to the group work outcome and discuss about it.

At the end of the workshop, a Google Forms link was sent to the audience to provide a feedback about the way the workshop was conducted.

# Appendix C: The activities of the workshop 2

This section is showing the activities conducted to achieve the objectives of the second workshop.

The first one was a presentation of the circular economy opportunities. These circular actions, showed in section 4.3, were presented to the participants to discuss about them and be aligned on what they entail and what could be their potential benefits and risks. The author was also open to additional suggestions of circular actions in order to include as many aspects of circular economy as possible. However, no further proposal was received.

The second activity was a presentation of the prioritization framework, presented in Appendix D, to make the participants understand the way the circular economy opportunities should have been prioritized during the group work.

Thirdly, a group work was organised. The participants were divided into 4 teams and each of them had the goal of prioritising, using the framework, all the presented circular actions in about 60 minutes. Each of the action was marked with a coloured dot and the groups were putting them in the graph according to their conception of importance and feasibility.

The fourth activity was a discussion about the prioritisation. A random group was asked to provide its idea of priority of a circular action and the reasons behind its choice. The other groups were interrogated about their own prioritisation of the same action and comment of the motivation behind the first selected group choice. In this way, discussion and brainstorming were stimulated with the aim of finding the definitive position of the action in the framework. This process was performed for all the circular economy opportunities.

Once all the circular activities were prioritised, the author asked the groups to decide which the 3 most important one were in order to assess their impact on the division's current business model. The focus was on *positive changes* and *no-pain gains* because of the fact that they are the kind of circular actions that have the highest priority.

Finally, the author presented the next steps of the thesis project and asked the attenders to fill a feedback survey, created using Google Forms, about the way the workshop was conducted.

# Appendix D: The prioritization framework

A tool was created in order to allow the second workshop's participants to easily assess the importance and feasibility of the actions and get a visualization of the resulting prioritization.

The framework should have been easy and composed of two dimensions, to make the attenders place each circular activity in a graph that would allow to visualize the impact and feasibility of the actions and consequently their priority (Evans & Bocken, 2013; Overall, 2017). The author comprehended that it was important to understand the economic and environmental impact of the actions, because of its importance for the aim of the thesis, and if the division was currently able to implement the circular action, building up on existing capacities, or if a change was needed.

These two dimensions therefore were considered as the two main building blocks of the graph as depicted in figure 0-1.

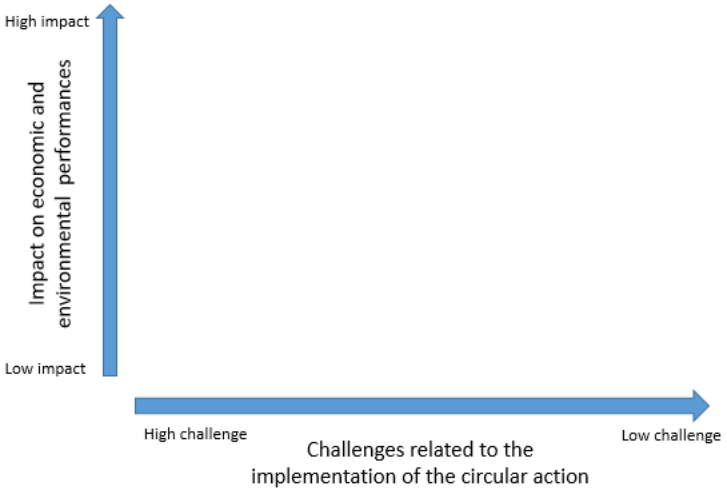


*Figure 0-1. The two dimensions of the prioritization framework.*

*Source: Evans & Bocken, 2013; Overall, 2017.*

*The impact on economic and environmental performances* has the aim of assessing the economic and environmental benefits and risks related to the circular actions, its influence on the stakeholders and the impact on corporate objectives (Evans & Bocken, 2013). Therefore, the aim is to comprehend if the action is able to increase the revenues and/or cut costs, improve customer satisfaction, create competitive advantage, reduce the environmental footprint, create benefits to the environment and/or allow achieving the division's sustainability ambitions. A *low impact* means that the economic and/or environmental risks outweigh the benefits. A *high impact* means that the economic and/or environmental benefits outweigh the risks. The economic and environmental impact, despite they have different way of being measured, have been placed together in order to get a holistic view of the benefits that the action can provide and do not focus on just one aspect. Moreover, in the division's decision-making process, environmental aspects are of secondary importance (Int. 1). Therefore, making the personnel consider also this aspect can have an educative purpose and bring benefits to the future way decisions are going to be taken. In case the circular action has a positive economic impact and a negative environmental one, or vice versa, the participants were exhorted to understand if the benefits outweigh the drawbacks and if the implementation of the action supports the achievement of the division's sustainability ambitions.

