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CIRCULAR VALUE CREATION IN DMR / MSW WASTE MANAGEMENT ECOSYSTEM VIA SMART ROBOTS

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ABSTRACT

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This research aims to explore circular value creation in DMR/MSW waste management ecosystems, how the value can be delivered to the end customers, the operators at waste sorting plants, by using artificial intelligence powered robots in the consumer waste management. This objective is achieved by interviewing different ecosystem actors from the focal actor's network, how does the ecosystem look alike and how do different actors contribute to the value creation.

This qualitative research was conducted in Helsinki, Finland in 2020. The collected data used in this study was gathered from the focal actors and other external actors in the same ecosystem. Totally eight company representatives were interviewed. Apart from the focal actor of the ecosystem, one interviewee was selected from each group of actors. As a result, three persons from the focal actor were interviewed and the rest five persons were from the other group of actors. Due to the COVID-19 situation in the whole world, all interviews were done remotely via video calls and over the phone. One of the interviews was done by email. The collected data was analyzed with the thematic analysis methods.

The results revealed the incoherency of the current ecosystem and the significance of legislation in the value capture and circularity, which was also identified as one of the bottlenecks in the ecosystem. Smart robots can help the end customers to reduce risks caused by legislation, as well as provide economic savings and better quality of recovered materials. In a circular ecosystem the value delivered via automated consumer waste sorting benefits the whole ecosystem; once the output quality of recycling improves, more materials can be recovered and re-used in the consumer products. From the consumers materials circulate back to the waste management companies, the end customers, which closes the loop.

TIIVISTELMÄ

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Tämän tutkimuksen tavoitteena on tutkia kiertotalouden arvonluontia kuluttajajätteenlajittelun ekosysteemissä, miten loppuasiakkaille eli tässä tapauksessa jätteenkäsittelylaitoksille, luodaan arvoa tekoälyä hyödyntävien robottien avulla. Tutkimusta varten on haastateltu ekosysteemin eri toimijoita kohdeyrityksen verkostoista. Haastattelujen tavoitteena on ollut selvittää, mitä eri toimijoita kuluttajajätteenlajittelun ekosysteemiin kuuluu ja miten eri toimijat osallistuvat arvonluontiin omalta osaltaan.

Tämä laadullinen tutkimus toteutettiin Helsingissä, Suomessa 2020. Tutkimuksen data kerättiin kohdeyritykseltä, sekä muilta ekosysteemiin kuuluvilta ulkoisilta yrityksiltä.

Kohdeyrityksestä haastateltiin kolmea henkilöä, kun taas muista ekosysteemiin kuuluvista yrityksistä haastateltiin yhtä yrityksen edustajaa per yritys. Yhteensä haastatteluja kertyi kahdeksan, kolme kohdeyrityksestä, ja viisi ekosysteemin muista yrityksistä. Maailmassa vallitsevan COVID-19 -tilanteen takia kaikki haastattelut suoritettiin etänä joko puhelimessa tai videopuhelun välityksellä. Lisäksi yksi haastattelu suoritettiin sähköpostitse. Datan analysoinnissa käytettiin temaattista analyysia.

Tulokset paljastavat nykyisen ekosysteemin toimimattomuuden sekä lakien ja säädösten roolin tärkeyden arvon luomisessa. Vaikka lait ja säädökset koettiin kiertotalouden ajureina, identifioitiin ne myös yhdeksi ekosysteemin pullonkauloista. Älykkäät robotit voivat auttaa hillitsemään muuttuvan lainsäädännön aiheuttamia riskejä ja parantaa kierrätettyjen materiaalien laatua. Näin ollen ne myös luovat taloudellista arvoa loppuasiakkaalle. Kiertotalouden periaatteita noudattavassa ekosysteemissä loppuasiakkaalle toimitettu arvo hyödyttää myös muita ekosysteemin toimijoita, kun lajitellusta jätteestä saadaan enemmän puhtaampia materiaaleja uusiokäyttöön. Näistä materiaaleista voidaan taas tuottaa uusia kuluttajatuotteita, jotka aikoinaan palautuvat takaisin jätteenlajittelulaitoksiin. Näin kiertotalousajattelun ympyrä sulkeutuu, kun tuotteiden materiaalit uudelleenkierrätyksen avulla hyödynnetään uusiokäytössä tehokkaasti ja kestävästi.

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Sarianna Heikkilä

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	Artificial Intelligence
AM	Additive manufacturing
CE	Circular economy
CEBM	Circular economy business model
DMR	Dry Mixed Recycling
GRI	Global Reporting Initiative
IA	Industry architecture
IoT	Internet of Things
LED	Light-emitting diode
MRF	Material recovery facility
MSW	Municipal solid waste
NIR	Near-infrared
PET	Polyethylene terephthalate
PFI	Profiting from Innovation
SDG	Sustainable Development Goals

1. INTRODUCTION

1.1. Background

After in the late 1990s when Global Reporting Initiative (GRI) was formed and the first and currently the most commonly adopted global standards for sustainability reporting were created, sustainability has only strengthened its importance in the business world (Globalreporting, 2016). In 2015 launched Sustainable Development Goals (SDGs) addressed global challenges related to environmental, not only financial challenges but social challenges as well (UN, 2020). These set goals encourage companies to improve their daily operations and find new more sustainable ways to do business, also regularly report their performance, how have they improved their business operations and actions in order to accomplish these goals (Wilson, 2017).

Growing global population and increase of the middle class set challenges for the environment and businesses, when the demand for resources increases and prices of raw materials just raises while their availability comes more and more challenging (Ellen MacArthur Foundation, 2013; 2012). The concept of *circular economy* (CE) has been discussed since the 1970s (Wautelet, 2018; Dani, 2019) and after Stahel's and Reday's research report for the European commission in 1976 the discussion around it has even boosted (Dani, 2019).

Some years later after the report for the European commission, Stahel (1981) envisioned in his own research paper an economy with circularity and its impacts on creating new jobs, saving natural resources and preventing waste production (Dani, 2019) in which, circular economy replaces the 'end-of-life' concept of traditional linear economy with restoration and regeneration. In addition to the economic benefits, circular economy benefits environment and society (Ellen MacArthur Foundation, 2012; Korhonen et al.,2018).

A big breakthrough for CE happened in 2012, when the World Economic Forum in Davos, McKinsey Company and the Ellen MacArthur Foundation (EMF) published a report on economic benefits of circular economy (Ellen MacArthur Foundation, 2012). This was followed by the European Commission's Circular Economy Action Plan in 2015, which included measures to help the transition towards a circular economy. Among other things, these measures aimed to increase the number of sustainable products in the EU and make circularity work for people, different regions, as well as cities. Ambitious goals also included boosting global competitiveness, encouraging economic growth, as well as generating new jobs (European Commission, 2020).

In addition to circular economy action plan, another environmental policy approach set by governments is Extended Producer Responsibility (EPR). EPR takes the responsibility from governments or municipalities to producers (EU, 2014; Europen-packaging.eu, 2020; Walls, 2006; Singh et al., 2014; OECD, 2019) for the treatment or disposal of consumer products (Singh et al., 2014). The concept by first introduced by Thomas Lindhqvist in Sweden 1990 (EU, 2014). EPR forces producers to reduce the environmental impacts of their product throughout its whole life cycle, including waste management and recycling after the use. It therefore also encourages producers to keep in mind environmental considerations into account during the design and manufacture of the product (EU, 2014; Europen-packaging.eu, 2020; Walls, 2006; Singh et al., 2014). Many countries have implemented EPR as a governmental policy regulation (Walls, 2006; Singh et al., 2014).

Extended Producer Responsibility and Circular Economy Action Plan was followed by a revised legislative framework on waste in 2018. This waste proposal sets long-term goals for waste management and recycling; EU targets to recycle 65% of municipal waste by 2035 and 70% of packaging waste by 2030 (European Commission, 2020).

In addition to waste legislation changes, there have been significant changes in the field of waste management how used materials are seen and treated. Waste collection and the reuse of recycled materials were not considered as a source of value before (Peltola et al., 2016). Even though some levels of recycling can be found back in the history of Ancient Greece (Paprec Group, 2020), waste was mostly seen an unwanted material that needs to be demolished (Peltola, 2016). The waste management has been developing significantly after the 1960s and 1970s, when the waste disposal issues were brought into the political agenda in response to resolve the growing environmental and financial challenges around waste (Singh et al., 2014).

Currently, waste collection and processing include recycling and reuse. In addition to the economic savings, sustainability and environmental friendliness are the driving factors in waste industry. Due to the technological advancements that enable the more efficient material separation, the waste itself has started to gain value. In many cases, the waste is also used as a value resource to produce value for the customer (Peltola, 2016). The new policies and regulations have forced companies to search for new solutions by employing such technologies to improve the quality of sorted waste and work conditions of current employees exposed to the waste (Climate-KIC, 2020).

Despite of the significant progress in waste management there are still big future challenges in this area. One of them is to reduce levels of the waste generation and the other one is to align waste management objectives with circular economy. New business models are needed so that the waste can be turned into a resource, high-quality secondary raw material, that can be used again in the production process (STOA, 2017).

However, in some cases, recycling is actually more expensive than using virgin materials. A good example is the plastic bottles; even though recycling them takes less energy than the use of virgin materials, plastics don't usually make a closed circular loop. This is because sorting and refining plastic bottles back into a good-quality product is too expensive with current methods and processes. Therefore, plastic bottles are often downcycled into a lower quality plastic that can't be recycled again. Furthermore, transport and labor costs also increase the price tag of recycling (Kemira, 2019).

The fourth industrial revolution (Industry 4.0) technologies combine information technology and factory automation (Kumar and Kumar, 2019). These Industry 4.0 technologies are disrupting business models and providing new possibilities also in the field of waste management. As KPMG (2017) states in their report, industry 4.0 has already and will continue to reframe the traditional business and industry value chain, creating competitive advantage for the companies. This means smart products and improved processes, how the company create the value for itself but also how the company can create value with these smart technologies for the end user and the whole ecosystem (Souchet, 2017).

The technology advancement has enabled also more efficient recycling practices. With the automated waste sorting, companies can reduce overall costs of recycling and standardize their processes (Kemira, 2019). With advanced technology and the help of artificial intelligence, AI guided robots provide more efficient way to sort waste, providing a step closer to circular economy (Climate-KIC, 2020).

1.2. Research gap

There are various articles and research around the concept of sustainability and circular economy. Even though circular business models are a new type of business models, they have already been researched by some scientists (Lüdeke-Freund et al. 2019; Centobelli et al., 2020). In addition, the concept of CE is widely discussed and researched and also adopted by companies; many companies have taken CE as part of their strategy and openly communicate about CE practices in their daily business. Therefore, circular economy can be seen as a tool to communicate sustainability and thus, it can bring competitive advantage for companies. To implement circular solutions, companies need to create innovative business models.

The technology development, Industry 4.0, has offered many new innovations and is also increasingly being explored by researchers and other stakeholder groups. Due to the technology advancement, artificial intelligence (AI) and robotics are hugely used in the daily operations. There are many studies in AI and robotics (Duan et al., 2019; Lu et al., 2018; Lenz et al., 2015) but most of them focus on their unique qualities and features, being more technical focused.

Artificial intelligence is the science and engineering of building intelligent machines or computer programs that imitate human intelligence to perform tasks. By using human reasoning as a model, AI can make its own decisions and further improve itself based on the information it collects (McCarthy 2007). A smart robot is an AI system that can learn from its environment and its experience, as well as develop its capabilities based on the collected knowledge (Brynjolfsson and McAfee, 2014). In this research the term *smart robot* is used to describe waste sorting robots that use artificial intelligence in sorting.

Some of research have discovered the possibilities of artificial intelligence and robots in value co-creation (Kaartemo and Helkkula, 2018) but based on search on Scopus articles, a very few of the conducted research were related directly to recycling with robots (Bogue, 2019) or waste management with AI (Abdallah et al., 2020). None of the founded articles was related to the value creation especially for the end customers and in consumer waste management ecosystems via artificial intelligence powered robots.

Many articles and research recognize the importance of AI for the more sustainable future (Ellen MacArthur Foundation, 2019; Pagoropoulos et al., 2017), but there is no clear research where the possibilities to create value for the end customers via automated consumer waste sorting would have been researched and recognized.

However, the waste management has been a popular focus of research (Bassi et al., 2017; Ma and Hipel, 2016; Dahlbo et al., 2015). In addition to the business context, it has also been discussed from the perspectives of legislation (EU, 2018). Many studies have been focused on municipal solid waste (MSW) treatment (Havukainen et al., 2016), as well as the challenges around the collection and sorting of it (Singh et al., 2014). Even though a few studies on the value capture in business ecosystems for MSW management can be found, (Peltola et al., 2016) studies around the MSW management ecosystems and their value capture via smart robots are absent.

Consequently, the research world still lacks a comprehensive understanding of consumer waste management via smart robots, how the value could be captured and created to the end customers with advanced technology solutions. Furthermore, even though the existing literature already provides an understanding of how the ecosystems are built and managed, the literature is currently lacking a conducted research on how an ecosystem is built around the customer waste management ecosystem and what value do different actors bring into it. In addition, what is the value industrial robots with AI software can bring to the end customers. It has not been further researched how is value circulated in DMS/MSW waste management ecosystems and as mentioned above, what value do robots with artificial intelligence software can bring to this kind of an ecosystem, especially to the end customers.

My objective in this study is to apply the business ecosystem and circular economy concepts to consumer waste management and analyze how to build an ecosystem around automated consumer waste management, as well as how this ecosystem enables value capture and creation. Furthermore, I want to find what do different ecosystem actors contribute to the automated waste sorting.

1.3. Research questions

In order to find answers to the above open topics my main research question is:

How to deliver value to end customers via automated consumer waste sorting?

To better scope the research question and to get as accurate answers as possible, I define three more sub-questions for the main research question.

Sub-questions:

- How to create an (efficient) ecosystem around automated consumer waste management?
- How the value is created and captured in an automated consumer waste sorting ecosystem?
- What value do different ecosystem actors contribute to the automated waste sorting?

1.4. Exclusions and limitations

The field of circular economy is very broad and there are various other terms used for the similar concepts of CE, for example “closed loop economy” and “zero waste economy” (Rosa et al., 2019; De los Rios and Charnley, 2017; European Commission, 2020;2014). Due to circular economy’s large range of different definitions (Dani, 2019), concepts related to CE such as performance economy, cradle to cradle, biomimicry and blue economy (Ellen MacArthur Foundation, 2012) are left out from the literature search.

This study aims to better understand what kind of value artificial intelligence powered robots bring to the end customers in the ecosystem. Concepts and theories are examined from the business perspective and therefore, specific technological concepts and functions on artificial intelligence and robotics, for example how smart waste sorting robots are built and how the software is designed, are left out.

The searched literature has been limited to the following keywords: *circular economy, circular value creation, value creation, ecosystem, DMR / MSW waste management, smart robots* being present in the title, keywords or an abstract of the circular ecosystem. This is because expanding the search key literature for CE with these alternative definitions would have broaden the topic too much and might have led to misleading results.

1.5. Structure of the study

This paper starts with the theoretical background, section 2 and 3 give an overview on theories behind the main concepts; circular economy, ecosystems and value creation in them. In section 4 Industry 4.0 opportunities are discussed. This is followed by an overview on smart robots applications / implementations in the current MSW waste management. Section 5 (Research design and methods) provides details about the research methods and how the data was collected and analyzed. In this section I also evaluate the reliability and validity of the research. In section 6 (Findings) results of the interview questions are presented. This is followed by section 7 (Discussion) where the answers for the research questions are provided based on the conducted interview results. We end this paper to the last chapter (Implications) where theoretical and managerial implications are provided, as well as the future research directions. In this final section we take a look at the future of automated waste sorting based on the interview results and the current available research.

2. CIRCULAR ECONOMY

Although the concept of circular economy can't be put under a single author or school of thought (Dani, 2019; Kirchherr et al., 2017) all schools of thoughts agree the traditional linear economy is not sustainable in the long term. The roots of circular economy are said to be in ecological and environmental economics and in industrial ecology (Ghisellini et al., 2016; Murray et al., 2017), CE is defined as an economic system which is restorative and regenerative (Charonis, 2012; Guldmann et al., 2019; Ellen MacArthur Foundation, 2013; 2012). Furthermore, theories such as performance economy, cradle to cradle (Korhonen et al., 2017) biomimicry and blue economy have further refined the concept of CE (Ellen MacArthur Foundation, 2013; 2012).

In the literature on CE theory and policy, CE implementation is separated in two main directions. The first one is a *systemic economy-wide implementation*, which means CE implementation at the local, regional, national and transnational level. The second one is a about *implementation with a focus on a group of sectors*, products, materials and substances (Kalmykova et al., 2018).

In the traditional linear economy model raw material are processed, transformed, used and after the use discarded to nature in the form of solid, liquid and gaseous wastes (Singh et al., 2014), causing environmental harm (Korhonen et al., 2018).

Figure 1. Traditional linear economy model according to Singh et al. (2014).

When a traditional linear economy (figure 1) can be seen as a linear process, circular economy (figure 2) creates value with its shape of a loop. Compared to a traditional linear economy model, in a circular economy model used products' materials are not disposed to the landfill after use but instead, gathered, recycled and used again in the production (Ellen MacArthur Foundation, 2012; 2016; Kalmykova et al., 2018; Korhonen et al., 2018). Products and their materials circulate in the loop for as long as they provide value (Lieder and Rashid, 2016; Kalmykova et al., 2018). The circular economy has the potential to generate better resource efficiency and generate environmental benefits (Stahel, 1994). Recirculating of materials decreases the need for virgin materials (Korhonen et al., 2018), lowers the emissions and the amount of disposed waste to the landfill (Kalmykova et al., 2018).

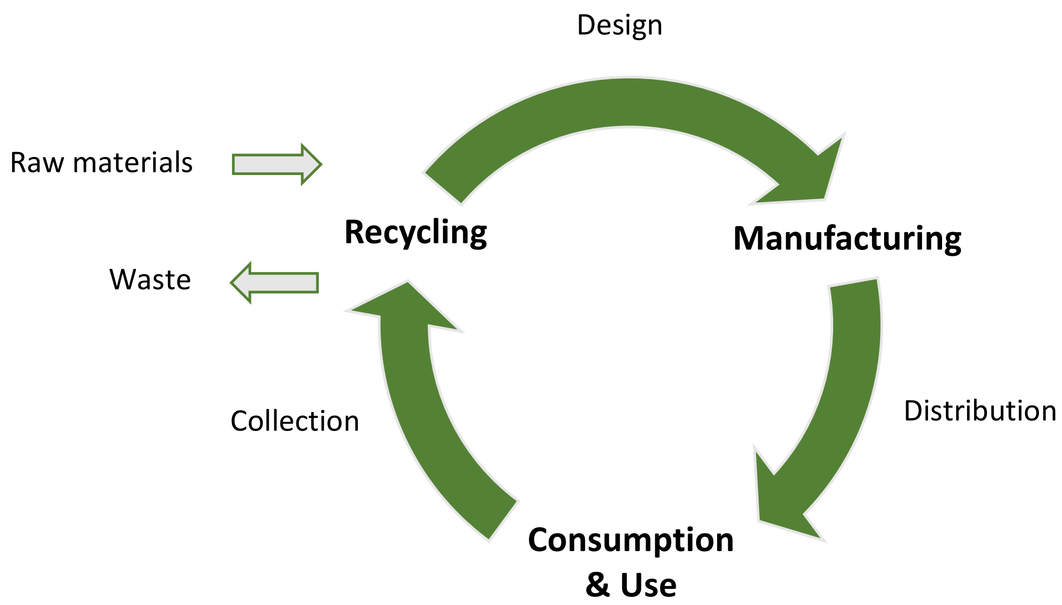


Figure 2. Circular economy model (modified) developed from Ellen MacArthur Foundation (2012); Kalmykova et al. (2018); Korhonen et al. (2018).

