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Circular Supply Chains in the Royal Dutch Army: An overview of the barriers

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A better world starts with
asking a better question

- Cécile van Oppen, Copper8

Abstract

The concept circular economy has become indispensable over the past decade. Scholars, policy-makers, and organizations have been working together to transition from a linear to a circular economy. In the Netherlands, this collaboration resulted in a program called Netherlands Circular 2050. All ministries, with the exception of the Ministry of Defense, have to adhere to this program. Though the Ministry of Defense is exempted from the program, there are some projects focused on circularity. These projects have faced a number of barriers which slowed down the transition to circular supply chains. Currently, there is very little literature on circular supply chains, let alone barriers to circular supply chains. This research therefore aimed to develop a framework of barriers to circular supply chains and to apply this to the Royal Dutch Army. This framework was constructed based on barriers to circular economy and sustainable supply chain management, which were divided into five categories: contextual, cultural, financial, organizational and technological. Three projects within the Royal Dutch Army were selected to apply this framework to. Moreover, the framework was discussed with interviewees who were not involved with the three chosen projects, but could provide an insight in circularity within Defense. The results of the interviews showed that all categories proposed in the framework entailed barriers to circular supply chains. The lack of knowledge and barriers related to the costs of a project were experienced by almost all interviewees. However, the main results show that the presence of barriers is mostly project specific and differs per actor group. Based on the results, a suggestion for a general framework of barriers to circular supply chains, including actor groups, was made. These findings not only add to the existing literature by broadening the knowledge on barriers to circular supply chains, they are also useful for the Royal Dutch Army. From these findings a roadmap could be created, which helps future project leaders with making their supply chains (more) circular.

Keywords: circular economy; sustainable supply chain management; circular supply chains; framework; barriers; dimensions; Royal Dutch Army.

Executive summary

In the Netherlands, the rising importance of a circular economy has led to a government-wide program called Netherlands Circular 2050. This program not only describes the vision of the government regarding the circular economy, it also provides strategic goals in order to achieve this (Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2016). Within the Ministry of Defense, a few projects have been launched which aim to include some form of circularity. This is however easier said than done. In the transition to a more circular supply chain, these projects have faced a number of barriers which often slowed this transition down. To gain an insight in these barriers, and to provide a roadmap to overcome these barriers, this research aimed to answer the question: *How do different barriers influence the implementation of circularity in supply chains in the Royal Dutch Army?*

To address this question, a framework of barriers was created. This framework was discussed in the context of Defense and, more specifically, in the context of the Royal Dutch Army. For Defense, interviews were conducted in which the framework was discussed explicitly to gain an insight in circularity within Defense. Moreover, interviews were conducted within Defense which had the aim to get a more general image of the organization. Besides these interviews, the framework was applied to three projects within the Royal Dutch Army. The first project is already working with recycled content for a couple of years, the second project started with a reverse logistics plan for recycling a year ago, and the final project has just started and does not yet aim to include circularity.

The interviews with all the actors showed that there were a few barriers which almost everyone experienced, such as the lack of knowledge and investment costs. However, other barriers were rather project specific, such as the perception and awareness of customers, in this case the soldiers. There were also a few barriers which were experienced by almost no one, such as risk aversion and trust among suppliers. Based on the results from the interviews, the initial framework was adjusted to provide a more accurate overview of barriers to circular supply chains. Moreover, the interviews showed that different actor groups experience different categories of barriers, based on their role in the project. The dimensions complexity and time were also studied. However, from these results no conclusions could be drawn.

Based on the interviews with the actors and the meetings during the internship, a roadmap was created which aims to transition projects within the Royal Dutch Army to circular supply chains. This roadmap contains four consecutive topics: (1) context, (2) knowledge, (3) program of demands, and (4) measurement. By following this roadmap, project leaders of future projects can make the transition to more circular supply chains. Thereby not only adding to the program Netherlands Circular 2050, but also to a more sustainable world. An extensive elaboration of this roadmap can be found in chapter 7.

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List of Abbreviations

BM	Business model
CE	Circular economy
CLAS	Command of the Royal Netherlands Army
CSC	Circular supply chain
CPE	Clothing and personal equipment
DMO	Defense Material Organization
DMP	Defense Material Process
DOSCO	Defense Support Command
EMF	Ellen MacArthur Foundation
KC	Center of Excellence
OTCLog	Knowledge- and training center logistics
MatLogCo	Material Logistics Command Land
SC	Supply chain
SSC	Sustainable supply chain
SSCM	Sustainable supply chain management

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1. Introduction

Over the past decade, there has been an increase in the interest in the topic of Circular Economy (CE), in the academic world (Geissdoerfer, Savaget, Bocken, & Hultink, 2017), in the European Union (Korhonen, Honkasalo, & Seppälä, 2018), and within companies (Ellen MacArthur Foundation, 2013). Although the concept of a circular economy is not new, Stahel and Reday-Mulvey (1981) discussed it already, it was not until the Ellen MacArthur Foundation (EMF) was founded in 2010 that awareness was really boosted (Stahel, 2016). The EMF defines a circular economy as "[…] an industrial system that is restorative and regenerative by intention and design" (Ellen MacArthur Foundation, 2012, p. 7). Such an industrial system is based on closed loops, in which the production and consumption of goods, environmental externalities linked to virgin resource extraction, waste generation, and pollution, are internalized (Sauvé, Bernard, & Sloan, 2016).

The aim of a circular economy is to shift from a take-make-dispose (linear) economy, to an economy where the functions of resources are changed and redesigned, so that waste of one process can be turned into input for another (IMSA Amsterdam, 2013). Moreover, instead of discarding used products, they should be repaired, reused or recycled.

Parallel to the circular economy, supply chain theory evolved. Mentzer et al. (2001) combined a number of definitions regarding supply chains, indicating that a Supply Chain (SC) contains upstream and downstream flows from source to consumer and that at least three organizations or individuals are involved. Over the years, different forms of supply chains have been identified, amongst which the Sustainable Supply Chain (SSC) (Touboulic & Walker, 2015) and the managerial concept Sustainable Supply Chain Management (SSCM). Seuring and Müller (2008) define SSCM as: "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, into account which are derived from customer and stakeholder" (p. 1700). Thus, SSCM is not only concerned with the economic profitability of a supply chain, it also focuses on the environmental and social dimension.

According to Genovese, Acquaye, Figueroa and Koh (2017), SSCM can be enhanced by aligning it to CE. This leads to supply chains that are more circular, taking sustainability a step further by adding restorative and regenerative design. Such a supply chain is described as a Circular Supply Chain (CSC) (Howard, Hopkinson, & Miemczyk, 2018), and builds on SSCM by integrating sustainable supply chains with circular economy. Batista, Bourlakis, Smart and Maull (2018) define CSC as "the coordinated forward and reverse supply chains via purposeful business ecosystem integration for value creation from products/services, by-products and useful waste flows through prolonged life cycles that improve the economic, social and environmental sustainability of organizations" (p. 446).