*The challenges related to the implementation of the circular action* entail considering the activities, resources (people, assets, knowledge, money…) and partnerships needed to implement the actions (Osterwalder & Pigneur, 2010; Richardson, 2017). The participants are encouraged to understand if implementing the action implies a change in the current way of working or if it is possible to build up on existing capacities without the need to incur in a change. Therefore, the attenders try to comprehend if they need to gather some new resources, define different processes, change the way they are working with their stakeholders and/or they need to establish new partnerships. In other words, if a change is needed and how big this change is. A *high challenge* means that the division needs to develop new capacities (skills, resources, activities, partnerships…) and/or change the current way of working to be able to implement the circular action. A *low challenge* means that the division can build up on existing capacities and/or processes to implement the action, without the need to incur in a drastic change.

The author took inspiration from frameworks such as the Kraljic or BCG matrixes (Azzone et al., 2011; Spina, 2012) in order to divide the graph into 4 boxes and allow the participants to have a better visualisation of the actions' priorities. This classification allows to have a better understanding of which category the actions belong to and favour the visualisation and definition of their prioritisation. The 4 resulting classifications, based on the two abovementioned dimensions, are the following:

- *No-pain gains*: actions that have and high impact, and thus importance, and are easy to implement. They could be adopted without big changes in the current way of working and thus bring benefits without too much effort.
- *Positive change*: circular activities that have a high impact but require an effort to be implemented. They are called positive changes because they have the potential to bring benefits to the division but it needs to embrace a chance in order to realise them.
- *Nice to have*: are the actions that are not very impactful but are easy to implement. For this reason, they are not of primary importance, because of the little beneficial effect, but could still be adopted thanks to the small effort they require.
- *Secondary actions*: are the one that have a low impact and are difficult to implement. Therefore, they can be classified as secondary importance because of the fact that they provide small benefits with a big effort.

The combination of the 2 dimensions and 4 classifications constitute the prioritisation framework, depicted in the figure below.

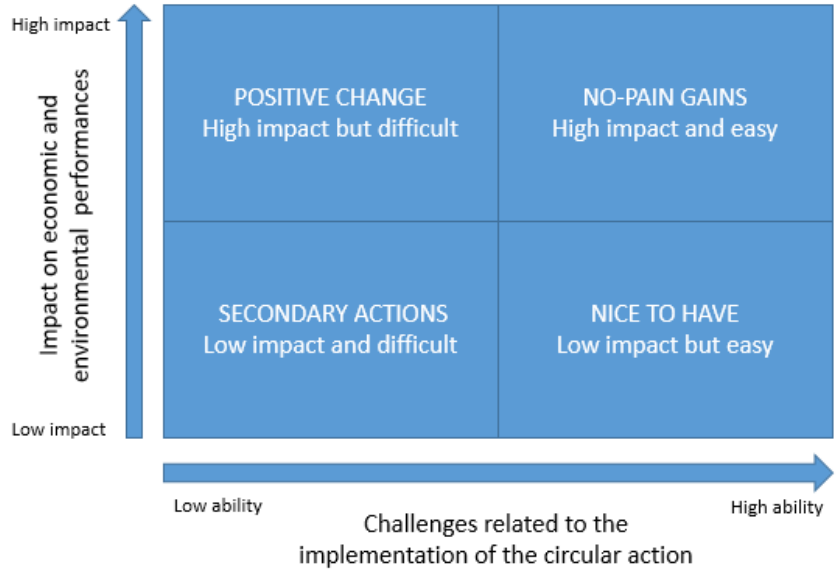


*Figure 0-2. Circular actions prioritisation framework.*

*Source: Azzone et al., 2011; Spina, 2012; Evans & Bocken, 2013; Overall, 2017.*