While most of the climate change and waste reduction discussion has focused on the *supply* side; finding new renewable energy resources to replace fossil fuels and developing more sustainable industrial production processes, the *demand* side; could companies re-use better the materials already produced, has got less attention (Sitra, 2018).

Circular economy moves the focus from the traditional supply side discussion to the demand side, how companies could recirculate a larger amount of materials, reduce waste in production, extend the life-time of products, also invent and develop new products and services around the concept of circular economy (Ibid).

2.1. Circular business model

A business model defines how the company makes business (Richardson, 2008). In other words, what is the company's organizational structure; how the company can create and deliver value to customers within a reasonable cost (Magretta, 2002; Teece, 2010) and make profit with received payments (Teece, 2010). Osterwalder and Pigneur (2010) agree with Magretta and Teece, adding also the aspect of value capture.

A business model should contain a compelling value proposition to customers, accomplish opportune cost-risk structures and to permit the company to capture value. If the aforementioned elements are not in place, even superior technology, products, outstanding people, great governance or strong leadership are improbable causes to produce sustainable profitability in a competitive environment (Teece, 2010). According to Richardson (2008) three major components form the framework of the business model; "*the value proposition, the value creation and delivery system, and value capture*" (Richardson, 2008).

Traditionally, business models have been designed based on the linear economic model (Rosa et al., 2019). Circular economy requires specific business models, which ensure a reliable return flow of materials, as well efficient reverse logistics processes for collecting and transportation (Ellen MacArthur Foundation 2016; 2019). Circular business models are new type of business models where the products even after the usage have economic value and can further be used for new types of market offerings (Rosa et al., 2019; Lüdeke-Freund et al., 2019). This reversed cycle forces companies to rethink their supply chain, as well as how they create and deliver value (Lüdeke-Freund et al., 2019).

In terms of value creation, circular economy business models (CEBM) benefit not only the company and its customers but also the society and the environment. With reduced usage of virgin materials and changed customer behavior, CEBMs reduce negative ecological and social impacts and generate cost savings. By lowering the dependence from virgin materials, using more renewable energy in the manufacturing phase, and greening the whole value chain, the economic value of the product can be maintained (Lüdeke-Freund et al., 2019).

Despite the benefits of CE, the transition from a linear business model towards a circular one requires big efforts from companies, governments and consumers. Because renewing and restoring materials can be very costly especially for companies, changes in business models are needed. Therefore, integration of circular strategies already in the product design process has an important role in the supply chain and value creation (Ghoreishi and Happonen, 2020). As Rosa et al. (2019) specify, implementing circular strategies need rethinking of the value creation logic to guarantee that they generate economic benefits (Rosa et al., 2019).

2.2. Circularity in consumer waste management

Municipal solid waste (MSW) generation is strongly linked to the rise of socioeconomic development index, as well as the income level of the population. Usually the greater the economic wealth, the bigger the amount of waste is produced (Singh et al., 2014).

The reuse of different materials is emerging as virgin materials become scarcer (EU, 2014; 2020; Sitra, 2018). Furthermore, resource extraction and processing cause greenhouse gas emissions and biodiversity loss which force us to move towards more sustainable consumption (EU, 2020). The Circular Economy model (figure 2) presented in the previous section offers us a solution to a cleaner and more sustainable future. In municipal waste (MSW) this means recycling and re-use of materials, especially dry mixed recyclable (DMR) waste, which contains paper, cardboard, metal (inc. aluminum) tins and cans and plastic (Sitra 2018).

In the following section we take a look at two materials, plastics and aluminum, that make a big share of the municipal solid waste and are in a significant role due to their high processing emissions and increasing virgin material scarcity (ibid).

Plastics

The EU has set ambitious plans for better usage of metals and plastics. By 2050 EU targets to recirculate 75% of steel, 50% of aluminum and 56% of plastics from the amounts that have already been produced. Even though it’s known recirculating materials reduces CO2 emissions and saves energy compared to the new production, the recirculating processes aren’t ready for large recycling rates yet. New materials are also needed to compensate flaws in quality; especially metals are mixed or downgraded. However, mixing and downgrading make plastics worthless so therefore, plastics should be mechanically recycled by types (ibid).

The financial worth of materials recirculation depends on the capacity to maintain the material value over the use cycle. Materials have the most value when they are produced from new raw materials. If the value of primary materials can be retained and recovered, high-quality secondary materials can be capable of substitute primary materials and like this provide CO2 and other resource benefits. In order to increase economic benefits of recycling in the long term, the cost of collection and secondary materials production need to be reduced or the value of the material produced needs to be increased (ibid).

Despite the benefits of secondary materials their production is challenging. One of the reasons is that current processes for product design and dismantling decrease the quality of materials. In addition, as technology continues to improve, technology costs continue to decline. This leads to a situation where the value of used, unrecycled materials would be more than costs of the used technology (ibid).

Recycling of plastics is challenging due to the material aging, contamination, additives and mixing of different types of plastics. Therefore, volumes of secondary plastics production are just 10% of total demand in the EU. However, the potential of recirculating plastics is high, most of them can be recycled and used multiple times (Sitra, 2018; EUR-Lex, 2018).

The Circular Economy Action Plan made by EU in 2018 set goals for waste management and recycling (European Commission, 2020). Same year, part of its transition towards a circular economy and reaching Sustainable Development Goals, the EU adopted *European Strategy for Plastics in a Circular Economy.* In addition of higher plastic waste recycling rates, this means better design, use and production of plastic products (EUR-Lex, 2018). Additionally, investments are needed for the development of technology in order to mark different plastic types and automate the plastics sorting and processing (Sitra, 2018). The goal is that by 2030, all plastics package materials on the EU market are either reusable or can be recycled (EUR-Lex, 2018).

Aluminum

The EU imports one-third of its aluminum. Big part of this is produced with coal-fired electricity, which causes high CO2 emissions (Sitra, 2018; European Aluminium, 2019). Re-melting existing aluminum requires just 5% of the energy of new aluminum compared to production of new material which causes 18 tons CO_2 per ton of aluminum. With more efficient re-use of the material, CO2 emissions of aluminum production could be cut up by 98% (Sitra, 2018).

Currently almost 30% of aluminum is lost. In order to better recycle and re-use aluminum products need better design and end-of-life treatment, additionally a higher amount of aluminum needs to be collected. This requires improved recycling practices and advanced sorting technology (Sitra, 2018), aluminum is a material that can be recycled multiple times without the material loses its original properties (European Aluminium, 2019). Currently the process is an “open loop”; after the first use, different aluminum alloys are mixed together and used to produce cast aluminum. However, many aluminum products are made from metal with much more strictly controlled alloy content. Therefore, recycled aluminum material has limited uses so downgrading of aluminum threatens to undermine recycling in the long term (Sitra, 2018).

The use of aluminum has continued to grow, and it is estimated that it is leading to 40 percent increase in demand in Europe by 2050. Some of this growth is generated by aluminum replacing other materials on different markets: automotive, construction and packaging being the biggest industries (European Aluminium, 2019).

European Aluminium’s Vision 2050 has set a target to make aluminums’ value chain decarbonized, circular and energy-efficient in Europe by 2050. Achieving aluminum’s full potential for circular economy will also contribute to the UN’s Sustainable Development Goals in SDG 12, “Responsible consumption and production”. In a scenario of high aluminum recycling, current emissions could be cut by 37 percent by 2030 and 46 percent by 2050. In addition of lower emissions, better and more efficient recycling of aluminum would help European industries to secure the increasing domestic demand for aluminum and reduce dependency on carbon intensive primary aluminum importers. (European Aluminium, 2019).

3. THEORY OF ECOSYSTEMS

An ecosystem is a group of independent economic actors that produce products or services that together create a coherent network (Pidun et al., 2019; Jacobides et al., 2018; Hannah and Eisenhardt, 2017) in which, creating, capturing and delivering value interdependent to all the factors of ecosystem (Adner, 2016). Paulus-Rohmer et al. (2016) specify the description of an ecosystem by adding that in some cases a company can be part of more than one ecosystem. Therefore, ecosystems can also overlap each other (Paulus-Rohmer et al., 2016). However, as Iansiti and Levien (2004) admit, defining precise boundaries of an ecosystem is impossible. Despite this the firm should be able to identify the actors with whom it interacts the most and determine the level and dependency of these relationships, how critical they are for the business (Iansiti & Levien, 2004).

Going further in the definition of an ecosystem in the business context, researchers have identified three different ecosystem models. The first model, *business ecosystem* underlines the individual firm in the center of its environment while *innovation ecosystem* is about the innovation or a new value proportion and its supportive actors being in the center. The third model, *platform ecosystem*, observes how actors organize around the platform (Jacobides et al., 2018).

The first model of business ecosystem focuses on an individual firm, viewing the ecosystem as an economic community of different actors that affect each other through their activities, creating and allocating value (Jacobides et al., 2018; Adner & Kapoor, 2010). Davidson et al. (2015) add to this definition the concept of *mutual value*, in which ecosystems create value that is greater than the value created by the individual actors. Ecosystem actors operate out rather mutual self-interest than and individual self-interest because in this way they can create more value. The ecosystem therefore practice “mutuality”, which considers the amount of shared ideas, standards and goals inside the ecosystem in order to improve the coordination in the ecosystem. In addition to mutuality, ecosystems are “orchestrated” which is related to the degree of coordination of interaction among ecosystem actors. Orchestration can be informal which means it is influenced by cultural norms or formal, which is driven by rules or physical presence of an orchestrator responsible for the management of ecosystem processes and interactions (Davidson et al., 2015).

Adner (2017) goes further in the ecosystem definition by dividing the term *ecosystem* into two different views. The first one, ecosystem-as-affiliation, defines ecosystem as a community that consists of different actors, defined by their networks and platform connections. Adner's second view sees ecosystems as structures, an assembly of activity defined by a value proposition. However, these two views are mutually consistent without closing out the other (Adner, 2017).

In the view of ecosystem-as-affiliation focal actor's centrality and power is increased by adding new linked actors to the ecosystem. With increased number of actors, the focal actor can gain more bargaining power and system value. Furthermore, with more ecosystem actors the likelihood to get more beneficial partners increases, which in turn could increase the whole system's value creation (Adner and Kapoor, 2010; Adner, 2017).

In the view of ecosystem-as-structure actors have defined agreed positions and activity flows among them, even though all actors do not necessarily share the same interests and end goals. Therefore, an ecosystem is naturally multilateral and successful when all actors are happy with their position, materializing the value proportion (Adner, 2017).

Innovation ecosystems underlines how actors that are dependable on each other interact to create and commercialize innovations which benefit the end customers (Jacobides et al., 2018). Innovation ecosystems can refer to clusters of innovation activities around specific topics or to business ecosystems formed around shared, challenging business goals (Adner and Kapoor, 2010). Ritala et al. (2013) specify this description by defining an innovation ecosystem as a business ecosystem, in which the goal is to create and capture the value from innovative activities (Ritala et al., 2013). However, firms' alignment of different agreements affects their capability to create value for the end customer (Adner, 2017).

The third view on ecosystems focuses on platforms, the interdependence of the platform's sponsor and the other additional actors that make the platform more valuable to consumers (Wareham et al., 2014). In the platform ecosystem these additional actors are connected to the central platform via open-source technologies or technical standards. Such actors around the central platform can generate complementary innovation, but also gain access to the central platform's customers (Jacobides et al., 2018).

3.1. Viable ecosystem strategies

Ecosystems have unique characteristics. First, they are formed around a final product which components are complementary. The interdependence among components can be challenging and the value can be created only if all components are present (Adner, 2017; Hannah and Eisenhardt, 2018). Second, some of these components cause bottlenecks in the ecosystem. These bottlenecks restrict the growth or performance of all the ecosystem because of poor quality, weak performance, or scarcity (Adner, 2012). Companies that cause these bottlenecks prevent other components and the entire system from operating at their potential and therefore restrict the ecosystem's growth (Adner & Kapoor, 2016; Hannah and Eisenhardt, 2018). Third, companies in the ecosystem need to balance between cooperation and competition; cooperatively create value with competitors and competitively capture value, which can sometimes be challenging (Adner & Kapoor, 2016; Hannah and Eisenhardt, 2018).

This kind of relationship where two or more horizontal actors practice simultaneous collaboration and competition is defined as *coopetition* (Ritala and Tidström, 2014). Bengtsson and Kock (2014) describe coopetition as a paradoxical relationship, adding that coopetition relationship between actors can also be vertical (Bengtsson and Kock, 2014). The game theory explains that coopetition is rational when cooperation with a competitor leads to a bigger market size and a situation where participants can share more among themselves than they could otherwise (Ritala and Hurmelinna-Laukkanen, 2009). Coopetition underlines the co-existence of value creation and capture. However, there might be differences in a coopetition strategy on a firm- and relationship-level how the value is created and realized by each actor (Ritala and Tidström, 2014).

Hannah and Eisenhardt (2018) introduce three viable ecosystem strategies; bottleneck, component, and system. According to them, companies successfully balance cooperation and competition by following one of these three strategies. The right ecosystem strategy depends on strategies of competitors and the number and crowdedness of bottlenecks (Hannah and Eisenhardt, 2018).

As mentioned above, the possible bottlenecks in the ecosystem affect the focal company's success. Therefore, the first viable strategy is called the bottleneck strategy. In this strategy the key contingency which determines the company's decision between cooperation or competition is bottleneck crowdedness. This strategy underlines agility (Hannah and Eisenhardt, 2018) and highlights the fact that challenges are not distributed evenly across ecosystem actors (Adner and Kapoor, 2010). When the bottleneck is crowded, innovation and cooperation are emphasized. And in contrast, when the bottleneck is uncrowded competition is highlighted. Bottlenecks are easy to identify, but hard to predict when will they arrive or how long will they stay (Hannah and Eisenhardt, 2018). Their location determines where innovation should be focused (Adner and Kapoor, 2010).

In the component strategy companies enter one or few components and depend on complementors for the rest. The component strategy emphasizes cooperation. The risk is not having access to components; companies that practice the component strategy are in a challenging position in their early stage when they do not yet have a complete ecosystem of complementors (Hannah and Eisenhardt, 2018).

In the third system strategy companies compete in components. This strategy emphasizes competition. Because it takes time to build components and create the integration across them, system strategy is expensive. Therefore, system strategy is often adopted in mature ecosystems where opportunism is seen as a problem rather than innovation (ibid).

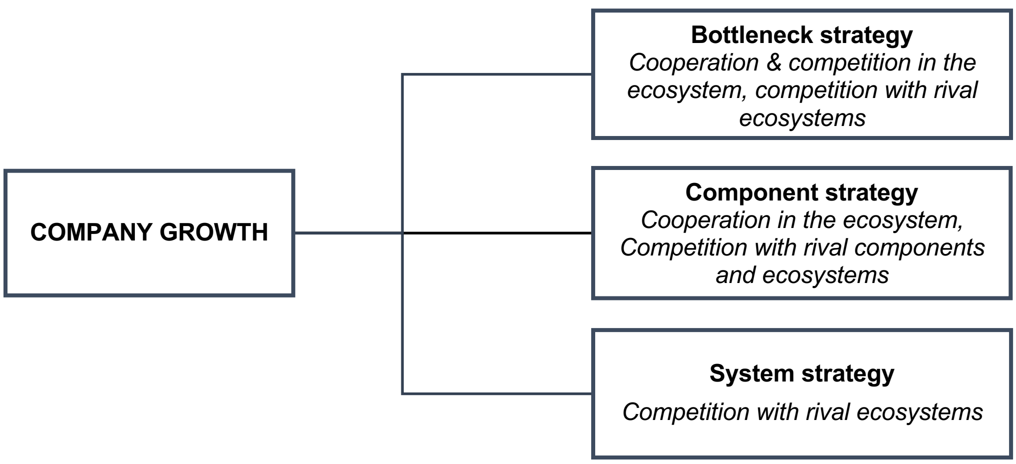


Figure 3. Viable ecosystem strategies according to Hannah and Eisenhardt (2018).

3.2. Innovation ecosystem

In this section we take a closer look at innovation ecosystems; how to create and manage an efficient innovation ecosystem. The term innovation ecosystem refers to set of actors around the central organization, the focal firm (Adner and Kapoor, 2010; Ritala et al., 2013), which create and capture value from innovation activities (Ritala et al., 2013). Relationships between actors are built on trust, collaboration and co-creation of value (Jiang et al., 2020).

Walrave et al. (2018) add that an innovation ecosystem is as a network of interdependent actors who co-create and deliver value proposition to end users, as well as take over the advantages received in the process by combining resources and/or capabilities. The focal firm orchestrates the ecosystem integration and the ecosystem value proposition (Walrave et al., 2018).

Companies usually think that in order to succeed and be technology leaders in their industry, they need to be first to introduce new innovations to the market. However, a new innovation's success depends on many other actors. If external changes are not in sync with the new innovation, it can dramatically fail on the market despite its greatness. Therefore, a new innovation's success depends on the level of innovation of other ecosystem actors, whether they also succeed to innovate or not (Adner, 2006; 2013; Adner and Kapoor, 2010).

Due to many interconnected pieces and players, formulating a strategy in an innovation ecosystem is a constant process (Adner, 2006). The choice of ecosystem strategy depends on a company's intentions, current position in an ecosystem, as well as strategic thinking (Valkokari et al.,2017). Once managers have created the vision about the prospect market and the product they want to launch, a preliminary agreement is made on the performance expectations that would determine success. After that risks are assessed; initiative risks, interdependence risks, and integration risks. This often forces managers to revise set performance expectations and rethink the original plan. As a result, managers might accept lower performance targets, allocate more resources to the project, reassign responsibility among the company and its partners, change the target market and so on. The decision between the market opportunity and the ecosystem risk – how to prioritize the options - is the core of the innovation strategy (Adner, 2006).

Initiative risks evaluate how does the project measure up. The company has to decide which initiative risks it will handle internally and which risks' management will be given to the suppliers. Assessing initiative risks means further feasibility analysis of the product itself, analyzing the competition and skills of the current project team (ibid).

Interdependence risks evaluate whose projects must succeed before the company's own project can. The more dependent the company's innovation is on others action, the less control it has over its own success. Interdependence risks can occur due to many reasons. Partners may have delays due to internal development challenges, financial problems, leadership crises or even because of their own interdependence with other ecosystem actors. In some of these cases where the company is far ahead of its ecosystem partners, the company can benefit from slowing down to let the other partners to catch up (ibid).

Integration Risks evaluate who has to adopt the solution before the customer can. Intermediaries are often positioned between the innovation and the final customer in the ecosystem. The higher in the value chain an innovation is set, the larger the number of intermediaries is needed to adopt it before the innovation can make great money. Therefore, when the number of intermediaries increases, so does the uncertainty on an innovation's success in the market (ibid).

The formulation of the ecosystem strategy and these three risks are presented in the figure below. We can add to the figure also innovation strategy, what kind of strategy the company chooses. In additions to the set performance expectations and the defined target market, the firm has to define where to compete, when to compete and how to compete.

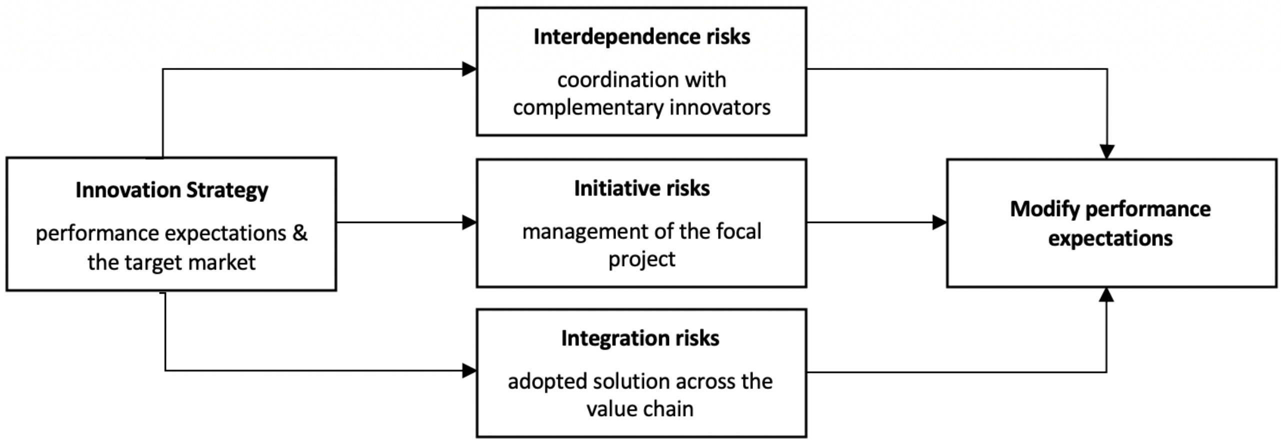


Figure 4. Formulating an ecosystem strategy according to Adner (2006). Modified.