There is little information available on how CSC can be introduced in a real-world context (De Angelis, Howard, & Miemczyk, 2018). Literature on CSC in case studies is rather scattered: Geissdoerfer

et al. (2018) looked into organizations ranging from a manufacturer to a bike sharing company; Mishra et al. (2018) explored CSC in the fast-moving consumer goods; Srai et al. (2018) focused on the chemical feedstock; Vlajic et al. (2018) research the food industry; Genovese et al. (2017) looked into the chemical and the food industry; and Bressanelli et al. (2018) studied organizations ranging from a pay-per-wash company to a manufacturer of household appliances.

Moreover, the concept of CSC is relatively new in the academic world. In databases such as Scopus and Web of Science, less than 15 articles are available on CSC (appendix I). From these articles, only two were published before 2018, indicating the novelty of the concept. The research conducted on CSC thus far was mainly focused on developing frameworks (Geissdoerfer et al., 2018; Jain, Jain, & Metri, 2018; Srai et al., 2018), and examining the link between different concepts (Gnoni, Mossa, Mummolo, Tornese, & Verriello, 2017; Larsen, Knudby, Van Wonterghem, & Jacobsen, 2017; Yang, Smart, Kumar, Jolly, & Evans, 2018). One study focused on identifying relevant barriers for CSC adoption (Mangla et al., 2018), providing a framework of barriers to CSC in developing countries. The research of Mangla et al. (2018) focused specifically on barriers to CSC in India, and did not develop a general framework. Barriers hamper the transition to a circular economy (Van Eijk, 2015); gaining insight in them allows for a more successful implementation of circularity in supply chains. This is also of importance for organizations, since it is expected that they cannot only create a competitive advantage by implementing circularity, but can also save money and become more environmental friendly (EMF, 2012). However, the novelty of CSC causes a lack of knowledge regarding barriers to CSC. Therefore, this study aims to address this gap in the literature and to propose a framework of barriers to CSC.

A CSC is a supply chain in which the focus lies on circularity. In a supply chain, by definition at least three different actors or actor groups are involved (Seuring & Müller, 2008), which all have different objectives. Due to these different objectives, actors or actor groups can perceive different barriers. Since it is useful to find out which barriers are perceived by which actor groups, this dimension is studied along the framework of barriers. Moreover, the perceived amount of barriers can vary with the complexity of projects (Moktadir, Ali, Rajesh, & Paul, 2018). If for instance a project is more complex, it is possible that more barriers are perceived. To examine this possibility, this dimension is also studied along the framework. Finally, the time dimension, which is focused on the appearance of barriers, is studied along the framework. Some barriers are expected to be relevant at the first stage of the transition to CSC, whereas others only become relevant at later stages (IMSA Amsterdam, 2013).

1.1 Empirical context

Circular economy is not just a topic of interest in the academic world; also the European Union is interested in its principles. The Netherlands is one of the countries taking measures to promote circular

economy (George, Lin, & Chen, 2015). In 2016, the Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs presented a document regarding CE in the Netherlands called Netherlands Circular 2050. With this document, a government-wide program which envisions a future-proof, sustainable economy was introduced. Via strategic goals related to the utilization of raw materials and developing new production methods, the government aims to transition the Dutch economy from a linear to a circular one.

One of the ministries involved with circular economy is the strongly regulated Dutch Ministry of Defense. This ministry is exempted from the program due to its operational character, however in 2014, the ministry started a project in the army entailing the recycling of clothing and restoring it to reusable fibers (PIANOo, 2016). Making clothes, towels and washcloths circular served as a starting point for circular supply chains in the defense sector. Yet, in a speech held by the Dutch Minister of Defense, there was a call for more circularity:

> The defense sector has stated too long that it had other things on its mind than waste disposal [...] Do our suppliers take into account the circular traits of the products they offer us? Are they willing to think with us and help us to clean up the supply chain? (Bijleveld, 2018)

Thus, besides addressing the defense sector, Bijleveld (2018) also specifically addressed suppliers and asked them about their willingness to work towards a cleaner supply chain. This makes sense, since in order to become more circular, the whole supply chain needs to be involved. Noteworthy, in the Royal Dutch Army, the implementation of circularity in supply chains is executed through projects.

1.2 Research question

Following from the problem context and the literature gap regarding CSC and its barriers, and based on the lack of knowledge in the army, a research question and two sub questions were formulated:

How do different barriers influence the implementation of circularity in supply chains in the Royal Dutch Army?

1) What are the barriers to circularity in supply chains in the Royal Dutch Army?
2) What is the influence of different dimensions (actor groups, complexity, and time) on barriers to the transition to CSC?

1.3 Relevance

1.3.1 Practical

The Royal Dutch Army is currently working on different projects to make its supply chains more circular. To attain procurements, very specific and detailed tenders have to be provided to potential suppliers. Once a tender is issued, it is not allowed to update the request, consequently ideas from actors within the SC cannot be factored in the tender during the process. Due to a lack of knowledge however, the

project leaders of the Royal Dutch Army are unaware how to make a tender circular. Therefore, this research aimed to develop and propose a roadmap for circular tenders, based on the knowledge gathered on the barriers to CSC. Moreover, the influence of three dimensions is taken into account during the creation of the roadmap.

1.3.2 Scientific

In 2018, Mangla et al. provided a framework involving barriers to CSC for developing countries, which contained individual barriers and was rather country-specific. Different from Mangla et al. (2018), who found barriers via interviews with experts, the current study combines barriers to both the circular economy as well as sustainable supply chain management. These barriers are clustered into five categories, with the aim to address the gap in the literature regarding barriers to CSC and to create a framework. Besides addressing this gap in the literature, this study contributes to the existing knowledge by broadening the understanding of barriers to CSC in relation to three dimensions, namely actor groups, complexity, and time.

Moreover, as previously mentioned, the context of this study is the Royal Dutch Army. Though it is aimed to provide a framework which is widely applicable in the end, it is important to keep in mind that some barriers are rather context specific and might not apply to other empirical contexts. Finally, this study adds to the understanding of circularity within a strongly regulated environment, since the framework is applied to projects within the Royal Dutch Army, which is part of the Ministry of Defense.

2. Theoretical Framework

The theoretical framework is divided in three sub-sections: the circular supply chain, barriers to CSC, and dimensions involved with CSC.

2.1 Circular Supply Chain

Aligning SSCM to CE enhances sustainability in supply chains and leads to circular supply chains (Genovese et al., 2017). CSC can be defined as "the embodiment of CE principles within supply chains" (De Angelis et al., 2018, p. 10), indicating that products or resources are reused, remanufactured and recycled within supply chains instead of discarded when they reach the end-of-life stage.

As mentioned in the introduction, current research on CSC focuses on developing frameworks and examining the link between different concepts related to CSC. Jain et al. (2018) seek to propose a conceptual strategic framework for CSC measurement; Srai et al. (2018) focus on providing a framework that explores the commercial viability of SCs which arise from renewable chemical feedstocks; and Geissdoerfer et al. (2018) propose a framework in which they aim to integrate a circular Business Model (BM) with circular supply chain management towards sustainable development. Though a few frameworks have been developed, these do not present a framework based on the integration of barriers to CE and SSCM, thereby indicating barriers to CSC.

Another CSC research topic is the link between different concepts. Links can be found in supply chain management (De Angelis et al., 2018), reverse supply chains (Batista, Bourlakis, Smart, et al., 2018; Larsen et al., 2017), business model innovation (Yang et al., 2018), closed-loop supply chains (Batista, Bourlakis, Smart, et al., 2018; Gnoni et al., 2017), recovery supply chains (Mishra et al., 2018; Vlajic et al., 2018), green supply chain management (Batista, Bourlakis, Smart, et al., 2018; Geissdoerfer et al., 2018), and SSCM (Batista, Bourlakis, Smart, et al., 2018; Geissdoerfer et al., 2018; Genovese et al., 2017). These articles show that CSC is related to different concepts. SSCM shows the biggest resemblance to CSC, since this concept is involved with supply chains as well as sustainability, which also includes circularity. Therefore, like CE, SSCM is used to identify barriers for the framework.

In their research, Prosman and Sacchi (2018) indicate that a CSC includes both forward as well as reverse activities, and discriminate between two different types of CSC. The first type is the closed-loop system, in which products eventually return to their point of origin. Only few closed loop systems exist; one of them can be found at Philips Lighting[1] (Bressanelli et al., 2018). Here, the same actor is responsible for all the processes, from product design to end-of-life processes. In an open-loop system, the second type, other parties than the original producer recover the value from discarded products

[1] Changed their name in 2018 to Signify: https://www.dutchnews.nl/news/2018/03/philips-lighting-changes-name-to-signify-products-will-retain-philips-label/

(Prosman & Sacchi, 2018). Smurfit Kappa is an example of an organization striving for CSCs in an open-loop system. They use paper fiber from Van Houtum[2]; phosphor, used to purify the water, is retrieved from a manufacturer which produces child food; and produced waste is supplied as biomass to a sister company (Cox, 2013). These examples show how Smurfit Kappa involves the whole supply chain to make hers circular.

2.2 Barriers to CSC

To develop the framework, this study does not look at barriers to CSC like they are presented in the study by Mangla et al. (2018). This is due to the fact that these barriers were focused on developing countries and are therefore not relevant nor applicable to the current study. Instead, this study identifies barriers regarding CE and SSCM and combines the two concepts to find barriers to CSC, since aligning these concepts leads to CSC (Genovese et al., 2017).

In figure 1, which can be found below, the categorizations of barriers to CE and SSCM is explained. The articles used in step 1 are found by using Web of Science or through forward and backward snowballing. In the search engine, different search terms such as “circular economy”, “CE”, “sustainable supply chain management”, and “SSCM” are used in combination with the search term “barrier*”. In step 2, the barriers found in the literature are written down in a clear manner, e.g. ‘cultural’, making a distinction between barriers to CE and barriers to SSCM. The third step provides a more in-depth explanation of the barriers, e.g. ‘cultural’ is broken down to ‘resistance to new BMs from inside the company’ and ‘risk averse’ (Torstensson, 2016). In the fourth step, the barriers are classified into seven categories based on their properties. These categories are contextual, cultural, financial, infrastructural, institutional, organizational and technological. For the fifth step, the barriers are written down per category, providing an overview of all the barriers found in the CE and SSCM literature. In step 6, redundant barriers were removed and the number of categories was brought down from seven to five, eliminating the institutional and infrastructural category. Barriers from the institutional category were also addressed in the contextual category (lack of regulations, standards and support). Barriers from the infrastructural category overlapped with barriers from the organizational category (e.g. exchange of materials is limited by capacity of reverse logistics). Finally, step 7 provides the framework of barriers as developed based on the literature regarding CE and SSCM. In the framework, a distinction is made between barriers to CE and barriers to SSCM, this distinction is explained prior to presenting the framework.

[2] Acquired by WEPA in 2018: https://fd.nl/ondernemen/1201224/limburgse-papierfabrikant-van-houtum-komt-in-duitse-handen

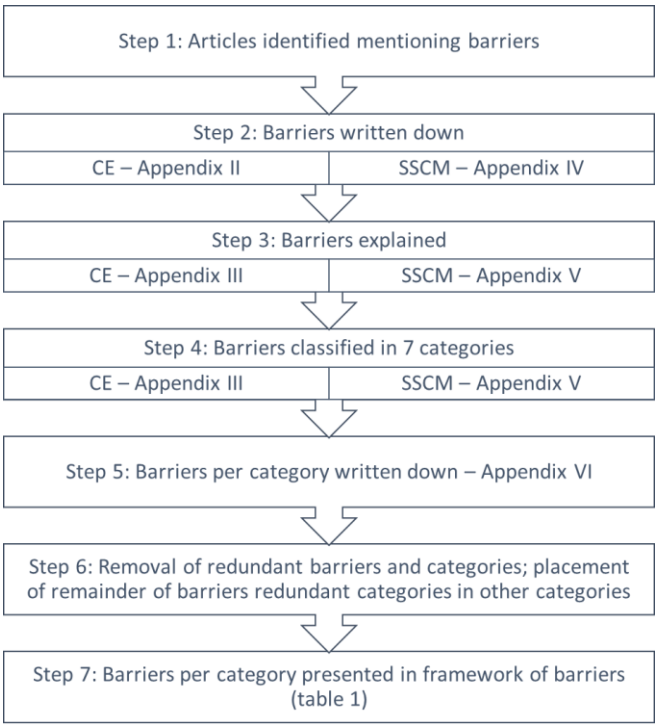


Figure 1: Categorization of barriers

2.2.1 Contextual

In 'Organization Theory and Design' Daft, Murphy and Willmott (2017) characterize the contextual dimension as "both the organization as a whole, including its size, technology, [environment, goals] etc. and the broader organizational setting" (p.24). In this research, the contextual category is formed by barriers related to customers and legislation. In the literature, four barriers in this category are identified. These barriers entail customer resistance (Co1), perception of sustainability (Co2), lack of awareness (Co3), and lack of regulations, standards and support (Co4).