As Paulus-Rohmer et al. (2016) summarize, it is not sufficient to develop a strategy only for the company. The strategy needs to be expanded to the whole surrounding ecosystem as well, taking also into consideration the position of the focal firm in it (Paulus-Rohmer et al., 2016).

In his book *The Wide Lens* (2013) Adner presents the concept of Wide Lense; instead of being an independent innovator, the innovating company should always take into consideration the whole ecosystem and be aware of blind spots. Even with the greatest product the company can't succeed if the innovation ecosystem won't come together. Therefore, the company's success depends on other ecosystem actors (Adner, 2013).

Traditionally the consumer has been considered the final arbiter of value. However, there are often partners and suppliers between the innovator and consumer who customize activities for every new launched product. Because these activities and the interaction between different partners tend to follow stable procedures and routines, these partners remain invisible and do not significantly affect the company's success as long as the company's innovation fit their routines. However, when the company's innovation requires a change in its partners routines, they will determinate the company's success. Therefore, the consumer is not the only arbiter of value (ibid).

The importance of partners and suppliers, the other ecosystem actors, are easy to overlook. Companies that focus only on their own innovation, often fail because they don't understand the innovation ecosystem and therefore, they don't see the blind spots. In order to successfully launch new products to the market, the company should look at the ecosystem with a wider perspective. In the below (figure 5) this concept of Wide Lens is presented.

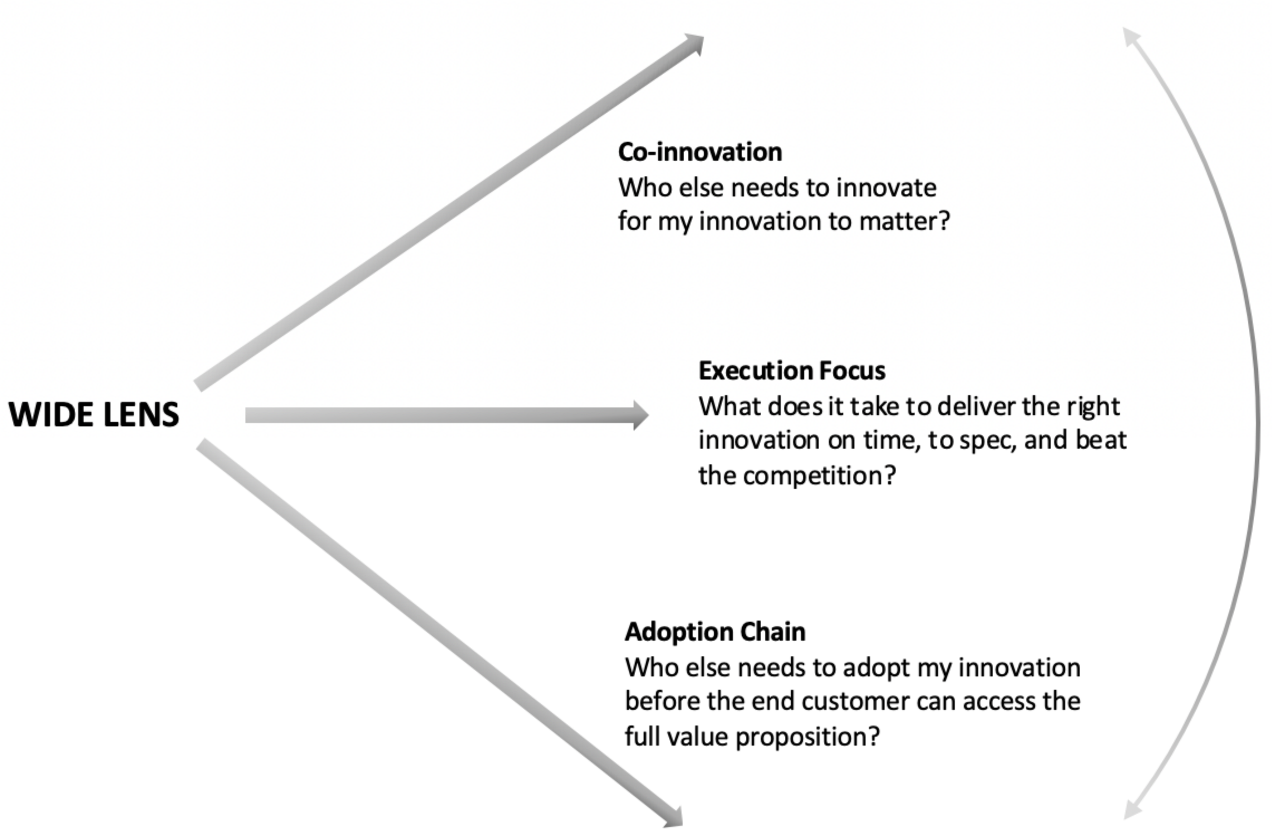


Figure 5. Wide Lens perspective (modified) on the innovation strategy according to Adner (2013).

The risks presented in figure 5 complement the risks in figure 4. The co-innovation risk is dependent on the others' success. In order to successfully commercialize the innovation, other companies need also successfully commercialize at some level. The execution focus risk is about the right timing. Even the greatest innovation can fail if the timing on the market is not right. Lastly, the adoption chain risk describes importance of partners and suppliers. Before the company has a complete solution available and the end customers can assess the full value proposition, partners will need to adopt the company's innovation at some level

(Adner, 2013). This Adner's *Wide Lens* approach is supported also by Paulus-Rohmer et al. (2016); instead of thinking according to the value chain, a company should think in ecosystems and the position it occupies in an ecosystem (Paulus-Rohmer et al., 2016).

3.3. Value creation and capture in an innovation ecosystem

When traditional market exchange models create value by innovating products, ecosystem actors collaborate with each other in order to create value that they could not make as a single actor (Davidson et al., 2015; Adner, 2006). Paulus-Rohmer et al. (2016) add that instead of thinking about creating value through the traditional value chain, the company should think about the value creation in the ecosystem, taking into consideration its position in the ecosystem (Paulus-Rohmer et al., 2016). A correctly implemented ecosystem helps its actors to streamline operations and reduce complexity (KPMG, 2019).

In order to create increasing value in ecosystems, companies need to recognize emerging opportunities and develop competencies to benefit from them. This means applying capabilities across the whole ecosystem and recognizing the compatibility gaps and needs. The company's position and role in the ecosystem depends on the level of activity it can fulfill within an ecosystem, how important and unique it is. By identifying new opportunities and developing skills to take the most out of them, organizations can create increasing value in their ecosystems (Davidson et al., 2015).

Teece (2010) specifies the concept of value creation by separating value creation and value capture as two different processes; a company's expertise and offerings together create value when the plan how to earn the revenues is about capturing the value (Teece, 2010). Hannah and Eisenhardt (2018) are on the same line and add that in order to be successful, companies need simultaneously create value and capture value (Hannah and Eisenhardt, 2018).

Going even further with concepts of value creation and capture in the ecosystem context, Ritala et al. (2013) separate mechanisms affecting value creation and value capture to two different phases; building and managing innovation ecosystems. The *ecosystem building mechanisms* define the premises of value creation and value capture, when the *ecosystem* *management mechanisms* help to maintain, realize and develop opportunities for value creation and capture once the ecosystem has already been established and key actors have been determined (Ritala et al., 2013).

In the context of an innovation ecosystem, *value creation* refers to activities and processes of creating value for customers. However, as Ritala et al. (2013) notify, *value capture* refers to the individual firm-related activity, how companies can gain competitive advantage and make profit (Ritala et al., 2013).

Jacobides (2006) complements the theory of value creation with the concept of industry architecture. Industry architecture (IA) describes how work is organized and structured within an industry and which companies capture value and make profit (Jacobides, 2006). Pisano and Teece (2007) add that industry architecture describes the structure of the relationships between the industry players (Pisano and Teece, 2007). By managing the industry's architecture companies can become the bottlenecks of their industry (Jacobides et al., 2006).

In addition to driving the direction of innovative activity, bottlenecks determine how an innovative combination creates and distributes value. Companies can achieve *architectural advantage* by fostering complementarity in a growing open ecosystem. This means stimulating intense competition in the complementary resources rather than in their own segments. Such companies can shape the structure of the industry based on the needs of their own innovation and their position in the ecosystem (Jacobides et al., 2006).

So far as the company has architectural advantage, it doesn't need to care about protecting or investing in complementary assets. However, in order to maintain its architectural advantage, the company should stick to one part of the production process and increase mobility in the other part (ibid).

According to Pisano and Teece (2007), managers usually pay attention to two essential things when making strategic decisions about how the capture value from the innovation; the intellectual property environment, also known as the appropriability regime*,* and the architecture of the industry. They provide the Profiting from Innovation (PFI) framework as an explanation why some innovators succeed with their innovation while others don't.

PFI framework claims that “aspects of economic organization, business strategy, technology, and innovation must all be understood” if the company wants to understand market reactions once the new technology is launched to the market (Pisano and Teece, 2007).

First, innovators should remember that only few innovations create value alone. Therefore, in order to create value an innovation needs complementary products, technologies, and services. Second, in addition of these complements, the delivery of an innovation requires movement of many components in the vertical chain of production. Therefore, when the innovator is not in control of the necessary components, the economic power of the innovator will be compromised by the economic power possessed by owners of required components (ibid).

PFI framework underlines the importance to own critical complementary technologies and/or control the bottleneck resources in the value chain. The bottleneck asset can be for example a technological complementarity that is created by a supplier or related to the system integration capabilities. If the innovator is not the owner of the bottleneck, there is a risk someone else who controls the bottleneck will be in a position to create the value and gain profit from the innovation (ibid).

4. INDUSTRY 4.0

In today's digital and connected world, more and more data is produced. This creates a need for systems that can make sense of large amounts of complex data (Ellen MacArthur Foundation 2019). Industry 4.0 is a globally used term for the significant transformation in ways we produce products and track their lifecycle due to the digitalization of manufacturing. Industry 4.0 consists of advanced nine technologies; internet of things (IoT), augmented reality, additive manufacturing (AM), big data, cloud computing, simulation, autonomous robots and cybersecurity (Nascimento et al., 2018; BCG, 2020).

Digital technologies offer new opportunities to optimize material flows and enable reverse material flow. Therefore, digital technologies play a significant role in the transition towards Circular Economy (Pagoropoulos et al., 2017). One of the digital technologies, artificial intelligence, can help companies to develop and design new circular products and businesses. In addition to circular product and materials, AI unlocks the potential to operate circular business models and to optimize the infrastructure to ensure circular material flows (Ellen MacArthur Foundation 2019).

Industry 4.0 will increase companies' productivity and their competitiveness (Gates et al., 2018; BCG, 2020). It makes possible to gather and analyze data across machines and produce higher-quality products at reduced costs (BCG, 2020). According to KPMG (2018), the biggest winners of Industry 4.0 are those who "*strategically use digitalization to create more valuable products or services*." Such companies benefit more than those who use digitalization as a cost-reduction tool. Digital transformation is strategic; it forces many companies to rethink their business and operating model. Furthermore, it requires managers to balance between short-term profitability improvements and long-term revenue growth (Gates et al., 2018).

Although, many companies have already adopted Industry 4.0 for their business, there are many organizations that still might deny the effect of Industry 4.0 to their business or could struggle to find the talent or knowledge how to adopt it to their own operation. As Gates (2018) from KPMG summarizes, "*full benefits of digital transformation are unlikely to materialize unless the strategy encompasses the entire organization*". Impacts of digitalization should be taken into consideration at every step of the value chain. This also means change in attitudes in the whole organization, thus successful digital transformation needs people with suitable skills to work with the new technologies (Gates et al., 2018).

One of the industry 4.0 technologies, artificial intelligence, imitates human-like cognitive functions with capabilities such as inductive reasoning and pattern recognition (McCarthy, 2007). AI helps companies to solve problems faster and beyond human capacity and therefore many companies already use artificial intelligence in their daily functions and operations. There are still untapped potential areas, where AI could improve the current processes (Brynjolfsson and McAfee, 2017; 2014). One of them is circular economy; with the help of AI new circular products and businesses could be developed and designed (Ellen MacArthur Foundation 2019).

In order to embrace this technology disruption, companies should understand how current competitors might behave and which technologies they might invest in. Furthermore, by tracking start-ups globally the company can reimagine the way business will be conducted. (Gates et al., 2018).

4.1. The role of industry 4.0 in innovation ecosystems

Industry 4.0 has a significant impact on a company's delivery model, as well as how a company chooses to organize itself (PwC, 2016). Industry 4.0 solutions require a high interdependency of technological complementarity and competences (KPMG, 2017), as well as seamlessly connected data analytics and system infrastructures so that full autonomy can be obtained (Jiang et al., 2020). Therefore, Industry 4.0 solutions that disrupt traditional business models (KPMG, 2017) change the character of supply-chain relationships from a traditional transaction-based model toward a value co-creation approach (Benitez et al., 2020). Once companies understand consumer behavior and can orchestrate the company's role within the ecosystem partners, breakthroughs in performance can happen (PwC, 2016).

In an innovation ecosystem a set of actors is formed around the focal firm (Adner and Kapoor, 2010; Ritala et al., 2013), that orchestrates the ecosystem integration and the value proposition (Walrave et al., 2018). The goal is to enable technology development and innovation (Jiang et al., 2020) by creating and capturing value from innovation activities (Ritala et al., 2013).

As an innovation ecosystem creates value that no single actor could have created alone, it utilizes a shared batch of complementary competencies or technologies (Jiang et al., 2020). With these technology solutions, companies can create the value for itself but also for the end user and the whole ecosystem (Souchet, 2017). In addition, companies can access highly developed automation and digitization processes, that again lead to a higher productivity, competency and efficiency in manufacturing (Jiang et al., 2020). As a result, Industry 4.0 enables smart products and improved processes (Agostini et al., 2019; Souchet, 2017), as well as plays a significant role in the field of innovation (Agostini et al., 2019). As an innovation ecosystem drives companies to surpass the limitations of innovation capabilities and resources, it also enhances companies' competitive advantage (Jiang et al., 2020).

Digital technologies enable connected system infrastructures between the ecosystem actors, but can also support communication, collaboration and coordination inside the company. In addition, Industry 4.0 can also help companies in knowledge management processes (Jiang et al., 2020).

4.2. Industry 4.0 and Circular Economy

Growing global population sets challenges to the environment, as well as to societies and the economy. Pollution, waste and scarcity of resources are just a few examples of negative impacts and challenges of the current, linear economic model (Ellen MacArthur Foundation, 2013; 2012). Therefore, new technologies and solutions are needed for redesigning key aspects of the economy (Ellen MacArthur Foundation, 2019).

The principle of circular economy is to keep products and materials in use as long as they provide value, as well as reduce and even design out waste and pollution (Ellen MacArthur Foundation, 2019). In addition to the environmental benefits, circular economy is considered to have a positive impact on society (Nascimento et al., 2018) by creating jobs and spurring innovation (Ellen MacArthur Foundation, 2019; Nascimento et al., 2018). From the economic aspect, the of execution Industry 4.0 with circular business models allow local business networks to develop. As the circular business model promotes recycling and re-using of materials, it increases the development of Industry 4.0 collection and processing techniques for urban waste (Nascimento et al., 2018).

As ISWA (2019) points out in its report, Industry 4.0 and circular economy are complementary. In addition to achieving sustainable development, Industry 4.0 technologies should also shift business processes. Industry 4.0 provides new opportunities for societal transformation, as well as breakthroughs in the field of technology. This technological disruption is needed in order to fully unlock the potential of Circular Economy (ISWA, 2019).

As Pagoropoulos et al. (2017) state, digital technologies help the transition towards circular economy by enabling reverse material flows and optimizing forward material flows. Hedberg et al. (2019) add that improved connectivity and information sharing can help to generate more circular products, services and processes. In addition, Industry 4.0 solutions can increase consumers’ awareness and push them to make sustainable choices (Hedberg et al., 2019). Therefore, digitalization can be seen one of the driving forces towards circularity (Ghoreishi and Happonen, 2020).

One of the Industry 4.0 technologies, machine learning, can handle a large amount of data and therefore, support process and system optimization in the context of circular economy. Intelligent enterprise systems designed with AI tools and techniques enable the next era of computing theory, as well as applications towards more circular business models. (Pagoropoulos et al., 2017). Ellen MacArthur Foundation (2019) is on the same page, highlighting that AI can play a significant role in the shift towards more sustainable, circular business models. AI could be used for example to improve and accelerate the design and material selection process based on circular design principles (Ellen MacArthur Foundation, 2019), as well as to solve solid waste problem (Abdallah et al, 2020). With the help of AI, a better reversed logistic infrastructure can be built, and loops can be closed (Ghoreishi and Happonen, 2020).

4.3. Smart robots in consumer waste management

Industry 4.0 has reshaped many industries and companies (KPMG, 2017). It has also reshaped the waste industry by opening new ways to eliminate and reduce waste from different sectors. Many cities already use digitalized waste collection and source separation recycling programs and both public and private sector operators adapting digital strategies (ISWA, 2019).

Municipal waste recycling is traditionally a tedious, labour-intensive and in many cases, also a hazardous practice. Artificial intelligence solutions can significantly improve MSW processes by replacing human performed tasks by smart robots. There are already many automated systems that are capable to separate individual materials such as paper, metals, plastics and glass by using "*magnetic, inductive, eddy current and near-infrared (NIR) sensing methods*" (Bogue, 2019). Autonomous robotic waste sorting systems enable separation of different, specific materials from waste streams. Compared to the traditional human sorting, robots can operate tirelessly around the clock and perform in hazardous environments. Making processes efficient, robotic waste sorting powered with artificial intelligence generates significant cost savings and improves revenue streams from high-purity recyclables. Furthermore, with the information provided by the sensors and visual recognition, operators are able to understand the waste input better and more easily adjust the lines accordingly based on the expected inputs (ISWA, 2019).

However, current methods can only separate a specific product or material (Bogue, 2019). The industry is calling for more effective sorting and recycling, one of the current technological challenges is related to the robotic automation of e-waste recycling. The pressure comes also from the national level when EU for example, requires that minimum 50 % of all household waste must be reused or recycled by 2020. In 2025 the recycling and reuse rate must be 55%, and the target for 2030 and 2035 is 60% and 65% respectively (Bogue, 2019; European Environment Agency, 2019).

It is predicted that industry 4.0 and artificial intelligence will continue to transform the waste management industry. Robotic recycling is already a reality and more and more companies will adopt it part of their processes in the next 10 years. The "robotic revolution" enables operators and companies more accuracy, more flexibility and transformation of material recovery facilities (MRF). In addition to technology requirements, contribution is needed also from product designers in order to fully unlock the potential of industry 4.0 technologies. Without the interaction and links between product designers and the waste management sector, the new products constructed from new and innovative composite materials could end up being non-recyclable and not possible to re-use (ISWA, 2019).

5. RESEARCH DESIGN AND METHODS

In this section the chosen research method and the research process are presented. First, the research design and the focal actor of this study are introduced. After this the research and data collection methods are presented. In the last chapter reliability and validity of the research are evaluated.