Customers are conservative in their behavior (Torstensson, 2016), which makes them resistant to change (Co1) and therefore provide a barrier to CSC. If there is no perception of sustainability (Pheifer, 2017), or if there is a negative perception (Sajjad, Eweje, & Tappin, 2015), customers are less motivated to change their behavior. Therefore, perception of sustainability (Co2) is a barrier as well. Closely linked to this is the barrier lack of awareness (Co3). When this barrier is perceived, customers do not understand the benefit of circularity (Moktadir et al., 2018), and do not feel the necessity to change.

The last barrier in this category is focused on rules and regulations (Co4). This barrier entails the need for an economy to be regulated, irrespective whether it is a linear or a circular economy. Since the current laws and regulations in place for a circular economy are not sufficient (Al Zaabi, Al Dhaheri, & Diabat, 2013; Torstensson, 2016), the lack of regulations, standards and support also forms a barrier to CSC.

2.2.2 Cultural

According to Daft et al. (2017), the culture of an organization is based on the beliefs, key values, understandings and norms. Mintzberg, Ahlstrand and Lampel (2009) add to this that culture entails shared ideas which are reflected in the customs and traditions of an organization. The barriers in this category are both focused on business models. In the literature, two barriers within the cultural category are identified. These are risk aversion (Cu1) and resistance to change the business model (Cu2).

Organizations perceive circular models as riskier than linear models and therefore tend to avoid them (Ritzén & Sandström, 2017). Due to this risk aversion (Cu1), the implementation of CSC is hindered. The second barrier in this category is the resistance to change the BM (Cu2). The current BM is based on the beliefs, values, the mission and vision of a company. In the absence of a sense of urgency to change (Pheifer, 2017) and many stakeholders not wanting the BM to change (IMSA Amsterdam, 2013), the management opposes to changing the current configuration. Since a change is needed in order to implement a circular business model, resistance to this change thus forms a barrier.

2.2.3 Financial

Daft et al. (2017) stipulate the importance of the financial category by indicating that an important source of power is control over money. Three barriers were identified in this category based on the literature. These barriers are associated with investment costs (F1), costs of recycled materials (F2), and the lack of financial support (F3).

Access to capital is more difficult for circular models than for linear models (IMSA Amsterdam, 2013). However, when transitioning to a CSC, changes need to be made in the design, manufacturing, and return processes. These are activities for which huge investments are needed (Narayanan, Sridharan, & Ram Kumar, 2018). Since access to capital is more difficult for circular models, the investment costs (F1) form a barrier to CSC. Furthermore, the cost price of recycled materials (F2) is sometimes higher than that of virgin materials, whilst the quality can be lower (Sarkis, Helms, & Hervani, 2010). This also makes it more difficult to implement a circular model, e.g. a model based on recycled content, and therefore also forms a barrier. Finally, banks, governments, and policy-makers tend to give less money to sustainable initiatives (Moktadir et al., 2018), since these are perceived to be bigger risks. Since a higher risk is perceived, there is a lack of financial support (F3). Moreover, organizations are not always able to show the importance of circular procurement (Kirchherr et al., 2018), due to a lack of financial support. Thus, the lack of financial support does not only form a barrier, it also leads to a vicious circle since organizations are unable to show the importance of circular procurements.

2.2.4 Organizational

The internal characteristics of an organization (Daft et al., 2017) and their barriers are placed in the organizational category. Following from the literature, four barriers are placed in this category. These barriers are focused on the strategy of an organization and involve lack of knowledge and skills (O1), trust among suppliers (O2), no reverse supply-chain in place (O3), and no alignment between circular business and the current strategy (O4).

Circularity requires proper knowledge and skills (Pheifer, 2017). Thus, capabilities and competencies need to be developed, since a lack of knowledge (O1) on circular practices leads to a lock-in in the current model (Moktadir et al., 2018) and thus forms a barrier. When transitioning to a CSC, it might be possible that an organization needs to revise its supplier base (O2), which comes with additional risks in terms of delivery of quality and performance (Torstensson, 2016). Changing the supplier base can have serious implications for the trust among suppliers and therefore this also forms a barrier. Another barrier to CSC is the lack of a reverse supply chain (O3). This means that there is an absence of a supply chain that allows for collection and/or disassembly of products or recycled materials (Mont, Plepys, Whalen, & Nußholz, 2017). Without such a supply chain, there are fewer or no recycled materials which can be used for new products. Lastly, circular business needs to be aligned with the strategy of the organization (O4). It does not matter how much support there is for circularity, until it has a place in the strategy, no actual plans to transition will be developed (Pheifer, 2017), thus hindering the transition to a CSC.

2.2.5 Technological

Daft et al. (2017) refer to technology as "the tools, techniques and actions used to transform inputs into outputs" (p.580). Five barriers involving the technological category were found in the literature. These are the lack of technical skills (T1), limited availability of recycled material (T2), design to disassemble/reuse/recycle (T3), quality control of recycled/reused material (T4), and the lack of technology, materials and processes (T5).

The importance of capabilities and competencies is extended in the technological category, since technical skills (T1) are needed to identify, asses and implement technical options (Rizos, Behrens, Kafyeke, Hirschnitz-Garbers, & Ioannou, 2015). The lack of these technical skills thus hinders the transition to a CSC. The availability of recycled material is currently still very limited (T2) (IMSA Amsterdam, 2013). This forms a barrier since, due to this limited availability, the production of new, more circular products still requires virgin materials. A barrier to remanufacturing, is the robust design of products (T3). Robust products are it harder to disassemble (Al Zaabi et al., 2013; Narayanan et al., 2018; Torstensson, 2016), and subsequent reuse, thus forming a barrier. Furthermore, the quality of the recycled or reused material (T4) might be unknown. Due to the bad shape some products are in, they cannot be reused or remanufactured (Mont et al., 2017), also leading to less materials available

for reuse. The bad quality of products thus also hinders the transition to more circular supply chains. A final barrier in this category is found regarding machines that are often outdated (Moktadir et al., 2018) and there is a lack technology and processes (T5) to produce in a circular way (Narayanan et al., 2018). This is forms a barrier, since suppliers need extra finances to replace the current technologies and machines in order to be able to make their supply chain more circular.

2.2.6 Framework of barriers

The framework used in this research is created based on categories of barriers which contain barriers to CSC, as identified in the previous paragraphs. The distinction between barriers found in CE literature and SSCM literature is illustrated by making the sources of the CE articles **bold** and the sources of the SSCM articles *italic.* The sources of the articles for this framework can be found in appendix VII.

Table 1: Framework of barriers

	Code	Barrier	Source	Context
Contextual	**Co1**	Customer resistance	**9**, **14**	Customers want to keep doing what they are doing
	Co2	Perception of sustainability	**9**, **10**, *12*, *13*, **14**	Customers have no/negative perception of sustainability
	Co3	Lack of awareness	**2**, *6*, **8**, *12*, **15**	Public awareness on the importance of the circular economy is limited
	Co4	Lack of regulations, standards and support	*1*, *6*, **14**	A circular economy needs to be regulated by laws, however the current regulations are not enough
Cultural	**Cu1**	Risk aversion	**5**, **10**, **14**	Circular BMs are perceived by (the management of) companies to have higher/more risks
	Cu2	Resistance to new business models (BM)	*1*, **2**, *8*, **9**, **14**	There is resistance from (top level management) within a company to change the current BM
Financial	**F1**	High up-front investment cost	**2**, *3*, **4**, **7**, *8*, **14**	To shift a BM from linear to circular, major investments are needed
	F2	Recycled materials more expensive	**2**	Recycled materials are often more expensive than raw materials
	F3	Lack of financial support	**4**, *6*, *8*, **9**	Few governmental financial incentives in place to stimulate the development of more circular BMs
Organizational	**O1**	Lack of knowledge and skills	*6*, *8*, **9**, **11**, *13*, **14**	Development of new capabilities and competencies is required
	O2	Trust among suppliers	*8*, **14**	Circular suppliers are expected to deliver the same/better performance/quality than linear suppliers
	O3	No reverse supply chain in place	**7**, **9**	Organizations lack the processes to take back products
	O4	Circular business does not align with strategy	**7**, *13*	The proposed circular BM is not in alignment with the current strategy of the organization
Technological	**T1**	Lack of technical skills	**4**, **11**	Lack of technical capacity
	T2	Limited availability of recycling material	**2**	Recycling often leads to downcycling; due to delay in production and discarding, there will always be a need for virgin materials
	T3	Design to reuse/recycle	*1*, *8*, **14**	Current products are often build without considering the reparability and reusability of parts or materials

	T4	Quality control of reused/recycled material	**2**, **7**, **14**	It might be unknown what has happened with the recycled material; parts of products are perhaps not possible to reuse/remanufacture due to the bad shape they are in
	T5	Lack of new materials and processes	*6*, *8*	Materials and processes are not environmentally friendly

2.3 Dimensions of CSC

Perceived barriers can be different for different actor groups (Ellen MacArthur Foundation, 2012), therefore, it is important to take this dimension into account. The complexity of a project, including its supply chain, also needs to be taken into account. Here, more or less barriers can be perceived based on the level of a project's complexity (Moktadir et al., 2018). Finally, it is important to take into account when a barrier appears within the project. Some barriers might only be relevant at the early stages of a project whereas others only occur at the end (IMSA Amsterdam, 2013), therefore the third dimension is time. These dimensions are discussed in relation to the categories of barriers instead of the individual barriers. Moreover, since they have different objectives, it is expected that depending on the dimension different categories of barriers are present.

2.3.1 Actor groups

Every supply chain consists of at least three organizations or individuals (Mentzer et al., 2001). In this study barriers perceived by project leaders, customers and suppliers are examined.

Project leaders play a key role in coordinating projects, which are used to implement circularity in the supply chain (Mentzer et al., 2001). For these actors, it is important to balance between the interests of the project, supplier and customers. There are a few categories in which barriers are expected to occur for project leaders, namely the contextual, cultural, financial and organizational category. A barrier such as resistance can stem from both the contextual category as well as the cultural category. If project leaders experience resistance from other actors towards the project, they can use their influence on the suppliers, the customers as well as the management (Clifford Defee & Stank, 2005). Another category in which barriers can be perceived is the financial category. Initially, a CSC will cost more than a linear supply chain (IMSA Amsterdam, 2013; Kirchherr et al., 2018; Torstensson, 2016), therefore project leaders face barriers regarding their initial budget for instance in higher investment costs. Finally, barriers from the organizational category can be perceived. An important part of the circular economy is the presence of a reverse supply chain (Pheifer, 2017). Project leaders need to establish such a supply chain in order to be able to reuse, refurbish, remanufacture or recycle their products, however the lack of such a supply chain forms a barrier. Overall, barriers perceived by project leaders are thus expected in the contextual, cultural, financial, and the organizational category.

Customers [3] also need to adapt in case a supply chain becomes more circular. These adaptations can be in the form of changing their work methods or mindset. Customers can face barriers which might be resolved by the help of the project leaders, e.g. barriers from the contextual category like the lack of awareness regarding CE or SSCM (Moktadir et al., 2018; Mont et al., 2017; Sajjad et al., 2015; Xue et al., 2010). In combination with suppliers, customers might also perceive barriers from the organizational category. If customers need to return used products to suppliers while there is no reverse supply chain in place, this is perceived as a barrier (Mont et al., 2017; Pheifer, 2017). Customers are therefore expected to perceive barriers in the contextual and the organizational category.

The third actor group is formed by the suppliers. These actors might be susceptible to financial barriers as investments are needed for process changes (Moktadir et al., 2018; Narayanan et al., 2018), thus perceiving barriers from the financial category. Next, the organizational category contains barriers which can be perceived as hindering for the suppliers, such as the lack of a reverse supply chain (Mont et al., 2017; Pheifer, 2017). Finally, suppliers have to change the design of products in order to make them more circular (Al Zaabi et al., 2013; Narayanan et al., 2018; Torstensson, 2016), and do quality inspection of the returned/recycled materials (Kirchherr et al., 2018; Mont et al., 2017; Torstensson, 2016). If this does not happen, barriers can be perceived from the technological category. Thus, based on the literature, barriers perceived by suppliers are expected to be found in the financial, organizational, and technological category.

An overview of the expected barriers per actor group can be found in figure 2.