5.1. Research design

This thesis is carried out as a qualitative, exploratory single case study. In a qualitative research the role of the theory is important in planning and executing the data collection. However, the theory is not restrictive. Exploratory study is used when an issue or a phenomenon needs more clarification. It aims to explore new insights about a topic of interest with open questions (Saunders et al., 2016).

A case study is often defined as "*an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context"*. It helps to gain understanding or insight into the chosen research topic which often is a contemporary phenomenon (Saunders et al.,2016). This is conducted by building an analysis of the context and processes related to the researched phenomenon (Johnston et al., 1999). A single case study is often used to analyze a critical or a unique case, a phenomenon that only a few have analyzed before (Saunders et al.,2016). With the case study the researcher can look at the phenomenon in context and therefore, find boundaries between the phenomenon and context that otherwise would not be clearly evident. One or multiple units of study can be investigated, using research methods such as interviews or surveys for data collection (Farquhar, 2012).

Yin (2009) adds that a case study approach should be considered when the research questions seek answers to "how" and "why" questions, when the researcher cannot manipulate research participants' behavior and when contextual conditions are needed to cover. In addition, a case study approach is useful when the causal relationship between the phenomenon and context are not clear (Baxter and Jack, 2008).

The qualitative case study was chosen because the case to be researched is based on a real-life situation. In a qualitative research, the data can be collected through secondary data, observation and interviews. Interviews are used when a deeper understanding of a certain phenomenon is needed. In addition, interviews as a data collection method allow the researcher to ask additional questions in order to get the full picture of the case (Saunders et al., 2016).

5.1.1. Case selection

In a case study the decision on selected cases originates from the research hypotheses (Johnston et al., 1999). As Ghauri (2004) highlights, the selected cases should be compatible with the research problem, as well as correlate to the used theoretical framework (Ghauri, 2004). In this thesis no hypotheses are used. Instead, in order to find answers to the research gap defined in the chapter 2.1, three sub-questions with the main research question are set. As the research questions in this study are looking for answers about the circular value via smart robots in the consumer waste management ecosystem, as well as the focus was on an innovation ecosystem, a company that uses produces such smart robots was selected as the case company. In addition, as circular economy and Industry 4.0 were part of the theoretical framework, the case company needed to operate in the field of circular economy and use specific, advanced technology such as AI in waste sorting.

The focal actor of the ecosystem in this research is ZenRobotics, a Finnish technology company that uses artificial intelligence in waste sorting robots. ZenRobotics was the pioneer for robotic solutions that can separate different materials from waste streams (Ellen MacArthur Foundation, 2019; Bogue, 2019). The company launched a commercial robotic waste sorter in 2011, being first in the market (Bogue, 2019; ZenRobotics, 2020).

ZenRobotics currently has two products, Heavy Picker and Fast Picker, that both use a combination of AI, machine learning and computer vision to pick and sort items from the waste stream. Heavy Picker, which is the strongest waste sorting robot in the market and is designed for the construction waste sorting, uses Near-infrared (NIR) sensors, a high-resolution RGB camera, a 3D laser sensing system, an imaging metal detector, as well as a visible light sensor. Fast Picker sorts lighter materials such as paper, plastics, cardboard and uses an RGB camera and LEDs (Bogue, 2019; ZenRobotics, 2020).

5.2. Data collection methods

The ecosystem actors were first identified based on the theoretic background and focal actors' perception of their network. This first draft of the ecosystem was later completed by some complementary new actors which were identified by the conducted interviews.

All interviews were executed in April-July 2020. Due to the Coronavirus (COVID-19) pandemic in the whole world (WHO, 2020), all interviews were conducted by video calls and / or phone calls to avoid human contact. Due to the geographic location and challenging schedule, one interviewee sent the answers to the questions in the written format. The data was collected not only from Finnish companies, in fact four of the interviewed companies operate in Europe and three of them are global ones, having operations around the world. Only the business-to-business actors were interviewed so no private people such as consumers were included in the group of interviewees.

The data was collected by non-standardized, semi-structured thematic interviews. The interview questions were formed based on the theoretical framework so that they could provide answers to set the research questions (Saunders et al., 2016). Even though interviewees were given a small introduction about the main themes and used terminology before the actual interview questions, the research topic and some questions required basic knowledge of the topics of circular economy and ecosystems. Therefore, in order to get as relevant answers as possible, the goal was to interview persons who have knowledge of the previously mentioned topics based on their position in the company or educational background (Marrelli, 2007).

As state, the sample size is rarely large in a case study. When selecting the sample, it's important to take into consideration variety, accessibility of the data, as well the opportunity to learn from an unusual case (Marrelli, 2007). The group of interviewees was chosen according to their position in the organization and the role in the ecosystem. All of them are in the middle management / top management positions. The aim was to get a good overview of the whole network around the focal company. Therefore, apart from the focal actor interviewees, external ecosystem actor interviewees were mainly found via the focal actor's network. However, after every interview, interviewees were asked who they would recommend interviewing from their network. Through this question, the author of the thesis got access also to the external ecosystem actors' networks and was able to broaden the collected data and improve its diversity.

Totally eight company representatives were interviewed. Apart from the focal actor of the ecosystem, ZenRobotics, one interviewee was selected from each group of actors. As a result, three persons from the focal actor were interviewed and the rest five persons were from the other group of actors.

All interviewees were interviewed individually, so they were not able to hear answers from the other interviewees. Apart from one interview that was conducted in Finnish, all interviews were held in English. In the majority of the interviews, interview questions were not provided to the interviewees beforehand. All the interviewed actors are presented in the table below. The table presents the industry of the interviewed person, type of the interview and the duration of the interview.

Table 1. Interview types and length of the case companies

Case company	Industry	Interview type	Duration
Focal actor 1	Recycling machinery & software	Videocall	24.09 min
Focal actor 2	Recycling machinery & software	Videocall	37.54 min
Focal actor 3	Recycling machinery & software	Videocall	38.18 min
Company X	Water, wastewater & waste management	Phone	39.52 min
Company Y	Plastics packaging	Phone	30.30 min
Company Z	Environmental services	Videocall	22.37 min
Company W	Plastics recycling	E-mail	N/A
Company Q	Consumer goods company (packaging)	Phone	37.32 min

The interview questions are in appendix 1. The interview questions were created from the research questions and the theoretical framework which was built based on the literature review. Because the goal was to allow interviewees to define and describe an event or a situation, as well as encourage them to provide a comprehensive answer, mainly open questions were used (Saunders et al., 2016). The interview questions were split into three different themes which were the following: *Ecosystem & Value creation*, *Challenges, risk management & regulations* and *Smart robots / Fast Picker*. As the research questions, these themes were derived from the literature review and common sense (Saunders et al., 2016).

The interview questions related to smart robots and ZenRobotics' product called Fast Picker varied a little bit, because due to different industries, not all interviewed actors had direct experience in smart robots in their daily waste management operations.

5.3. Data analysis methods

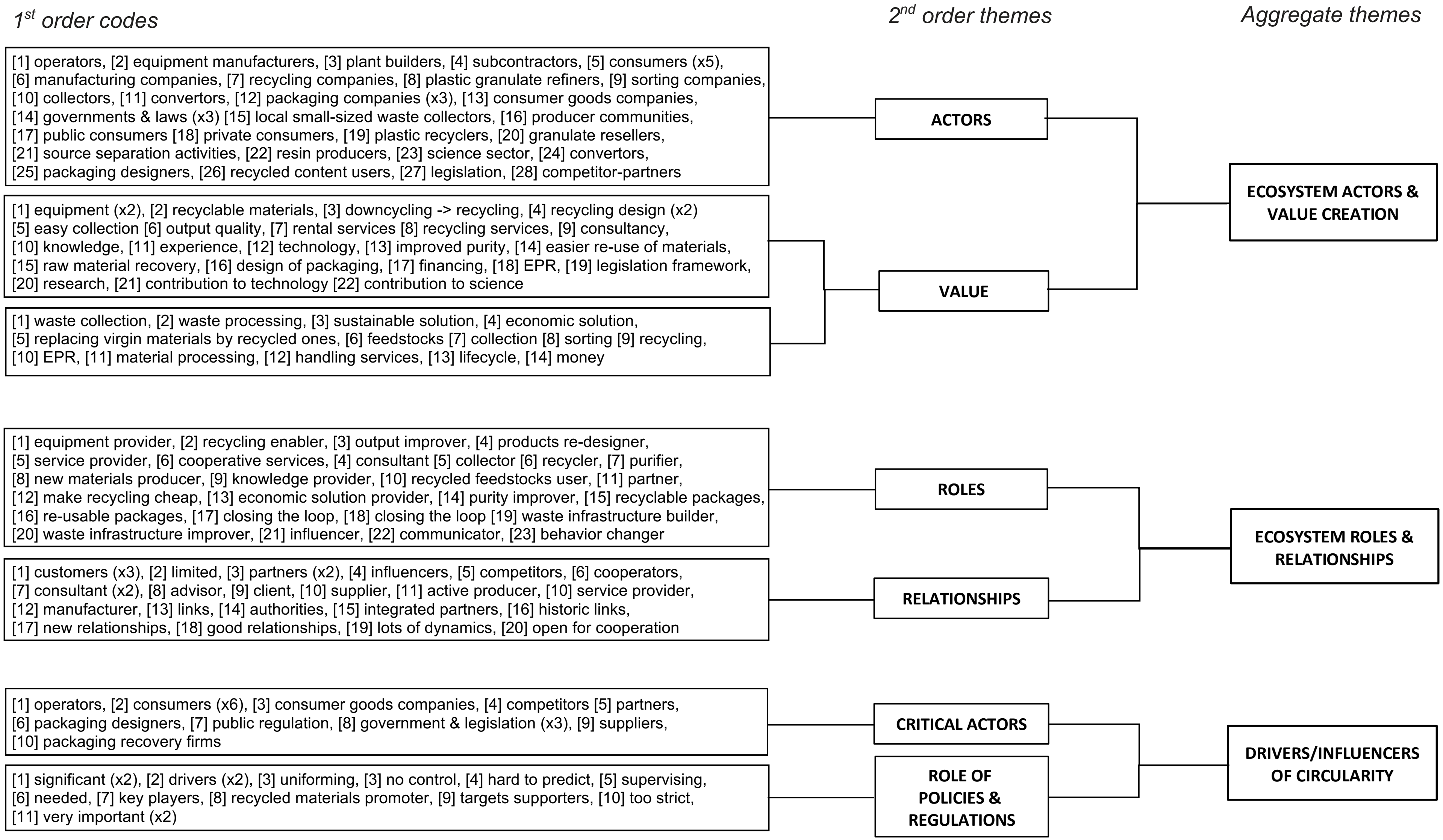
The data analyzed in this research was received from the eight conducted interviews. In order to find answers to the research questions, it was obligatory to find patterns, themes and relationships from the data. Therefore, thematic analysis was chosen as a method because it provides a flexible but systematic approach to analyze qualitative data (Saunders et al., 2016).

The analysis of the data followed the thematic analysis process by Saunders et al. (2016). The interviews were recorded and later transcribed into text within max. two days after the actual interview. Only one interview was done by email without recording (Company W). Because answers were already in the text form, this interview did not need to be transcribed. Transcription of the interviews gave me the opportunity to better familiarize myself with the data. In addition, in order to summarize the key points from each interview, short summaries were made out of each interview.

To better identify different themes and the relationships between them, the data was coded after the transcription. The coding of data is a process where the collected information is transformed into labeled categories (Allen, 2017; Saunders et al., 2016). A code is a word or a phrase that is given to a unit of data, representing important and recurring themes in responses (Saunders et al., 2016). Coding can be deductive or inductive, in this thesis deductive coding has been used which means using a predefined set of codes and then assigning these codes to the new qualitative data (Miles and Huberman, 1994).

The list of codes can be found in the appendix 2. Mostly *in vivo* codes were used, which means codes that are based on the terms and words used by the interviewees (Saunders et al., 2016). In addition to *in vivo* coding, some labels were developed by the author to best describe the data.

The coding structure is presented in figure 6. First, all the responses to the interview questions were coded. This first level of coding is called open coding or initial coding (Hahn, 2008). In this first level coding descriptive, low inference codes are used. First level coding gives the basis for the more explanatory higher order coding, second level coding (Elliott, 2018). After *1st order codes* were created, these codes were put under *2nd order themes.* This second level coding is also called category development or focused coding (Hahn, 2008) and it focuses on pattern codes which are more descriptive (Elliott, 2018). In the third level of coding codes are clarified enough so that they can be used in publications and reports. This third level coding is also known as thematic coding or axial coding (Hahn, 2008). As a result, seven different *aggregate themes* were built based on the 2nd order themes.


1st order codes
2nd order themes
Aggregate themes
[1] operators, [2] equipment manufacturers, [3] plant builders, [4] subcontractors, [5] consumers (x5), [6] manufacturing companies, [7] recycling companies, [8] plastic granulate refiners, [9] sorting companies, [10] collectors, [11] convertors, [12] packaging companies (x3), [13] consumer goods companies, [14] governments & laws (x3) [15] local small-sized waste collectors, [16] producer communities, [17] public consumers [18] private consumers, [19] plastic recyclers, [20] granulate resellers, [21] source separation activities, [22] resin producers, [23] science sector, [24] convertors, [25] packaging designers, [26] recycled content users, [27] legislation, [28] competitor-partners
ACTORS
[1] equipment (x2), [2] recyclable materials, [3] downcycling -> recycling, [4] recycling design (x2) [5] easy collection [6] output quality, [7] rental services [8] recycling services, [9] consultancy, [10] knowledge, [11] experience, [12] technology, [13] improved purity, [14] easier re-use of materials, [15] raw material recovery, [16] design of packaging, [17] financing, [18] EPR, [19] legislation framework, [20] research, [21] contribution to technology [22] contribution to science
[1] waste collection, [2] waste processing, [3] sustainable solution, [4] economic solution, [5] replacing virgin materials by recycled ones, [6] feedstocks [7] collection [8] sorting [9] recycling, [10] EPR, [11] material processing, [12] handling services, [13] lifecycle, [14] money
VALUE
ECOSYSTEM ACTORS & VALUE CREATION
[1] equipment provider, [2] recycling enabler, [3] output improver, [4] products re-designer, [5] service provider, [6] cooperative services, [4] consultant [5] collector [6] recycler, [7] purifier, [8] new materials producer, [9] knowledge provider, [10] recycled feedstocks user, [11] partner, [12] make recycling cheap, [13] economic solution provider, [14] purity improver, [15] recyclable packages, [16] re-usable packages, [17] closing the loop, [18] closing the loop [19] waste infrastructure builder, [20] waste infrastructure improver, [21] influencer, [22] communicator, [23] behavior changer
ROLES
[1] customers (x3), [2] limited, [3] partners (x2), [4] influencers, [5] competitors, [6] cooperators, [7] consultant (x2), [8] advisor, [9] client, [10] supplier, [11] active producer, [10] service provider, [12] manufacturer, [13] links, [14] authorities, [15] integrated partners, [16] historic links, [17] new relationships, [18] good relationships, [19] lots of dynamics, [20] open for cooperation
RELATIONSHIPS
ECOSYSTEM ROLES & RELATIONSHIPS
[1] operators, [2] consumers (x6), [3] consumer goods companies, [4] competitors [5] partners, [6] packaging designers, [7] public regulation, [8] government & legislation (x3), [9] suppliers, [10] packaging recovery firms
CRITICAL ACTORS
[1] significant (x2), [2] drivers (x2), [3] uniforming, [3] no control, [4] hard to predict, [5] supervising, [6] needed, [7] key players, [8] recycled materials promoter, [9] targets supporters, [10] too strict, [11] very important (x2)
ROLE OF POLICIES & REGULATIONS
DRIVERS/INFLUENCERS OF CIRCULARITY

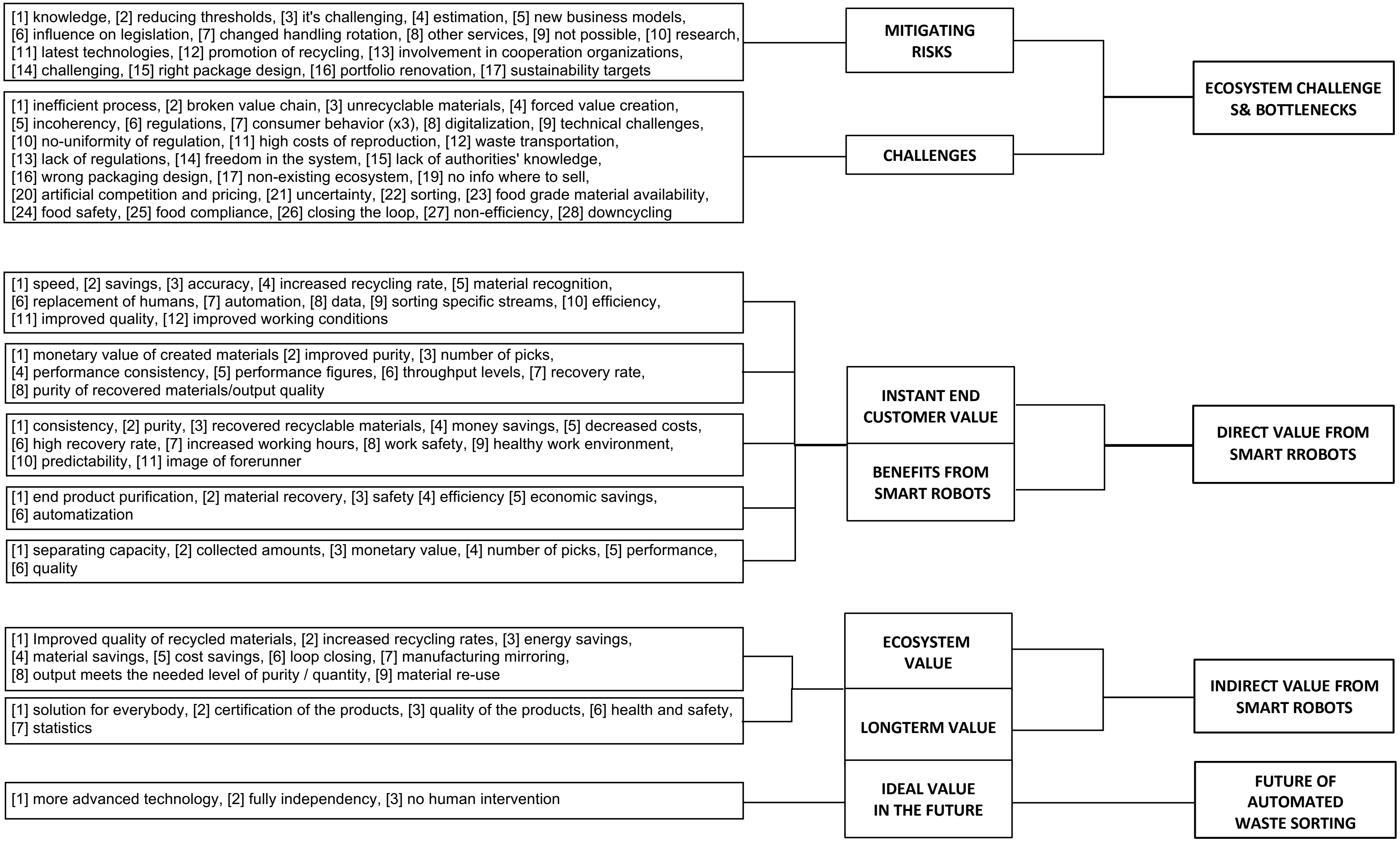


Figure 6. Coding structure

5.4. Reliability and validity

Reliability and validity are important factors when analyzing the quality of the research. Reliability refers to the replication of the research, is it possible to get the same, consistent answers if the research would be conducted again. Validity refers to the accuracy, how well the measurement tools used in the research actually measure what they are supposed to measure (Saunders et al., 2016).

Even though some researchers say validity can't be used in a qualitative research, they also realize the need for a qualifying check for their research. The role and importance of validity and reliability shares opinions between qualitative researchers. When reliability in a quantitative study evaluates quality with a purpose of explaining, in qualitative study reliability has a purpose of generating understanding (Golafshani, 2003). In some cases, reliability can be misleading in qualitative research. As Stenbacka (2001) states, "*if a qualitative study is discussed with reliability as a criterion, the consequence is rather that the study is no good*". Therefore, it is irrelevant in qualitative research (Stenbacka, 2001).

Patton (2002) sees the role of reliability differently, stating that reliability with validity are both important while designing a research; how the results will be analyzed and how the overall quality of the research will be judged. Saunders et al. (2016) are on the same page, identifying different threats that can affect reliability. These threats were taken into consideration when designing this research, also in the data collection and analysis.

Because participants were able to select the most suitable time slot for them and there was some extra time reserved for the interview questions, the *participant error* was minor. *Participant biases* were mitigated by conducting all interviews separately. No one else could hear interviewees' answers and anonymity of the responses was highlighted. Researcher errors and biases were minimized by preparing to the interviews well in advance and not letting personal thoughts affect the interview process or result analyzation.

Trustworthiness of a qualitative research is critical (Golafshani, 2003). In order to get as truthful answers as possible, the research was conducted anonymously. Anonymity was highlighted for the participants and they all were very open with their answers. All responders were already familiar with discussed concepts, circular economy and ecosystems.

Therefore, no further explanations about concepts were needed. Due to interviewees' knowledge about the circular economy and its terminology, we can conclude all interviewees understood the questions well and answered them based on their best knowledge.

6. FINDINGS

In this section the results and findings of the data analysis process are presented. Relevant quotes have been included in some cases in order to give examples of a certain discussed phenomena or to highlight important, risen themes and challenges around discussed topics.

Based on the coding structure (figure 6), seven different themes were identified; Ecosystem Actors and Value Creation, Ecosystem Roles and Relationships, Drivers / Influencers of Circularity, Ecosystem Challenges and Bottlenecks, Direct Value from Smart Robots, Indirect Value from Smart Robots and Future of Automatized Waste Sorting. In the following section we go through each theme and present the findings.

Ecosystem Actors and Value Creation

Every interviewee saw the current ecosystem around the consumer waste management a little bit differently. Most interviewees mentioned actors that were linear to them and therefore, did not consider the ecosystem as a circle. In the table below answers are presented by each interviewee.

Table 2. Ecosystem actors by each interviewee

	Who do you think other actors in the ecosystem are and how do they contribute to the value creation?
Focal actor 1	Operators, equipment manufacturers, plant builders, subcontractors, consumers
Focal actor 2	Consumers, manufacturing companies, recycling companies, plastic granulate refiners, sorting companies, granulate suppliers
Focal actor 3	Waste collectors, mechanical treatment, convertors, consumer goods companies, packaging companies (recycled materials)
Company X	Packaging material firms and designers, public consumers, private consumers, regulators
Company Y	Consumers, government & laws, other companies
Company Z	Local smaller waste collectors, producer communities
Company W	Customers, granulate buyers, waste producers
Company Q	Resin producers, science sector, convertors, packaging designers, recycled content users, legislation, consumers, competitor-partners

When all the interviewees' responses are gathered together, the current consumer waste management ecosystem looks as follows (figure 7). Company W mentioned *waste producers* as one group of actors, but because the public or private waste producer is also a consumer when buying the product, the waste producers are put under the label *public consumers* and *private consumers*. Furthermore, the response *competitor-partner (coopetitor)* is not presented in the figure below because competition / collaboration relationships differ by actors. However, *coopetition* will be analyzed later as phenomena. The focal actor is presented in the middle as an equipment manufacturer, this is the term many of the interviewees brought up, so it's therefore used for the focal company.

Figure 7. Current consumer waste management ecosystem according to the interviewees

When the interviewees were asked how the other actors in the ecosystem contribute to the value creation, responses revealed each company's dependency on the other actors. The value creation in almost every case was linked to the closest partners, suppliers or competitors, also consumers were mentioned. Many of these value creation relationships very reciprocal, bringing value or other benefit to the other company as well.

According to Focal actor 1, operators contribute to the value creation by collecting the waste itself or using subcontractors either from consumers or from the industry. After that they process it in the waste sorting plants and then trade the sorted material for re-use. The plant builders are responsible for creating the actual plant designs that use the equipment provided by the focal actor and subcontractors contribute to practical processing.

Focal actors 1 and 2, as well as Companies Y, X, W and Q mentioned consumers as ecosystem actors. As Company Y stated, if consumers don't want to buy a product it's very hard to sell it, even though it would be circularly speaking a very good product. Company Q was on the same page, saying that consumers make the purchase decision and dispose the used packages. Focal actor 2 added, that consumers are driving the change towards recycled products in reality. Company W felt the same way; if people and industry consciously would use the raw materials instead of throwing them into the sea or onto the street, the waste problem would definitely not be so fateful. Therefore, consumers contribute in many ways to the ecosystem value creation.

Company W also underlined the role of their customers, who decide to recycle plastics and either process the material itself or resell the granulate. This opens up the possibility of seeing waste as a valuable material. To Company Z, local smaller waste collectors are mostly bringing the value because as partners they bring materials and provide services to them, which again benefits the whole ecosystem.

Then, companies were asked what they bring to the ecosystem and what are the circular benefits. Many interviewees mentioned experience and knowledge in addition to the special services or products they offer. All interviewees had a clear picture of how their company is contributing to the circular value creation. Company Z mentioned its rental service of EUR pallets and recycling services for aluminum cans. Like this products and materials circulate, which benefits the ecosystem actors but also the environment when less waste is produced. Company X intervenes on almost all steps of the ecosystem chain, bringing knowledge and services through different roles that can vary from the situation. They can act as a consultant or an advisor, a client, a supplier, a partner or sometimes even an active producer.

Company W said that they are bringing knowledge about the latest technologies from suppliers to the customer and sharing experiences about proven and durable systems. These newer technologies would consume less energy, which has a positive effect on the customer as well as on the environment. Company Q was also contributing to science and technology; they had just opened a new packaging institute where they are looking for new materials. In addition, they make sure the package they are launching comply to design for recycling rules and is a sustainable package. Furthermore, as a consumer goods company, they finance the extended producer responsibility, so they are paying for the collection and recycling infrastructure.

Like Company Q, Company Y stated that one of the most important things they are bringing is the design for recycling. If their products are designed the right way in the first place, this also makes the collection easier and gives a good output quality of recycled material that is collected and sorted. Company Y does cooperation regarding the design with brand owners and retailers, etc., and these actors are also contributing to some design of recycling guidelines. Once everything is done right, the output quality of recycled materials at the end of this loop is good and well enough so that it can be re-entered as a recycled material in their products.

All three Focal actors said they are bringing to the ecosystem the machinery that is needed to recover the raw materials. As Focal actor 1 specified, they are providing the possibility to sort some fractions that would not have been possible to sort without their technology. In addition, they are also providing technologies to improve the purity of sorted materials which make the actual re-use of those materials easier.

Focal actor 3 also brought up downcycling, how they are helping companies to reach the gap from downcycling to actual recycling.

“ … we are enabling our customer to truly have recyclable materials. For them to produce the required quality, so that they can actually market their commodities as recycled materials … Reaching the gap that it required to go from downcycling to recycling, we are helping companies to go from downcycling to proper recycling.”

(Focal actor 3, 2020)

Ecosystem Roles and Relationships

In the question 2 and 4, interviewees were asked to describe the relationships between other ecosystem actors and to define, what is their role or position in the ecosystem regarding circular economy. Responders considered themselves to be in a consultant, an advisor or a service provider role, providing value for the other actors. In some cases, competitors were seen also as cooperators. As we saw earlier in the literature review, this kind of relationship is identified as *coopetition*.

Focal actor 1 and 3 said they are an equipment provider for the processing of the collected waste so that it can be used as a recycled material. They are improving the purity of materials, outputs specifically from mechanical recycling. Focal actor 2 added that they are offering a solution that is more economic, which also saves in labor costs or health and safety. If they make recycling cheaper there will be more recycling.

“ There is now very little recycling. The more economic you make it, the more it will happen, it will be more recycling. Any manufacturer of a plastic product, they have no interest in using virgin plastic - the only reason is it’s cheaper than recycled plastics because recycling is a very heavy process and you don’t get the quality. So our task is to make the recycling so cheap, that it actually conquers the whole market. ”

(Focal actor 2, 2020)

Company Y saw their role as a plastics converter to improve the design for recycling and make their products suitable for recycling, they also use recycled feedstocks as much as possible in their products. What comes to the relationships, Company Y has historic links to the feedstock manufacturers, as well as brand owners and retailers. However, the circular economy has created new links as well. These new relationships are related to the renewable feedstock. Without the right quality from recycles, they can’t produce new products and therefore, can’t close any loops. Company Y also says they have relationships and influence on sorting and collection sector, as well as recyclers. They are also contributing on a national level to some projects where everybody in this ecosystem is part of, like the brand owners, collectors, retailers etc. Company Y summarizes that when it's circular, every link of the chain has some influence on converters like their company.

Company W said their role is to make customers, who want to enter the recycling business, aware of the many recycling options (mechanical or chemical). Many companies often do not recognize the potential of recycling and therefore choose the incineration. Therefore, company W acts as a consultant and service provider between plastics recycling companies (their customers), and manufacturers of recycling machines, sorting systems, washing systems, etc. (their suppliers).

Company Z stated that the waste collectors are their competitors but also cooperators, this competitor-cooperator dynamic also defines their role in the ecosystem. They also do cooperation with producer communities.

Focal actors 1, 2 and 3 said they have customer relationships with plant builders and waste management companies. Focal actor 3 also mentioned public authorities, municipalities and governments, but admitted that they have very little influence over them.

Company X said their role and relationship to the other ecosystem actors vary depending on the situation, they intervene on almost all steps of the chain. They can either be a consultant or an advisor, a client, a supplier, a partner or even an active producer. First, as a partner of municipalities, they help to educate the public on how to sort correctly and how to avoid waste. They also advice their industrial clients and producers of packaging material on how to optimize their waste production. Secondly, they are delivering collection service for MSW or DMR. The third part is the sorting and recycling and in the fourth step, they send the purified fibres, plastics, wood, ferrous or glass to different industries to produce new source material. This final recovery is sometimes done inhouse, sometimes with partners such as paper mills, glass producers, producers of plastic grains. The secondary fuel or energy is produced by incineration or methanization from the materials that can't be recycled.

Company Q said they are focusing on three areas in terms of circular economy. First is about the packaging; they make sure their packages are either recyclable or re-usable by 2025. Secondly, they want to create a waste-free future and close the loop. They are doing this by building up the waste infrastructures and improving the already existing ones for the collection, recycling and re-using of materials. Thirdly, they want to change behaviors by spreading information and communicating especially with the consumers.

Therefore, Company Q's relationships to the different ecosystem actors varies but like the interviewee stated, they have good relationships with other actors. As Company Q said about actors' relationships in this circular economy:

" …more and more stakeholders realize it's not a single company effort or task to solve, it needs joints efforts. I think there is still too much powerless efforts and not really focused ones, that's a challenge but also an opportunity. Not to work in silos, but really join forces and work towards one and towards common goal, using the resources in an efficient way."

(Case Company Q)

Drivers / Influencers of Circularity

When the responders were asked who the most important actors in the ecosystem are, six out of eight responders mentioned consumers. The consumers and the increased awareness about environment-related challenges, recycling more sustainable options were seen vital for the whole ecosystem operation.

"…if we have the best product designed for the recycling and the best collection system etc. but the consumers don't care and throw their trashes in the ocean or in the nature… recycling won't happen without the consumers."

(Case Company Y, 2020)

Other important mentioned actors were *operators* (Focal actor 1), *consumer goods companies* (Focal actor 3), *packaging designers and recyclers* (Company X), *public regulations and laws* (Company Y, W and Q), as well as *competitors-cooperators* (Company Z), *suppliers* and *packaging recovery firms* (Company Q).

Even though laws and regulations weren’t mentioned by as many responders as consumers in the question of the most important actors, all the responders said laws and regulations play a big role when a question (question 9) about their role was asked later. The responders described the role of municipal policies and public regulations significant and needed. They were said to be the drivers of the circularity, because without the taxation and other policies the waste would be dumped to the landfills because traditionally, the operators just want to get rid of the waste as cheaply as possible. Furthermore, with policies bigger markets for circular products can be generated once everyone is operating according to the same guidelines and boundaries. Governments need to promote recycled materials and give incentives to design recyclable packages.

However, public regulations and municipal policies were also seen hard to predict and many of the responders felt they don’t have any control over them. In the figure (figure 8) below the current consumer waste management ecosystem is presented with the most important actors by interviewees. As mentioned earlier, *competitor-partner* is not presented in the figure because this term is not specified enough to present a certain actor group. Furthermore, *packaging recovery firms* are put under the label *recycling companies*.

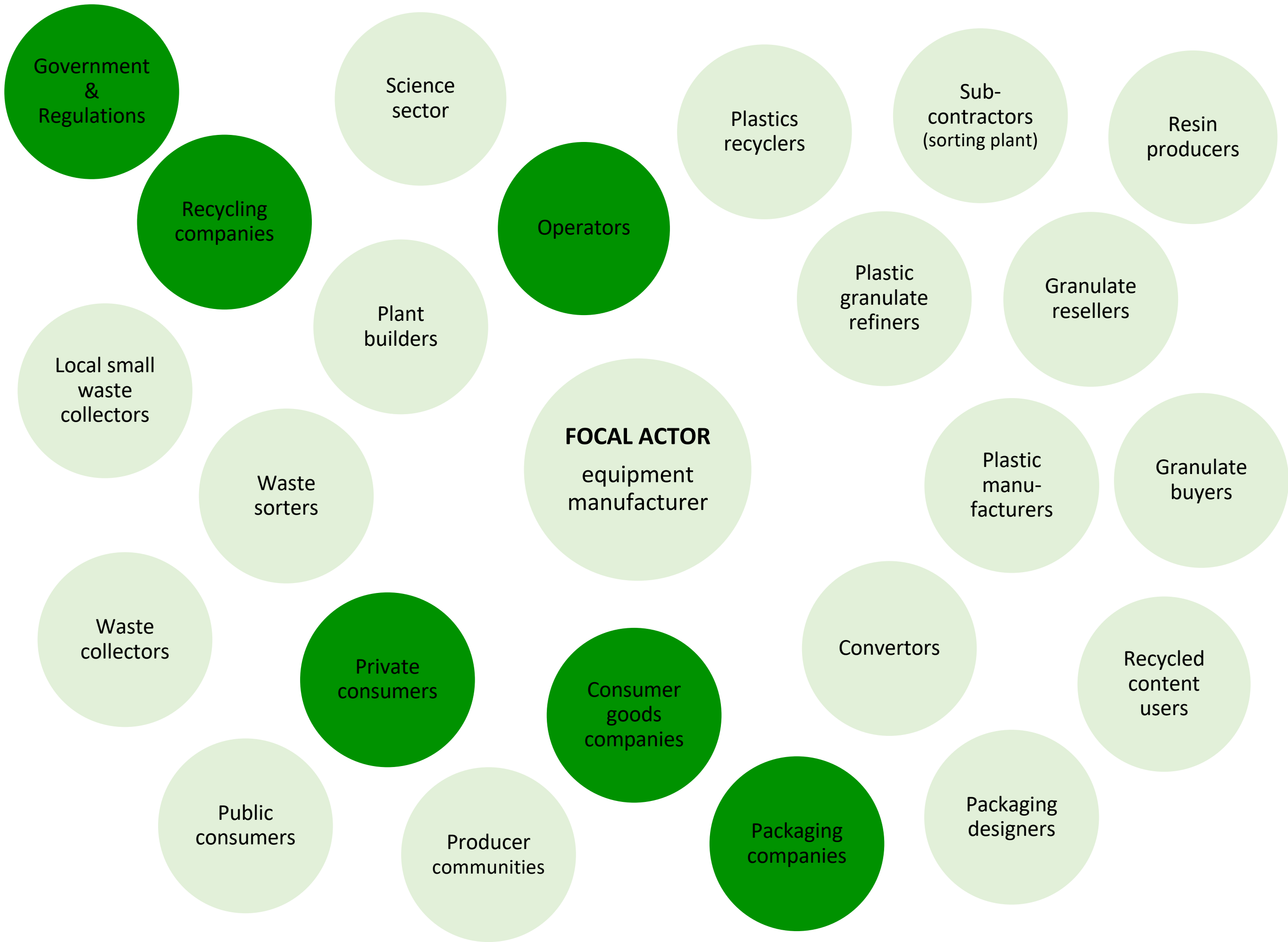


Figure 8. The most important actors (dark green) in the consumer waste management ecosystem according to the interviewees

Challenges and Bottlenecks

All interviewees admitted risks in the ecosystem are hard to predict and therefore, almost impossible to manage. Only one interviewee (Company Z) was involved in cooperation organizations as an advisor so like this had a small influence on legislative changes. Regulations and the uniformity of legislation were seen as one of the biggest challenges because companies don't have much influence on them and in the current market, waste laws aren't the same in every country. Furthermore, in some cases it's still cheaper to produce new materials from virgin materials than new materials out of recycled ones.

The lack of uniform legislation was said to cause too much freedom in the system also from the consumers' side. Consumer behavior was seen hard to control and as a root of the problem. When consumers don't dispose waste the right way, it causes problems to the whole ecosystem.

However, despite the uncertainty caused by the constantly changing legislation, Company Y, Z and Q said they are seeing circularity as an opportunity. Company Y and Z had invented new business models and services to tackle risks affecting their industries. Company Q said that in the first place, they can ensure the right design of their packaging; they make sure at least their product can be properly recycled and sorted. They are also renovating the existing portfolio, aiming to the company target that by 2025, all their packages will be recyclable or re-usable.

"At the moment many companies see it (circular economy) as something they have to do, not as an opportunity"

(Case Company Y, 2020)

Furthermore, four out of eight interviewees said they mitigate risks internally by making sure they have the right knowledge in the company and by doing continuous research. Company W also educates other ecosystem actors about the new, more sustainable technology solutions and the benefits of recycling. Other challenges mentioned were related to the digitalization (Company Z) and the current technology used in the recycling (Company Y).

Focal actor 2 also gave critic to the packaging manufacturers, saying that because their incentives regarding the package design is to protect the product and maximize the sales of the product, they couldn't care less about recycling. Therefore, there are materials that are tremendously difficult to recycle. By small changes to material choices, color, patterns, shapes, labels many products could be easily recycled. Company X also mentioned technical challenges related to the packaging design. Once the design is correctly done, they will be able to fully recover the majority of the materials.

Some of the challenges mentioned by the responders were identified as bottlenecks for the whole ecosystem. The non-existing uniformity of regulations and overall incoherent ecosystem were seen problematic and affecting every actor in the ecosystem.

“I think it’s not really possible to perform in this circular economy alone, it’s always a combination of players in the supply chain, in this ecosystem … This would also be the most challenging part because there is a high degree of freedom in the system, if you have trouble with a design in recycling you will have problem with the quality of material if you have many consumers who don’t dispose products the right way you will have big problems in the sorting facilities …. the ecosystem doesn’t work if everyone is not involved.”

(Case Company Y, 2020)

Like Company Y said, if the product is not designed the right way, all the other following steps in the recycling, material processing and re-use after the dispose will be affected. In addition to wrong package design and materials that are difficult to recycle, the suppliers and buyers of recycled materials do not meet:

“You go in a company and tell them now you can sort polyethylene plastic with 99% purity and they look at you saying there is no market I don’t know where to sell it. And at the same time, you can talk to people who – like plastics manufacturing companies who say we can’t find plastics recyclables anymore.”

(Focal actor 2, 2020)

Another challenge is the cost of recycling vs willingness of the public to pay for it. In some cases, it’s cheaper to produce new materials out from secondary products and in some cases it’s still more expensive to produce new materials out of recycling (Company X).