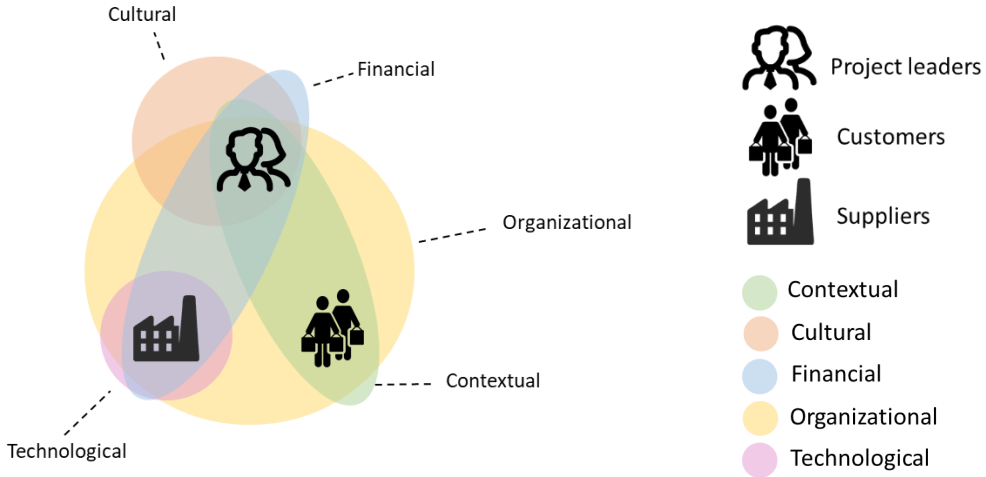


Figure 2: Expected categories of barriers per actor group

[3] The customers in this study are represented by the soldiers of the Dutch army.

2.3.2 Complexity

Projects can be classified based on their complexity. Baccarini (1996) defined complexity as "consisting of many varied interrelated parts" (p. 202). The complexity of a project will bring associated barriers. Here, it is expected that the more complex a project is, the riskier it is, and thus the more barriers are perceived.

Barriers are expected to be perceived in both less complex as well as more complex projects. Regarding the contextual category, it is expected that in more complex projects, as opposed to less complex projects, a change in behavior still needs to occur. Thus, none or few barriers are expected for the less complex projects, whereas (almost) all barriers from this category are expected for the more complex projects. For the cultural category it is expected that barriers are perceived in both less complex and more complex projects, since people are risk averse (Ritzén & Sandström, 2017), independent of the complexity of a project. This is also the case for the financial category, in which financial support is necessary for new projects (IMSA Amsterdam, 2013), irrespective of the complexity of a project. In the organizational category, there is a difference in expected barriers to be perceived. Here, it is expected that for the less complex projects a reverse supply chain is for instance already in place, while this is not the case for more complex projects. Therefore, none or a few barriers are expected to be perceived for less complex projects, and (almost) all barriers are expected to be perceived for more complex projects. Finally, the barriers expected to be perceived in the technological category are expected to differ based on the technical changes needed for the product.

Table 2: Expected complexity projects

	Categories of barriers					
Complexity		Contextual	Cultural	Financial	Organizational	Technological
	Less	Low	High	High	Low	Medium
	More	High	High	High	High	Medium

2.3.3 Time

Regarding the time dimension, little literature is available. There is however one report available in which steps to transition to a circular economy are discussed. The report by IMSA Amsterdam (2013) presents a list with steps, which are translated to the categories used in this study. These steps provide an insight in when barriers may occur. Following these steps, the first barriers that come up are the barriers in the financial category, since a lot of money needs to be invested to be able to start the transition. These barriers occur at practically the same time as the cultural barriers, since a change in business models is required to start the transition as well. When the transition has started, CSC principles need to be incorporated in education and training, in order to evolve the technical skills and reduce the lack of knowledge. Thus, barriers from the technological and organizational category occur

at the same time. Since for instance a reverse supply chain already needs to be in place in order for the supplier to get access to recycled materials, it is expected that barriers from the technological category are perceived longer than those of the organizational category. Finally, the barriers from the contextual category occur. For these barriers, a change from the customers is required, which is only necessary at the end of a project when a product is implemented.

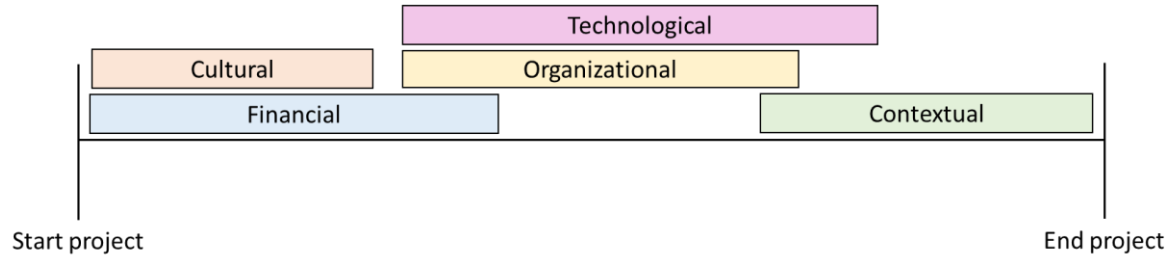


Figure 3: Expected occurrence barriers per category

3. Methods

This research aims to address a gap in the literature regarding barriers to CSC and to propose a roadmap for tenders involving circularity, by answering the following question: *How do different barriers influence the implementation of circularity in supply chains in the Royal Dutch Army?* To answer this question, a qualitative strategy is adopted, since this aims to provide "an in-depth and interpreted understanding of the social world, by learning about people's social and material circumstances, their experiences, perspectives and histories" (Snape & Spencer, 2003). Moreover, qualitative research offers the possibility to increase the knowledge on newly developing social phenomena (Ritchie, 2003). Since the notion of barriers to circular supply chains and barriers is still rather novel, a qualitative strategy is applied in this study.

3.1 Research Design

A common research design in qualitative research is the case study. According to Swanborn (2010), particular features often associated with case studies are the selection of either one or several cases; the intensity and level of detail of the study; the case is studied in its natural context; and several sources are used to collected the data. In this study, a multiple-case study is conducted. This means that several cases were studied via different means such as through interviews and by reading documents and reports, i.e. a vision document of the Clothing and Personal Equipment (CPE)-company. Moreover, to get a better idea of the context, some open interviews are conducted. By following this research design, insight in barriers to CSC for specific projects in the Royal Dutch Army is gained as well as insight in barriers to CSC in a more general context of Defense. Furthermore, by conducting interviews and by reading documents and reports, an insight is gained in the influence of three dimensions on the barriers to CSC.

3.2 Case selection

Sampling can be done in different ways, one of which is purposive sampling (Mason, 2002), meaning that samples are chosen based on specific features. Here, a distinction can be made between different approaches. For this research, homogeneous sampling was adopted to get "a detailed picture of a particular phenomenon" (Ritchie, Lewis, & Elam, 2003, p. 79). In this study, three projects within the Royal Dutch Army are examined. These are currently the only ones involved with circularity in the Royal Dutch Army. The three chosen projects (CPE-company, PET-bottles, and tent systems for deployment) vary in the phase they are in, which allows for retrospective as well as real-time research. Furthermore, the projects vary in complexity, which gives insight in which barriers are perceived for less complex and more complex projects.