During the interview, Company X also brought up challenges regarding the plastics and their recycling. There are already discussions ongoing in the industry, with producers and users of plastics packages, how the variety of products could be limited.

“ Of course we recycle a lot of plastics and give them a second live. But few of them can be used in an identical way as the source material. That is why I’ve said: plastics are really hard to recycle in a circular way; the most clear example is PET bottles; if they are all transparent you can produce transparent flakes. But the more you add red or green PET bottles less your transparent flakes are transparent. We turn resources into an extraordinary number of products making it so difficult to come to a high number of real circular plastics … once

beyond a certain point, you can only produce a lower grade of product but no longer a source product. ”

(Case Company X, 2020)

Company Q was on the same page with Company X about the challenges with recycled plastics; one of the biggest challenges for sorting and closing the loop is plastics, particularly in the food packages. It’s difficult to get recycled food grade materials because of the safety and compliance of these materials. According to Company Q this challenge should be fixed with better sorting at sorting facilities.

Furthermore, because the circularity is currently run by laws and regulations, the competition and pricing are artificial, leading to forced value creation (Focal actor 3).

I see the broken value chain as a main problem … in recycling you might have issues with recognizing certain materials because they are not made to be recycled … this is the major problem to solve, how to create an ecosystem. Organic ecosystem growth or creation is not fast enough … the main bottleneck in recycling – it is the ecosystem.”

(Focal actor 2, 2020)

Direct Value from Smart Robots

The direct value created by the smart robots was said to be measured by the number of human pickers they can replace. Currently the waste industry is often using manual sorting, so all the responders saw the automatization of the waste centers as a significant value factor.

Compared to humans, interviewees said that the robot can operate tirelessly and sort different materials into very specific streams (company Y), providing performance consistency. Smart robots are capable of detecting different materials and providing valuable data and statistics to the sorting facility, what has been picked during the day. Therefore, due to the better sorting accuracy, the quality of recovered materials is purer (Company X). With this improved output quality more materials can be recycled and returned back to the re-use.

In addition to efficiency and consistent performance, responders also mentioned that smart robots bring them economic savings. One of the value metrics is the obtained price from the sorted materials vs. what the monetary value would be if the waste would be handled unsorted (Company Z, Focal actors 1 & 3).

Indirect Value from Smart Robots

Smart robots were considered to reduce the energy consumption and the raw material consumption in the whole ecosystem with their accuracy to sort specific streams. With the improved quality of recycled materials, the re-use of materials is doable for something that wasn't possible in the past, so smart robots eventually increase the recycling rate. As Focal actor 1 stated, currently a big portion of the material goes through unsorted, because it's too complex for the other systems to catch as much value from that stream as possible. With smart robots, valuable materials such as PET bottles or aluminum cans, can be recovered. With the increased capability to recycle used raw materials, energy and economic savings can be obtained.

"One of the discussions have been that the world is running out of raw materials, this planet can't sustain so many people because we run out of raw materials … I claim that there is no lack of raw materials, there is lack of recycling. We don't need all the time raw materials if we can recycle used ones. That's what the robots are doing to the ecosystem. It's money, raw materials and energy."

(Focal actor 2, 2020)

In addition to Fast Picker's capacity to recognize different types of objects; the possibility to replace the human picker and further automate the sorting centers, Fast Picker also provides valuable data:

"It's difficult to ask a human picker at the end of the day how many papers, how many PET bottles, how many green bottles and how many red bottles he did take. But the FastPicker will easily tell. Information is the second very important value created by FastPicker."

(Case Company X, 2020)

Therefore, smart robots offer the first step towards the digitalization of the waste stream. Focal actor 3 also mentioned that an automated waste sorting system gives companies an image of forerunner:

> *"It's a little bit a PR thing… the companies that we have so far delivered systems to have received really big benefits from showing that they are the forerunners of the industry and so on and so forth."*
>
> (Focal actor 3, 2020)

Furthermore, because the municipal waste recycling is a tedious, labour-intensive and in many cases, also a hazardous practice, smart robots make the work environment safer and healthier (Focal actor 2 & 3). However, like Company X added, the indirect value is more complicated to measure as the value can be partially from the smart robot and partially from the other actions taken. This indirect value is related to the performance of the plant and the quality of the end product.

Future of Automated Waste Sorting

Smart robots can already provide data but ideally, they could also be able to mirror the effective manufacturing industry, which is already automated, and where the created value is easy to calculate. If recycling would be able to mirror manufacturing with the same level of efficiency with the output that would always meet the needed level of purity and quantity, materials could be used again in the manufacturing. This would close the loop. (Focal actor 3).

Sorting of different, specific streams is already possible, but still more is needed from the technology and the statistics the robots provide. Company Z mentioned as an example the sorting of bottles made by polyethylene terephthalate (PET) by color and Company Y and Focal actor 3 the possibility to automatically certify the outgoing products. Company Q wished robots would be able to identify food grade materials, so that the separation would be done by food and non-food items. This would allow them to get into mechanical recycling and close the loop.

Furthermore, even though smart robots can already perform quite independently, human intervention is currently still needed. Company X said that a dream would be to have fully independent robots, that would not need any human intervention. Like this, operators would be able to redesign the sorting centers and fully automate the waste processing and handling.

7. DISCUSSION

In this section the results of the interviews are reflected on earlier researches and theories which were presented in the theoretical part. This section also provides answers to the sub-research questions, as well as the main research question.

Like Sitra states in their report (2018), circular economy forces companies to invent and develop new products and services around the concept of circular economy. These new circular business models are new type of business models where the products even after usage have economic value and can further be used for new types of market offerings (Ellen MacArthur Foundation 2016; 2019)

The change towards more circular business models was seen from the interviewees' answers. Many of them had invented new services but were also constantly educating themselves and investing in or taking part in research. Like Rosa et al. (2019) point out, new circular strategies need rethinking of the value creation logic. Even though smart robots in MSW waste management weren't directly linked to every responder's daily operations, all the responders were very open for the advanced technology and they admitted, that automatization of waste management is something that will take more place in the future.

7.1. The structure of the ecosystem around the automated consumer waste management

<u>Sub-question 1</u>*. How to create an (efficient) ecosystem around automated consumer waste management?*

To answer the first sub-question, the actors in the consumer waste management ecosystem were first needed to be identified. The answers to the question "*Who do you think other actors in the ecosystem are and how do they contribute to the value creation*?" were different by every actor. We will analyze separately the value creation factor in the following chapter, so first we take a look at the responses about the ecosystem actors.

The perceptions about the ecosystem size varied from two to eight different actors in addition to the interviewee company. In the figure below all the actors mentioned by interviewees are gathered together. To uniform the figure and the responses by each interviewee (Table 1), *waste collectors* and *local small waste collectors* are put under the label *Waste Collectors*. The same has been done for *packaging companies* and *packaging designers*, which are put under the uniforming label *Packaging Companies* thus these two functions are usually done under the same roof. The actors that were mentioned by more than one interviewee, are presented bigger in the figure.

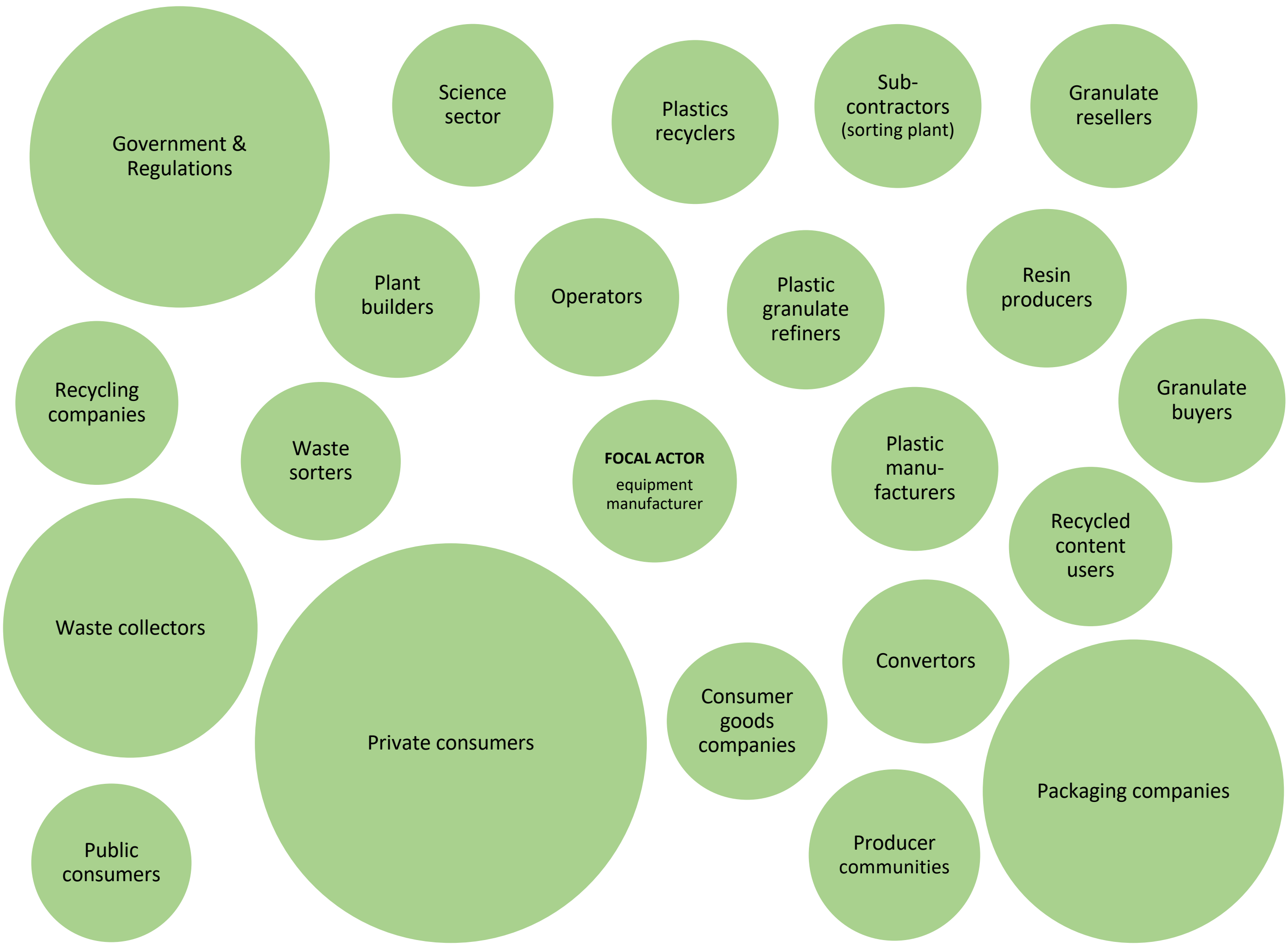


Figure 9. The consumer waste management ecosystem by the interviewees

From this figure above we can see that four actors were mentioned by more than one interviewee. Consumers (private ones) were mentioned by six out of eight interviewees, government & regulations and packaging companies / designers were mentioned by three interviewees and waste collectors were brought up by two out of eight interviewees.

Referring to Jacobides et al. (2018) three different ecosystem types, the current MSW waste management ecosystem present the *innovation ecosystem.* In this ecosystem type the innovation or a new value proportion and its supportive actors are in the center, and different clusters of innovation activities are formed around specific topics (Adner and Kapoor, 2010). One of the innovation ecosystem characteristics is the actors' dependency on each other (Jacobides et al., 2018). This dependency on others was strongly recognized by every ecosystem actor, interviewees said they can't operate in this circular ecosystem alone. Therefore, it was surprising how differently every actor saw the current ecosystem and how powerless interviewees saw themselves in the front of some ecosystem actors.

Strategy is a very important part of the ecosystem efficiency. In addition to a chosen ecosystem strategy (figure 3), as well as the coopetition strategy on a firm- and relationship-level (Ritala and Tidström, 2014), Adner's *Wide Lens* (figure 5) gives a good framework to the current consumer waste management ecosystem formation. All three risks; *the execution focus risk*, *the co-innovation risk* and *the adoption chain risk*, play a role in the innovation's success, but the adoption chain risk can be seen as one of the most important factors in the current consumer waste management ecosystem.

The adoption chain risk can be completed with *the integration risk*. These both risks highlight the importance of partners and suppliers. They need to adopt the company's innovation at some level before the company has a complete solution available and the end customers can assess the full value proposition. Now due to the incoherency between the actors, this adoption chain risk, as well as the integration risk are affecting every ecosystem actor. As Adner (2017) points out, a company's alignment of different agreements affects its ability to create value for the end customer. External changes need to be in sync with the new innovation, otherwise the company can't succeed (Adner, 2006; 2013; Adner and Kapoor, 2010).

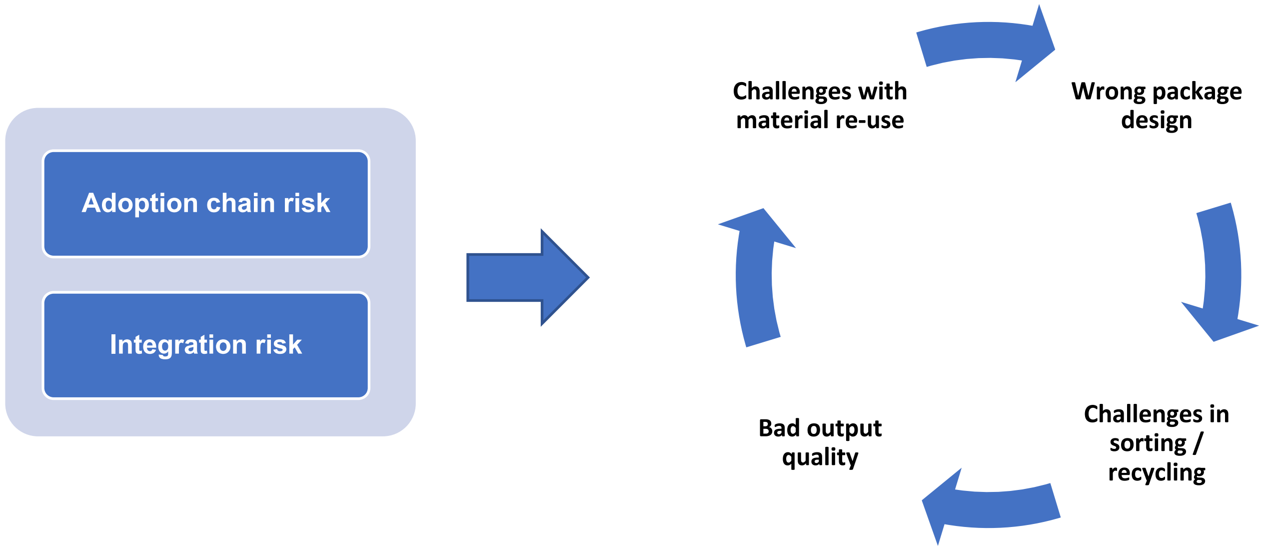


Figure 10. Adoption chain risk and integration risk in the current ecosystem

In conclusion, even though we can build a framework of the consumer waste management ecosystem based on the interview data, the current ecosystem is not working properly due to incoherency and inefficiency. Despite this inefficiency and non-uniformity of the current ecosystem, all actors were open to increase cooperation and recognized the need to join the forces with others in order to operate in the field of circular economy. As Company Z and Q stated, in some cases competitors are also partners and therefore, vital to the company's success and the whole ecosystem's efficiency. This balance between cooperation and competition is supported by Adner & Kapoor (2016) and Hannah and Eisenhardt (2018); companies need to cooperatively create value with competitors but also competitively capture value, which can be challenging sometimes.

Simultaneous collaboration and competition, coopetition (Bengtsson and Kock, 2014; Ritala and Tidström, 2014) can enhance resource integration through shared market context. Coopetition gives competitive actors a better understanding of the industry's technologies and business logic, which leads to more fluent knowledge sharing (Ritala and Tidström, 2014). As a strategy, coopetition can form a foundation for innovation in high-tech industries (Ritala and Hurmelinna-Laukkanen, 2009; Gnyawali and Charleton, 2018).

7.2. Value creation and capture in an automated consumer waste sorting ecosystem

<u>Sub-question 2.</u> *How the value is created and captured in an automated consumer waste sorting ecosystem?*

In an innovation ecosystem, *value creation* is related to activities and processes of creating value for customers. V*alue capture* refers to the individual firm-related activity, how the company can gain competitive advantage and make profit (Ritala et al., 2013). The value creation in almost every case was linked to the closest partners, customers or cooperator-competitors, also consumers were mentioned. All responders admitted that they can't operate alone in the ecosystem, the dependency between other actors were clear to all the responders. Many of the value creation relationships very reciprocal, bringing value or other benefit for the delivering company as well. This collaboration is one of the key definitions of the ecosystem, ecosystem actors cooperate because the value created together is bigger than the value they could create alone as a single actor (Davidson et al., 2015; Adner, 2006). Therefore, these activities capture value also for the company itself.

Above the interviewees' responses about the ecosystem actors were presented. The results can be divided into two groups; the first group consists of actors that usually are close partners and/or suppliers, as well as customers, with whom the company operates regularly and has at least some influence over. The other group consists of actors that the company has no contact with or no power over. Only two actors belong to this group; consumers, which were mentioned by six out of eight interviewees and public authorities, mentioned by three out of eight responders.

The majority of the interviewees mentioned consumers as important ecosystem actors, contributing to the ecosystem value creation. The role of the consumers was argued being significant, because at the end they have the purchasing power and they contribute to the recycling by making the decision to properly dispose a used plastic bottle rather than for example throwing it into the sea. In addition, the consumer who don't dispose products the right way also causes problems in the sorting facilities.

In traditional thinking the consumer has been considered the final arbiter of value. Nonetheless, companies often have partners and suppliers, who customize activities for every new launched product. Because these partners usually follow the company's routines and therefore, not significantly affect the company's success, they remain invisible as long as the company's innovation fits their routines. However, when the company's innovation requires a change in these partners' routines, they will determine the company's success. Therefore, the consumer is not the only arbiter of value (Adner 2013).

Because the consumers are not part of the business ecosystem in this research and they are a very heterogenous and scattered group, they are left out of this analysis. Furthermore, even though consumer awareness is positively affecting companies' sustainability, the automated waste sorting does not directly create value for the consumers.

The role of uniform regulations and laws, as well as the collaboration between all actors were seen as an essential part to build the premises of value creation and capture. The supportive role of the institutional environment in adoption and transition to CE is supported by Ranta et al. (2018). The regulatory system can support CE by spurring circularity and discriminating against careless use of resources. However, the regulatory system can also restrict CE by, for example, banning the reuse of specific products (Ranta et al., 2018).

The focal firm had an open role towards other ecosystem actors, being the equipment provider for the processing of the collected waste so that it can be used as a recycled material. The principle was that in addition to the end customers, in this case plant builders / operators of the waste sorting plant, there needed to be other actors in the ecosystem who would also consider automated waste sorting to create value for them and / or for the ecosystem.

Based on the answers, different value creation processes were identified by each ecosystem actors. Even though in the first place the value was created to the closest partner or customer, the created value was also beneficial and essential for the whole ecosystem functionality. Despite the fact that all actors had a financial interest to capture value, the value creation to the closest partners and the whole ecosystem was more important because without that, the delivering company could not necessarily capture the optimal value. As a conclusion, in the ecosystem where the value is delivered via automated waste sorting, value creation is a precondition to the value capture.

In order to create increasing value in ecosystems, companies need to identify new opportunities and develop skills to get the most out of them. This means applying capabilities across the whole ecosystem and recognizing the compatibility gaps and needs. (Davidson et al., 2015). Companies Y and Z said they have invented new business models and services to tackle risks affecting their industries and also like this, creating new value to the whole ecosystem. Furthermore, four out of eight interviewees said they mitigate risks internally by making sure they have the right knowledge in the company and / or by doing continuous research. Company W said they also educate other ecosystem actors about the new, more sustainable technology solutions and the benefits of recycling.