3.2.1 Clothing and personal equipment

In 2014, the Ministry of Defense started a project involving the recycling of military clothing (PIANOo, 2016), since the army uses a lot of textile products (e.g. clothes, towels, wash cloths). It was decided to look at this project not just by focusing on the army, but also throughout the entire supply chain. New suppliers were found that used recycled fibers in new textiles, and used clothing was sorted and reduced to usable fibers (Schuurman, 2017). Two Belgian suppliers eventually won the tenders and started the supply of products which had recycled materials in it (PIANOo, 2016), making the supply chain more circular. The contract with these suppliers runs until 2020, then a new tender is set out for which the current suppliers as well as new suppliers can register.

3.2.2 PET-bottles

Upon her return to the Netherlands, after a deployment in Mali, Captain Aarssen addressed the problem of litter in Mali. She described how local contractors would pick up the waste at the Dutch base and dump it two hundred meters outside the base. Upset by this, she wanted to do something about the amount of waste and was backed by minister Bijleveld. In a speech minister Bijleveld (2018) gave at the symposium of Circular Economy, she mentioned the importance of clean procurement. During the speech, she asked whether there were biodegradable alternatives for PET-bottles. Since there are no (affordable) alternatives just yet, and the contract for PET-bottles had to be renewed, this formed the opportunity to look at circular solutions. Eventually, a supplier was found which arranged not only the takeback of the PET-bottles at exercises, but also delivered the bottles to a foundation which eventually shreds them to PET from which new bottles can be made. In order for this to work, soldiers are not allowed to crumple their PET-bottles, otherwise these cannot be counted by the foundation. Since 2018, two pilots have been conducted regarding the reverse logistics of PET-bottles during exercises. There were some issues that needed to be smoothed out during implementation, however even with that in mind the pilots were evaluated positively by the actors involved. The contract with the supplier of the PET-bottles runs until 2022.

3.2.3 Tent systems for deployment

A third project in which there is also a possibility for more circularity just started. This project entails the procurement of tent systems, which are used for training exercises as well as for missions and thus need to be of decent material. This research focuses on tent systems for deployment, since these need to be procured three years earlier than the tent systems for training. This means that the project tent systems for deployment is currently up and running, since the project leader has to procure new tent systems in 2021. The project leader tent systems for training on the other hand, can take it slow, he has until 2024 to procure new tent systems. This also means he can provide less insights in barriers he encountered and is expected to encounter. The knowledge- and training center logistics (OTCLog)

works as an advisory body for this project, and aims to implement some form of circularity in it. Currently, the expert, whose function is explained below, got the project leaders interested in making the tents more circular. However, both project leaders have clearly stated that they do not want circularity to be a showstopper to the projects.

3.3 Data collection

Data for this research was collected by reading documents and reports, and conducting both semi-structured as well as open interviews. A framework of barriers to CSC was created based on barriers found in literature on CE and SSCM. This framework was translated to a so-called list of barriers, in which both the barriers per category and an explanation of the barriers was written down. The objective was to discuss this list of barriers with all interviewees via semi-structured interviews, however not all interviews lent themselves for this. Therefore, more open interviews were conducted with interviewees with whom the list of barriers was not discussed. Secondary data was also used for the data collection since the soldiers involved with the PET-bottles project were hard to reach. In the case of the CPE-company and the tent systems for deployment, no soldiers were involved, since no active change is needed of them in order for the projects to succeed. The actors with whom the interviews were conducted were selected based on discussion with the expert, as well as via forward-snowballing, after which the possible interviewees were approached via e-mail. The selected actors offer a Defense-wide image of circularity, as well as a more detailed focused of circularity within three projects of the Royal Dutch Army.

3.3.1 Interviews

Though a topic list is created, the order of questioning differs between interviews (Arthur & Nazroo, 2003). This is due to the fact that every actor reacts differently to questions and addresses different things, which leads to different follow-up questions. The interviews were used to get insights in the different projects at the Royal Dutch Army as well as in circularity within Defense as an organization. In the interviews, open questions about circularity and barriers were asked, after which the list of barriers was discussed. The actors were asked to go through the list of barriers and mark which barriers they perceived. Moreover, the actors from the projects under study were asked to place the categories of barriers on a timeline when they occur(ed) in the project. The topic guide used for the semi-structured interviews can be found in appendix VIII. For the open interviews, no topic guide was used. Instead, at the beginning of the interviews an introduction into the study was made, after which a conversation naturally followed.

Additionally, an expert provided insights on all three projects via a semi-structured interview. Since the expert was asked to provide information on barriers to all three projects, to make a division based between the projects based on the complexity, and to place categories of barriers on a timeline

per project, a different topic guide was used. The topic guide used for this interview can be found in appendix IX.

3.3.2 Interviewees

Within the projects, multiple actors were selected to be interviewed: project leaders, a purchaser, a project associate, and suppliers. Initially, the role of a purchaser was not mentioned in the theory section. However, since the purchaser procures the products at the CPE-company, the clothing and personal equipment-company, he was taken into account. The project associate is also a role not mentioned in the theory. This interviewee can be considered as someone who discusses the project with the project leader, but is not formally involved with the project. An expert is also interviewed to obtain his professional opinion on the projects and to provide a helicopter view. He works at the Center of Excellence (KC), which is a part of the education and training center logistics from the Royal Dutch Army. In this role, he is familiar with the projects at the CPE-company and the PET-bottles projects, and he serves as an advisory body for the tent systems for deployment.

As previously explained, not all interviews lent themselves to go through the list of barriers. Regarding the projects under study, the project leader of the CPE-company only wanted to discuss his successes. With Supplier A (CPE-company) and supplier PET-bottles the interviews took place over the phone. Both suppliers did not have sufficient time to discuss the list of barriers, therefore the interviews were open. Supplier B (CPE-company) did not have time to discuss the interview over the phone, therefore an e-mail containing the barriers including an explanation was sent to this supplier. Finally, secondary data was used for the soldiers (PET-bottles), since it was not possible to reach them. The roles of the different actors are discussed in the table below, the actors which discussed the list of barriers are marked with an asterisk (*).