An interesting view to the value creation comes from the concept of industry architecture. According to Jacobides (2006), IA describes how work is organized and structured within an industry and which companies capture value and make profit. By managing their own IA, companies can become the bottlenecks of their industry. These bottlenecks determine how an innovative company creates and distributes value.

Based on the interviewees' answers, the current consumer waste management ecosystem has two clear bottlenecks; non-existing uniformity of regulations and the incoherency of the ecosystem. As Hannah and Eisenhardt (2018) point out, in order to be successful, companies need to simultaneously create value and capture value. Currently, these bottlenecks in the ecosystem prevent the full value capture.

The incoherency of the ecosystem causes problems and challenges, that cumulate from one actor to another, leading to a broken value chain and eventually causing bigger problems to the whole ecosystem. As Company Y and Focal actor 2 pointed out, the problems start from the materials which are not made to recycle, as well as the design which is not right (Company X). When there are already troubles with materials and the design, it causes big problems in the sorting facilities and affects the output quality of recycled materials. In addition, the supply vs. demand on the available, good quality recycled materials do not meet. This challenge concerns especially recycled plastics and food grade materials made out of plastics. As Kemira (2019) states in its report, the sorting and refining plastic bottles back into a food-quality product is too expensive with current methods and processes. Therefore, plastic bottles are often downcycled into a lower quality plastic that can't be recycled again.

Municipal policies and regulations play a big role in the ecosystem and all interviewees agreed, that they are needed. However, due to the lack of uniformity, current laws and regulations do not always support the circularity. In some cases, it's still cheaper to produce new products out of virgin ones vs. produce new products out of recyclable ones. This loophole in the legislation again goes back to the other ecosystem actors, affecting the whole ecosystem's coherency. And here we have a circle. Because laws and regulations are part of the ecosystem as an actor group, we can conclude that the actual current bottleneck is the ecosystem – or in fact, the inexistence of it.

Because the ecosystem has not properly been created, the *ecosystem building mechanisms* that define the premises of value creation and value capture are incomplete. Therefore, even though ecosystem actors do create and capture value with services and shared knowledge, as well as contribution to the science, the *ecosystem management mechanisms* that help to maintain, realize and develop opportunities for value creation and capture (Ritala et al., 2013), are not at their optimal level.

In addition to the non-existing uniformity of regulations, laws and regulations were seen to lead to forced value creation in the ecosystem. This is because the circularity is currently run by these laws and regulations, which makes the competition and pricing artificial. This also leads to a situation where organic ecosystem creation or growth is not fast enough. As a result, companies see circular economy as something they need to do, not as an opportunity.

7.2.1. Value from smart robots

Interviewees were also asked what kind of value smart robots / Focal actor's product Fast Picker bring to them (Company actors) and to the ecosystem. Because currently the waste industry is often using manual sorting, all the responders saw the automatization of the waste centers as a significant value factor. Smart robots were seen to offer the first step towards the digitalization of the waste stream, also giving their users an image of a forerunner in the industry. As Ghoreishi and Happonen (2020) state, AI with other Industry 4.0 technologies can help companies to overcome the obstacles towards circularity. In addition to better product circulation, AI can improve predictive maintenance and smart management. Since AI is capable to huge and complex data analysis, it enables to redesign key features such as faster learning process and feedback collection to a better economic model (Ghoreishi and Happonen, 2020).

Compared to traditional waste sorting done by humans, interviewees said that smart robots can operate tirelessly and sort different materials into very specific streams, providing performance consistency. Bogue (2019) also highlights this in his research, artificial intelligence solutions can significantly improve MSW processes when human performed tasks are replaced by smart robots. Because smart robots make processes efficient, it leads to significant cost savings and improves revenue streams from high-purity recyclables. Therefore, smart robots are creating direct value to the operators. Furthermore, with the information provided by the sensors and visual recognition, operators are able to understand the waste input better and more easily adjust the lines based on the expected inputs (ISWA, 2019).

Another thing the interviewees considered a significant value was the data and statistics provided by smart robots, what has been picked during the day. As metrics, how the value is measured, companies used the obtained price from the sorted materials vs. what the monetarily value would be if the waste would be handled unsorted. Digital technologies such as AI improves the transparency and traceability throughout the product's lifespan, as well as help to collect data about the used materials (Ghoreishi and Happonen, 2020). As Jiang et al. (2020) also mention, industry 4.0 solutions can support communication, collaboration and coordination inside the company, as well as help companies in knowledge management processes (Jiang et al., 2020).

In addition to the direct value to the waste management companies, smart robots were seen to benefit the whole ecosystem, providing also indirect value. With the improved output quality more materials can be recycled and returned back to the re-use. Like this smart robots bring value also to the whole ecosystem, when recycling rates increase. Valuable materials such as plastics and aluminum can be recovered, which leads to reduced energy consumption and economic savings. This reuse of different materials is a huge value for the whole ecosystem as virgin materials become scarcer (EU, 2014; 2020; Sitra, 2018). Furthermore, because the municipal waste recycling is a tedious, labour-intensive and in many cases, also a hazardous practice, smart robots make the work environment safer and healthier.

7.3. Ecosystem actors' contribution to the automated waste sorting

<u>Sub-question 3</u>. *What value do different ecosystem actors contribute to the automated waste sorting?*

Based on the interviewees' answers, ecosystem roles and relationships varied. Like Iansiti & Levien (2004) state, the firm should be able to identify the actors with whom it interacts the most and determine the level and dependency of these relationships, how critical they are for the business. In order to analyze how different actors contribute to the automated waste sorting, we have to look at actors that are closely interacting with the focal actor or their end customers. From the collected data we can identify direct contributors and indirect contributors.

To first summarize the role of the focal actor in the ecosystem; the focal actor is offering the machinery for the collected waste so that it can be used as a recycled material. Therefore, they are improving the purity of materials and in addition, offering a solution that is more economic than normal human sorting. All interviewed focal actors said that they mainly have customer relationships with the waste management companies; plant builders and operators.

Companies Y and W belong to the group of direct contributors. These actors have direct relationships with the focal actor or their end customers. Company Y contributes to the automated waste sorting by improving the design of their products for recycling. They also aim to use recycled feedstocks as much as possible in their products. Company Y interacts with the feedstock manufacturers, brand owners and retailers. Due to the circular economy they also have new relationships with the renewable feedstocks. Therefore, they have relationships and influence on sorting and collection sector, as well as recyclers. In addition, they contribute on a national level to some projects with the brand owners, collectors, retailers etc.

Company W contributes as a consultant by sharing awareness of the different recycling options to their customers. Many companies do want to enter the recycling business, but they do not recognize the potential of recycling. Company W also acts as a service provider between plastics recycling companies and manufacturers of recycling machines, sorting systems, washing systems, etc. Therefore, Company W is contributing directly to consumer waste sorting.

Company Z and Q belong to the both groups, direct and indirect contributors. Company Z cooperates with producer communities and interacts with waste collectors, who are their competitors but also cooperators. They also have different material handling services. Therefore, they have an indirect and direct relationship with the focal actor and their end customers.

Company Q contributes by making sure that their packages are either recyclable or re-usable by 2025. They are also building up the waste infrastructures and improving the already existing ones for the collection, recycling and re-using of materials. Furthermore, they communicate with the consumers and spread information in order to change consumer behavior.

Company X’s role and relationship with the other ecosystem actors vary depending on the situation. They can be a consultant or an advisor, a client, a supplier, a partner or even an active producer. First, as a partner of municipalities, they help to educate the public on how to sort correctly and how to avoid waste. They also advise their industrial clients and producers of packaging material how to optimize their waste production. Secondly, they are delivering collection service for MSW or DMR. The third part is the sorting and recycling and in the fourth step, they send the purified fibres, plastics, wood, ferrous or glass to different industries to produce new source material. This final recovery is sometimes done inhouse, sometimes with partners such as paper mills, glass producers, producers of plastic grains. The secondary fuel or energy is produced by incineration or methanization from the materials that can’t be recycled. Therefore, they also belong to both the groups, having both direct and indirect relationships with the focal actor and other end customers.

Table 3. Interviewees' contribution to automated consumer waste sorting

Actor	Relationships	Role / contribution	Type of contribution
FOCAL ACTORS	Client relationships with plant builders / operators (waste management companies)	Equipment provider	direct
COMPANY X	Varies; partner of municipalities (educate public), consultant to clients, waste collection service provider (industrial /household), waste sorting & recycling provider, active producer	Varies; consultant, collector, recycler, purifier, producer of new materials	direct / indirect
COMPANY Y	Links to feedstock manufacturers, brand owners, retailers. New relationships with renewable feedstocks, influence on collection and sorting sector, recyclers.	Product design improver & recycled feedstocks user	direct
COMPANY Z	Cooperation with producer communities, coopetition with other waste collectors / service providers	Service provider, responsible for EPR	direct / indirect
COMPANY W	Consultant to customers, service provider between plastics recycling companies and manufacturers of recycling machines, sorting systems, washing systems etc.	Consultant & service provider	direct
COMPANY Q	Waste infrastructure builder, communication to consumers, coopetition with other actors	Package designer, EPR financer, recycled content user, waste infrastructure builder, consumer communicator & consumer behavior influencer, packaging science	direct / indirect

The Circular Economy model (figure 2) offers us a solution to a cleaner and more sustainable future (Sitra 2018). Digital technologies, such as AI, offer new opportunities to optimize material flows and enable reverse material flow (Pagoropoulos et al., 2017). AI unlocks the potential to operate circular business models and to optimize the infrastructure to ensure circular material flows (Ellen MacArthur Foundation 2019). Therefore, digital technologies play a significant role in the transition towards Circular Economy (Pagoropoulos et al., 2017).

As automated waste sorting is about circularity, actors that support it should be identified. In order to identify these drivers / influencers of the circularity that significantly contribute to the automated waste sorting, the interviewees' answers from the three different questions (appendix 1) were combined together:

<u>Questions</u>

3. Who do you think other actors in the ecosystem are and how do they contribute to the value creation?
6. From your perspective, who are the most critical actors in the ecosystem? Why?
7. In your opinion what are the challenges that affect circular value creation in the ecosystem?

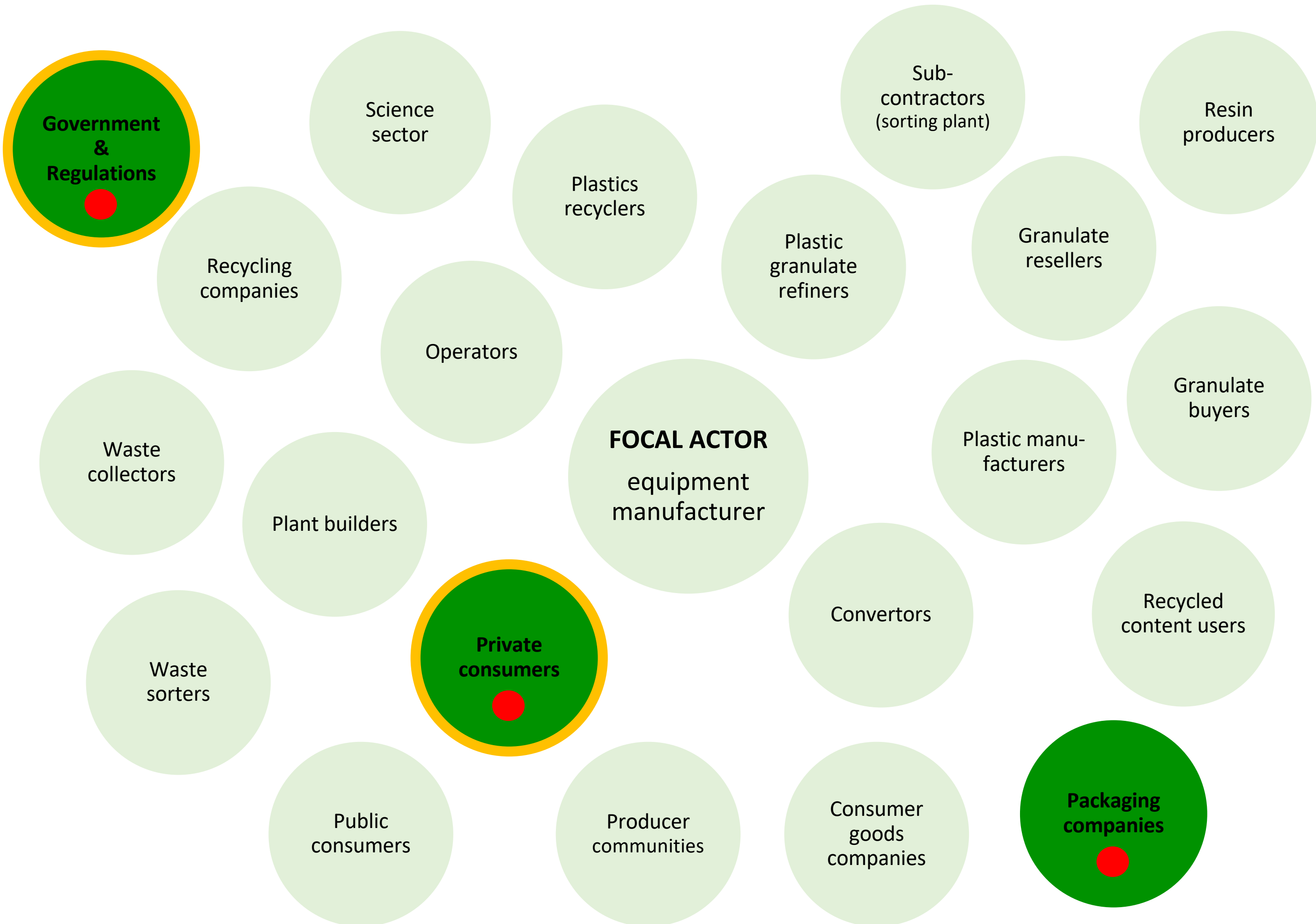


Figure 11. Drivers / influencers of the circularity

First, referring to the question 3, those actors that were mentioned more than one interviewee were marked in dark green to the ecosystem map (figure 8). Then, an orange circle was added around for those actors that were identified as the most important actors, mentioned by more than one interviewee. Lastly, the responders' answers to the question 7 were evaluated. Actors that were brought up by more than one interviewee, were marked with a red spot.

Based on the analysis of the answers to these three questions (Questions 3, 6 and 7) clear drivers and influencers of circularity were identified. Therefore, we can conclude that government and laws, as well as (private) consumers are the most significant drivers of the circularity.

However, the packaging companies also play a very significant role. They were mentioned by three interviewees in the question 3, by one interviewee in the question 6 and in the question 7, they were mentioned by two interviewees. Even though their role is not so significant compared to the role of the government and regulations or consumers, it can be said that they are also one of the drivers of the circularity and their contribution to automated waste sorting is bigger than the other ecosystem actors' contribution. As ISWA (2019) points out in its report, in order to fully unlock the potential of industry 4.0 technologies, a contribution is needed also from product designers. Without the interaction and links between product designers and the waste management sector, the new products produced from new and innovative composite materials could end up being non-recyclable and not possible to re-use.

As Davidson et al. (2015) states, the company's position and role in the ecosystem depends on the level of activity it can fulfill within an ecosystem, how important and unique it is. Based on the interviewees' answers the drivers / influencers of the circularity are at the end (customers) and in the beginning (packaging manufacturers) of a product's life cycle. The government and laws can be seen as a root of circularity, affecting all different steps and actors in the ecosystem.

7.4. Summary and conclusions

The current ecosystem presents an innovation ecosystem, where actors that are dependent on each other interact to create and commercialize innovations that benefit the end customers (Jacobides et al., 2018). The goal is to create and capture the value from innovative activities (Ritala et al.,2013). *Value creation* is related to activities and processes of creating value for customers and *value capture* refers to the single firm-related activity, how companies can gain competitive advantage and make profit (Ritala et al., 2013). However, firms' alignment of different agreements affects their ability to create value for the end customer (Adner, 2017).

This innovation ecosystem consists of clusters of innovation activities around specific topics (Adner and Kapoor, 2010) so therefore, there is more than one end customer. However, the end customer in this research is the waste management companies, specifically the plant builders / operators of the waste sorting plants.

In the previous chapters the sub-questions of the thesis were answered. Finally, based on these sub-questions and the gathered data from the interviewees, we can now answer the main research question. The main research question of the thesis was related to the end customer and the delivered value to them.

<u>Main research question:</u>

How to deliver value to end customers via automated consumer waste sorting?

As we saw from the sections above, each ecosystem actor contributes to the ecosystem value creation differently. In order to answer the research question, we need to look closer at those actors and phenomenon that directly have an effect on the focal actor or the end customer, the plant builders and operators. First, it has to be noted that in the ecosystem where the value is delivered via automated waste sorting, value creation is a precondition to the value capture.

In the current consumer waste management ecosystem, the integration risk (figure 4) with the adoption chain risk (figure 5) can be seen to affect the focal actor more compared to the other risks. These both risks highlight the importance of partners and suppliers, which need to adopt the company's innovation at some level before the company has a complete solution available and the end customers can assess the full value proposition. Due to the incoherency in the current ecosystem, this adoption chain risk is not only affecting the focal company but also every ecosystem actor when challenges cumulate from one actor to another, leading to a broken value chain and eventually causing bigger problems in the whole ecosystem.

This incoherency of the current consumer waste management ecosystem was identified one of the ecosystem bottlenecks, preventing the value capture. Another bottleneck according to the interviewees was the lack of uniformity of regulations; laws and regulations were not always seen to support circularity. Furthermore, they were seen to lead to forced value creation in the ecosystem. This is because the circularity is currently run by these laws and regulations, which makes the competition and pricing artificial, as well as the organic ecosystem creation or growth too slow. As a result, companies see circular economy as something they need to do, not as an opportunity.

Despite the inefficiency and non-uniformity of the current ecosystem, all actors admitted the importance of other ecosystem actors in the value creation; the value created together is bigger than the value they could create alone as a single actor. Therefore, all interviewees agreed that cooperation needs to be improved. In some cases, companies needed to cooperatively create value with competitors but also competitively capture value as a company, which represents a bottleneck strategy (figure 3).

Because the automated waste sorting is strongly driven by circularity, the most significant drivers and influencers of circularity in the ecosystem were needed to be identified first (figure 11). The government and laws, as well as consumers were identified as the most significant drivers of the circularity. Also packaging companies can be identified as drivers and influencers, which is supported by ISWA's (2019) report; the potential of industry 4.0 technologies can't fully be unlocked without the contribution from the product designers. Packaging companies create value for the end customers by a package that is suitable for recycling. In addition to the right design, this means the right materials.

The government and laws are an interesting actor group because they were identified as drivers of the circularity, but they also cause challenges and bottlenecks in the ecosystem.

All the responders said they are important and needed, but at the same time they admitted, that they are not fully in control of the regulation, which is causing uncertainty and making risk management challenging.

In addition to municipal policies and national legislation, EPR challenges companies to take responsibility for the treatment or disposal of consumer products, also encouraging better design and manufacturing of the product (EU, 2014; Europen-packaging.eu, 2020; Walls, 2016; Singh et al., 2014). This forces companies to change their business models so that the waste can be turned into a resource, high-quality secondary raw material, that can be used again in the production process (STOA, 2017).

The municipal waste sorting has traditionally been a labour-intensive and in many cases, also a hazardous practice. Manual labor sets its challenges, how fast and how accurate the sorting of different materials can be done from the waste streams. This is problematic to the companies when the pressure for better material recovery is becoming stricter and stricter. The EU requires that a minimum of 50 % of all household waste must be reused or recycled by 2020. In 2025 the recycling and reuse rate must be 55%, and the target for 2030 and 2035 is 60% and 65% respectively (Bogue, 2019; European Environment Agency, 2019). Furthermore, the target is that all plastics package materials on the EU market are either reusable or can be recycled by 2030 (EUR-Lex, 2018).

Artificial intelligence solutions can significantly improve MSW processes by improving revenue streams from high-purity recyclables (Bogue, 2019), providing a step closer to circular economy (Climate-KIC, 2020). As Ellen MacArthur Foundation (2019) states in its report, AI helps companies to unlock the potential to operate circular business models and to optimize the infrastructure that guarantees circular material flows. In addition to better separation of different, specific materials from waste streams, smart robots provide valuable data, which helps operators to understand the waste input better and more easily adjust the lines accordingly based on the expected inputs (ISWA, 2019). As Company X stated, smart robots are able to provide valuable data and statistics to the sorting facility, what has been picked during the day.

Therefore, as a first conclusion smart robots help the end customers to take the first step towards circularity and to manage and reduce risks caused by changing legislation.

Secondly, smart robots increase process efficiency. Compared to traditional human performed sorting, AI guided robots provide a more efficient way to sort waste (Climate-KIC, 2020), reduce overall costs of recycling and help companies to standardize their processes (Kemira, 2019). As the company Y said, robots can operate tirelessly and sort different materials into very specific streams, providing performance consistency. Because the quality of recovered materials is purer, more materials can be recycled and returned back for re-use (Company X).

Thirdly, this material recovery is beneficial and profitable for the end customers, as well as the whole ecosystem. As policies and regulations require that more and more new products need to be made out of recyclables in the future, this increases the need for high purity, recycled materials (European Commission, 2020; Sitra 2018). With smart robots, companies can recover more raw materials with a high degree of purity and like this, also get a better profit out of them. As some responders mentioned, one of the metrics of how the value is measured is the obtained price from the sorted materials vs. what the monetary value would be if the waste would be handled unsorted.

The demand for raw materials is increasingly growing due to the growth of the global population and living standards. However, at the same time the prices of raw materials raise, while their availability becomes more and more challenging (Ellen MacArthur Foundation, 2013; 2012). By lowering the dependence from virgin materials, using more renewable energy in the manufacturing phase, and greening the whole value chain, the economic value of the product can be maintained (Rosa et al., 2019). In addition, companies that are able to sort waste well, save money on waste disposal taxes (Climate-KIC, 2020).

Fourthly, smart robots bring economic savings in labor costs and make the work environment safer. Because a robot can operate tirelessly without a salary, the concept of working shifts with possible sick days or vacations is no longer needed. Therefore, smart robots decrease the price tag of recycling (Kemira, 2019). Also, because municipal waste recycling is in many cases a hazardous practice, smart robots make the work environment safer and healthier.

Lastly, with smart technologies companies can create value for themselves, but also for the end user, as well as the whole ecosystem (Souchet, 2017) when the output quality of recycling improves, and more materials can be recovered. When the ecosystem is circular, the benefits to the whole ecosystem till the consumers will circulate back to the waste management companies, the end customers.

A summary of these benefits of smart robots to the end customer are presented below (figure 12).

DIGITALIZATION & CIRCULARITY	• Risk mitigation caused by changing legislation
PROCESS EFFICIENCY	• Reduced recycling costs • Standardized processes • Performance consistency • Better output quality
PROFITABLE MATERIAL RECOVERY	• Growing market for recycled materials • More recycled pure raw materials • Better profits • Decreased dependency on raw materials
LABOR COSTS SAVINGS & SAFER WORK ENVIRONMENT	• Robots operate 24/7 • Reduced employee costs • Reduced price tag of recycling • Safer and healthier work environment
CIRCULAR VALUE	• Better output quality → more recovered materials • Value for the whole ecosystem

Figure 12. Benefits of smart robots to the end customer

8. IMPLICATIONS

In this last part of the thesis, the theoretical and practical implications are presented. After these, suggestions for the future research are given and the future of automated consumer waste sorting is evaluated based on the interviewees' answers and the current, available studies.

8.1. Theoretical implications

Industry 4.0 and its possibilities are increasingly being explored by researchers and other stakeholder groups. Current researches in AI and robotics focus mostly on their technical features and qualities, but some of them have also discovered the possibilities in value co-creation (Kaartemo and Helkkula, 2018).

Even though a few research on the value capture in business ecosystems for MSW management can be found, (Peltola et al., 2016), a few of the conducted researches from the Scopus database were related directly to recycling with robots (Bogue, 2019) and none of the founded articles was related to the value creation for the end customers. This might be because of the novelty of smart robots in the consumer waste sorting. Even though there are already companies who use AI powered robots in their waste sorting stations, we can't talk about a mainstream phenomenon.

Because the literature was lacking a conducted research on how an ecosystem is built around customer waste management and what value do different actors bring into it, I found the topic very interesting. Furthermore, I wanted to find out what is the value industrial robots with AI software can bring to the end customers.

My objective in this study was to apply the business ecosystem and circular economy concepts to consumer waste management and analyze how to build an ecosystem around automated consumer waste management. Furthermore, I wanted to find how do different ecosystem actors contribute to the automated waste sorting and how the value is delivered to the end customers.

Building a consumer waste management ecosystem is challenging, because waste infrastructures and policies vary in different countries. Therefore, ecosystem actors and their relationships are different in each country. The consumer waste management ecosystem model built in this research presents an ecosystem, whose frontiers extend from Northern Europe to Central Europe. Taking actors for example from Southern Europe or even from Asia would have provided a little bit different result. Therefore, the ecosystem built based on the collected data presents only one point of view of this topic.

The findings support the already existing theories about the innovation ecosystem value creation, how ecosystem actors also in the consumer waste management see the collaboration as a very important factor in order to create bigger value (Davidson et al., 2015; Adner, 2006). To create increasing value, some responders had also invented new business models or were doing active research. These activities are identified also by the literature (Davidson et al., 2015), how companies should recognize new opportunities and develop skills to benefit from them.

Despite all actors admitted cooperation is needed, the lack of functionality of the ecosystem was very surprising. Even though the actors recognize the importance of other ecosystem players, the current ecosystem consists of smaller clusters, being otherwise very scattered and incoherent. This incoherency of the ecosystem was identified also by interviewees. As a result, due to the incoherency, the value chain is considered broken.

As drivers / influencers of the circularity, responders identified consumers, governments and regulations, as well as the packaging companies. As previous studies have shown, the role of circular strategies already in the product design process has a significant role in the supply chain, as well as value creation (Ghoreishi and Happonen, 2020).

Even though the institutional environment to CE is also recognized in the literature (Ranta et al., 2018), challenges in CE practices caused by regulations and laws have not been further discussed. In addition to the support regulations and laws can give to CE, they can also have a very negative impact on circularity. The findings of this research reveal that regulations and laws can even cause bottlenecks in the whole ecosystem. Because regulations and laws are considered to make the competition and pricing artificial, leading to forced value creation, some of the companies see circular economy as something they need to do, not as an opportunity. Since the government and laws have a significant effect on circularity and the ecosystem actors, their role and influence should be further discussed and researched in consumer waste management.

8.2. Managerial and policy implications

CE policies and regulations have forced companies to search for new solutions to improve the quality of sorted waste and also the work conditions of current employees exposed to the waste (Climate-KIC, 2020). AI among the other Industry 4.0 technologies provide new possibilities in the field of waste management with smart products and improved processes, creating a competitive advantage for the companies (KMPG 2017). AI also makes possible to gather and analyze data across machines and produce higher-quality goods at reduced costs (BCG, 2020). This digital transformation is strategic; it forces many companies to rethink their business and operating model and requires managers to balance between short-term profitability improvements and long-term revenue growth (Gates et al., 2018).

For the managers and business practitioners in the field of consumer waste management, this study provides an overview of the circularity in the consumer waste management, as well as the dynamics in the current ecosystem. In addition, this study provides possibilities and development areas in some implications. Furthermore, for the companies that are planning to take the first steps towards digitalization and improve the circularity, this study presents a good overview of the possibilities, as well as possible challenges.

Currently the ecosystem around the consumer waste sorting is not working properly due to the incoherency. This leads to a broken value chain and affects every actor's capability to create and capture value, creating a bottleneck. To improve the functionality and the coherency of the ecosystem, managers can do their best to improve communication and coopetition inside the whole ecosystem. Even though the competition in the field of new technologies can be intense sometimes, it's essential that companies learn to balance between cooperation and competition; cooperatively create value with competitors and competitively capture value.

Even the greatest innovation can fail if the timing on the market is not right, other companies do not successfully commercialize their own product or partners do not adopt the company's innovation at some level. As Adner (2013) states, managers should look at the ecosystem with a wider perspective so that blind spots can be avoided.

In addition to the ecosystem incoherency, laws and regulations set challenges to the ecosystem due to their uncontrollability and non-uniformity. Like many other industries, the waste industry is facing a change forced by the legislation and circular economy, when the pressure to recycle more materials with a better output quality increases. As we saw in the chapter 7.4., automated waste recycling can help companies to manage the requirements set by legislation and therefore, reduce business risks. Artificial intelligence also helps to recover materials, which is essential when the availability of virgin materials is becoming more and more challenging.

No one of the interviewed actors had direct relationships with the policy makers. The lack of contacts to the government side generates uncertainty and feeling of powerlessness what comes to the set waste policies and regulations. A dialogue between the industries and government is needed in order to fully unlock the potential of CE. To increase policy makers' knowledge about the current possibilities and challenges in technology and in the field of waste management, companies could for example arrange them visits where knowledge and information would be shared. This could be done on an individual company basis but also in cooperation with other ecosystem actors. These events would be a great example of coopetition, when competitors would unite their resources in order to create a greater value for themselves and for the all ecosystem actors. Furthermore, policies and incentives that support circularity should be strengthen as currently in some cases, it is still cheaper to make products out of new materials than out of recycled ones.

Lastly, as Gates et al. (2018) point out, a successful digital transformation needs people with suitable skills to work with the new technologies. As some of the interviewees' mentioned, companies should make sure they have the right people and knowledge inside the organization. Sometimes this also means cooperation with the universities and the science sector in the field of research, as well as sharing knowledge with the other ecosystem actors. As there are still some untapped areas and challenges with smart robots, the use of AI in waste sorting should be further researched on to make the robots efficient and capable to handle all sorts of wastes. Research on software enhancement and making the robots further cheaper to run and operate would create higher value proposition and enhance profit potential for the companies.

8.3. Future research directions

The thesis doesn't provide generalizable results about the topic as there are only 6 case companies in the study. Not all the consumer waste management ecosystem actors were interviewed so to get more insights into this phenomenon, also the other ecosystem actors could be interviewed. In addition, this study's frontiers extend from Northern Europe to Central Europe so a study conducted in a different area would most likely provide different results.

However, as the main focus was on the end customers of the automated consumer waste sorting, the collected sample and interviewed ecosystem actors present the most relevant actor groups based on their position in the ecosystem and value creation. Furthermore, because automated waste sorting is still not adopted by all industry players and the knowledge about the technology is limited, we can conclude that the collected data in this research presents the best possible sample that can be gathered here and now. Also, the global COVID-19 situation set challenges to the data collection, so taking into consideration the circumstances, I can be happy with my collected data as a researcher.

An interesting approach for future research is to conduct the research in different countries and with all ecosystem actors as a comparative case study, what are the differences. However, this kind of research would require more time.

8.4. The future of automated waste sorting

It is predicted that industry 4.0 and artificial intelligence will continue to transform the waste management industry providing accuracy, more flexibility and transformation of MRFs (ISWA 2019). As a last question (question 17), external actors were asked what other additional value smart robots / FP bring to them in an ideal situation.

All the responders saw the automatization of the waste centers a significant value factor. Even though sorting of specific streams is already possible, responders needed more from the technology and the statistics. Currently for example sorting of PET bottles by color is not at the optimal level (Company Z). Company Q also wished robots would be able to identify food grade materials, which would allow them to get into mechanical recycling and close the loop for their products.

Furthermore, even though smart robots can already perform quite independently, human intervention is currently still needed. Company X said that a dream would be to have fully independent robots, that would not need any human intervention. This would enable operators to redesign the sorting centers and fully automate the waste processing and handling.

As Brynjolfsson (2017) and McAfee (2014) states, there are still untapped potential areas, where AI could improve the current processes. In addition to improved processes, the legislation is also putting pressure on more effective waste handling and recycling processes in the future. Only the time will tell how the field of waste management will transform in the future. However, as ISWA (2019) states in its report, robotic recycling is already a reality and more and more companies will adopt it part of their processes in the next 10 years.

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10. APPENDICES

Appendix 1. Final interview questions

Ecosystem & value creation

1. In your opinion what is a circular ecosystem referring to your industry?
2. What do you think your role/position is in the ecosystem regarding to circular economy?
3. Who do you think other actors in the ecosystem are and how do they contribute to the value creation?
4. What is your relationship to the other ecosystem actors?
5. What do you bring to the ecosystem? What are the circular benefits?
6. From your perspective, who are the most critical actors in the ecosystem? Why?

Challenges, risk management & regulations

7. In your opinion what are the challenges that affect circular value creation in the ecosystem?
8. How do you mitigate risks that might have an impact to ecosystem?
9. From your perspective, how do you see the role of municipal policies / public regulations in circular value creation?

Smart robots / Fast Picker (FP) – questions for the focal actor

10. What do you think, what is the need customers want to fill by buying FP?
11. From your perspective, what is the additional value FP gives to the customers?
12. How do you ensure and measure the level of created value for the customers?
13. What are the circular values that FP creates to the ecosystem?

Smart robots / Fast Picker (FP) – questions for external actors

14. What are the circular values that smart robots / FP create to the ecosystem?
15. What kind of value smart robots / FP bring to you or your customers?
16. How do you measure the level of value smart / FP robots create?
17. In an ideal situation, in addition of the current created value, what other additional value would smart robots / FP bring to you?

Appendix 2. The list of codes

INTERVIEW QUESTIONS	CODING
Ecosystem & value creation	
In your opinion what is a circular ecosystem referring to your industry?	[1] waste collection, [2] waste processing, [3] sustainable solution, [4] economic solution, [5] replacing virgin materials by recycled ones, [6] feedstocks, [7] collection, [8] sorting, [9] recycling, [10] EPR, [11] material processing, [12] handling services, [13] life-cycle, [14] money
What do you think your role/position is in the ecosystem regarding to circular economy?	[1] equipment provider, [2] recycling enabler, [3] output improver, [4] products re-designer, [5] service provider, [6] cooperative services, [4] consultant, [5] collector, [6] recycler, [7] purifier, [8] new materials producer, [9] knowledge provider, [10] recycled feedstocks user, [11] partner, [12] make recycling cheap, [13] economic solution provider, [14] purity improver, [15] recyclable packages, [16] re-usable packages, [17] closing the loop, [18] closing the loop [19] waste infrastructure builder, [20] waste infrastructure improver, [21] influencer, [22] communicator, [23] behavior changer
Who do you think other actors in the ecosystem are and how do they contribute to the value creation?	[1] operators, [2] equipment manufacturers, [3] plant builders, [4] subcontractors, [5] consumers (x5), [6] manufacturing companies, [7] recycling companies, [8] plastic granulate refiners, [9] sorting companies, [10] collectors, [11] convertors, [12] packaging companies (x3), [13] consumer goods companies, [14] governments & laws (x3) [15] local small-sized waste collectors, [16] producer communities, [17] public consumers, [18] private

	consumers, [19] plastic recyclers, [20] granulate resellers, [21] source separation activities, [22] resin producers, [23] science sector, [24] convertors, [25] packaging designers, [26] recycled content users, [27] legislation, [28] competitor-partners
What is your relationship to the other ecosystem actors?	[1] customers (x3), [2] limited, [3] partners (x2), [4] influencers, [5]competitors, [6]cooperators, [7] consultant (x2), [8]advisor, [9] client, [10] supplier, [11] active producer, [10] service provider, [12] manufacturer, [13] links, [14] authorities, [15] integrated partners, [16] historic links, [17] new relationships, [18] good relationships, [19] lots of dynamics, [20] open for cooperation
What do you bring to the ecosystem? What are the circular benefits?	[1] equipment (x2), [2] recyclable materials, [3] downcycling -> recycling, [4] recycling design, (x2) [5] easy collection, [6] output quality, [7] rental services, [8] recycling services, [9] consultancy, [10] knowledge, [11] experience, [12] technology, [13] improved purity, [14] easier re-use of materials, [15] raw material recovery, [16] design of packaging, [17] financing, [18] EPR, [19] legislation framework, [20] research, [21] contribution to technology, [22] contribution to science
From your perspective, who are the most critical actors in the ecosystem? Why?	[1] operators, [2] consumers (x6), [3] consumer goods companies, [4] competitors [5] partners, [6] packaging designers, [7] public regulation, [8] government & legislation (x3), [9] suppliers, [10] packaging recovery firms

Challenges, risk management & regulations	
In your opinion what are the challenges that affect circular value creation in the ecosystem?	[1] inefficient process, [2] broken value chain, [3] unrecyclable materials, [4] forced value creation, [5] incoherency, [6] regulations, [7] consumer behavior (x3), [8] digitalization, [9] technical challenges, [10] no-uniformity of regulation, [11] high costs of reproduction, [12] waste transportation, [13] lack of regulations, [14] freedom in the system, [15] lack of authorities' knowledge, [16] wrong packaging design, [17] non-existing ecosystem, [19] no info where to sell, [20] artificial competition and pricing, [21] uncertainty, [22] sorting, [23] food grade material availability, [24] food safety, [25] food compliance, [26] closing the loop, [27] non-efficiency, [28] downcycling
How do you mitigate risks that might have an impact to ecosystem?	[1] knowledge, [2] reducing thresholds, [3] it's challenging, [4] estimation, [5] new business models, [6] influence on legislation, [7] changed handling rotation, [8] other services, [9] not possible, [10] research, [11] latest technologies, [12] promotion of recycling, [13] involvement in cooperation organizations, [14] challenging, [15] right package design, [16] portfolio renovation, [17] sustainability targets
From your perspective, how do you see the role of municipal policies / public regulations in circular value creation?	[1] significant (x2), [2] drivers (x2), [3] uniforming, [3] no control, [4] hard to predict, [5] supervising, [6] needed, [7] key players, [8] recycled materials promoter, [9] targets supporters, [10] too strict, [11] very important (x2)

Fast Picker / Smart robots - Focal actor	
What do you think, what is the need customers want to fill by buying the Fast Picker?	[1] end product purification, [2] material recovery, [3] safety [4] efficiency [5] economic savings, [6] automatization
From your perspective, what is the additional value Fast Picker gives to the customers?	[1] consistency, [2] purity, [3] recovered recyclable materials, [4] money savings, [5] decreased costs, [6] high recovery rate, [7] increased working hours, [8] work safety, [9] healthy work environment, [10] predictability, [11] image of forerunner
How do you ensure and measure the level of created value for the customers?	[1] monetary value of created material [2] improved purity, [3] number of picks. [4] performance consistency, [5] performance figures, [6] throughput levels, [7] recovery rate, [8] purity of recovered materials
What are the circular values that Fast Picker creates to the ecosystem?	[1] Improved quality of recycled materials, [2] increased recycling rates, [3] energy savings, [4] material savings, [5] cost savings, [6] loop closing, [7] manufacturing mirroring, [8] output meets the needed level of purity / quantity, [9] material re-use
Fast Picker / Smart robots - External actors	
What are the circular values that smart robots create to the ecosystem?	[1] speed, [2] savings, [3] accuracy, [4] increased recycling rate, [5] material recognition, [6] replacement of humans, [7] automation, [8] data, [9] sorting specific streams, [10] efficiency, [11] improved quality, [12] improved working conditions
What kind of value Fast Picker / smart robots bring to you?	[1] solution for everybody, [2] certification of the products, [3] quality of the products, [4] capacity to detect materials, [5] capacity to sort, [6] health and safety, [7] statistics, [8] purity of the output quality
How do you measure the level of value Fast Picker / smart robots create?	[1] separating capacity, [2] collected amounts, [3] monetary value, [4] number of picks, [5] performance, [6] quality

In the ideal situation, what other value would Fast Picker / smart robots bring to you?	[1] more advanced technology, [2] fully independency, [3] no human intervention, [4] food grade materials identification