Table 3: Interviewees projects

Project	Actor	Role
CPE-company	Project leader	Has the direction over projects at the CPE-company
	Purchaser*	Procures products for projects at the CPE-company
	Supplier A	Supplier of overalls
	Supplier B	Supplier of towels
PET-bottles	Project leader*	Has the direction over the project
	Project associate*	Not formally involved with the project, however discusses with project leader a lot
	Soldiers	Had to use and return PET-bottles during their training exercises
	Supplier	Supplier of PET-bottles
Tent systems for deployment	Project leader*	Has the direction over the project
Expert	Expert KC*	The expert is familiar with the CPE-company, has had discussions with the project leader and project associate of the PET-bottles project, and is trying to create awareness to include circularity in the project involving tent systems

Besides actors involved with the projects, other actors are also interviewed. Though these are not involved with the projects under study, they do provide an insight in circularity within Defense. All but one of these actors are placed in the 'organization wide' category, the remaining actor however refers to circularity regarding his own project and is therefore placed in the 'project specific' category. Here, the actors with whom the list of barriers was discussed are also marked with an asterisk (*). The list of barriers was not discussed with all interviewees since the objective of these interviews was to get a more general image of circularity within Defense. Moreover, three interviews were conducted which gave an insight in how Defense works, the list of barriers was also not discussed here. Since the objective of these interviews was not to discuss barriers, these interviewees have not been taken into account in the results section. These interviewees are put in *italics* in the table below.

Table 4: Other interviewees

Project	Actor	Role
Project specific	Project leader combat shirt*	Direction over a project regarding combat shirts, requested his team and his supplier to think about sustainability
Organization wide	Head of environment DMO	Charged with environmental issues at the Defense Material Organization (DMO), the part of Defense responsible for all the materials for the four armed forces
	Head of environment CLAS	Charged with environmental issues at the Royal Dutch Army, involved with guaranteeing the environmental management system
	Purchaser DOSCO*	Procures products at the Defense Support Command (DOSCO), which is focused on supporting tasks related to i.e. buildings, education, food, and healthcare
	Purchaser MatLogCo	Procures products at Material logistics Command Country (MatLogCo), which is involved with the maintenance of all land systems such as vehicles and weapons
	Project leader tent systems training	Direction over a project regarding tent systems for training, this project is similar to the tent systems for deployment project, however it has a larger timeframe
	Project leader water treatment	Direction over a project regarding water treatment installations, also member of the working group Circular Economy at the Royal Dutch Army
	Strategic advisor energy and environment	Involved with writing the policy for environmental and energy objectives within Defense
	Policy advisor	Advisor for purchasing management at General Management of Operations (HDBV), with a focus on socially responsible procurement (MVI)
	External purchaser MatLogCo*	Contract manager hired by Defense to facilitate the conservation of contracts arranged by DMO, who is specialized in circular procurement
	Consultancy company*	Interview with two consultants who offer an online tool to make circularity quantifiable, one category of customers is small governments

As can be seen in the two tables, there is a project leader tent systems for deployment and a project leader tent systems for training. It is important to keep in mind that the project tent systems for deployment is the one under study, the tent systems for training is not.

3.4 Data analysis

The interviews were recorded and the collected data was transcribed and analyzed using the coding program NVivo. Codes were assigned to the mentioned barriers (e.g. Cu1, F3, O2); the complexity of projects; and the place on the timeline as perceived by the actors. Moreover, additional codes following from the interviews were also assigned. The final coding tree can be found in appendix X. The secondary data was analyzed by pinpointing which questions from the survey were relevant for this study. After that, the answers by the respondents were documented and coded as well.

The information on the barriers per project is mapped in tables per category (table 5). At the end of each category of barriers, an overview of the barriers is provided (table 6). At the end of the entire section, an overall overview is given which shows all barriers per project grouped in their respective categories (table 7).

Table 5: Example barriers per project

Clothing and personal equipment				
	Co1	Co2	Co3	Co4
Project leader				
Purchaser				
Supplier A				
Supplier B				
Expert				

Table 6: Example overview of barriers per category per project

Contextual				
	Co1	Co2	Co3	Co4
Clothing and personal equipment				
Expert				
PET-bottles				
Expert				
Tent systems for deployment				
Expert				
Other – project specific				
Other – organization wide				

Table 7: Example overall overview of barriers

	Contextual				Cultural		Financial			Organizational				Technological				
	Co1	Co2	Co3	Co4	Cu1	Cu2	F1	F2	F3	O1	O2	O3	O4	T1	T2	T3	T4	T5
Clothing and personal equipment																		
Expert																		

Besides looking into the barriers, the dimensions are also analyzed. For these dimensions, only the data from the projects under study, thus CPE-company, PET-bottles, and tent systems for deployment was used. For the actor groups this means that per actor group it was checked which barriers were present and in which categories they belong. This was then mapped out by first assigning the categories to them, after which this information was compiled into a figure.

To get an idea of the complexity of the projects, the expert was asked to provide his professional opinion to differentiate between less complex and more complex. A distribution regarding the amount of barriers belong to high/medium/low was made, based on which the complexity was filled out. The classification for high, medium, and low is based on the number of barriers within a category and can be found in the table on the right. By classifying the barriers in this manner, the categories become more comparable. Finally, an analysis regarding the time dimension was made. This was presented in the form of a timeline for each project, which also shows the (perceived) occurrence of the barriers.

		Classification		
		Low	Medium	High
Number of barriers per category	Three	0/1	2	3
	Four	0/1	2/3	4
	Five	0/1	2/3	4/5
	Six	0/1/2	3/4	5/6

3.5 Quality indicators

The quality of a research is based on its reliability and validity. Reliability is understood to entail the replicability of research findings (Lewis & Ritchie, 2003). By explaining the procedures this study followed, this study can be replicated, which should lead to similar findings. However, CSC is still a rather new concept and very little literature is available. It is expected that a few years from now, more literature is available on CSC, and on barriers to CSC. This could result in a different framework of barriers, which has consequences for the results of the research since a different list of barriers is then discussed with the actors. Moreover, a different framework of barriers can also influence the dimensions, since some categories of barriers might not be present then, which are now, and vice versa. More importantly, if there is a shift to a circular economy in a few years from now, fewer barriers to CSC might be perceived by actors, since then circularity is more embedded in society.

Moreover, the validity of a research is traditionally seen as the 'correctness' or 'precision' of a research (Lewis & Ritchie, 2003). Here, a distinction can be made between internal and external validity, with the first focused on whether the relationship under research is really being researched, and the latter focusing on the generalizability of the research (Lewis & Ritchie, 2003; Swanborn, 2010). The internal validity in this study was partially ensured. By constructing the topic guide based on the theoretical concepts used in this study, the results from the semi-structured interviews were in relation to the theory and the framework of barriers. This ensured the internal validity for the semi-structured interviews. For the open interviews however, the internal validity could not always be ensured. This was due to the fact that in these interviews was refrained from the framework of barriers. However, in these interviews the focus remained on circularity, thereby still linking the interviews to the theory.

The context of this study is the strongly regulated Royal Dutch Army. It could be opted that this study is generalizable to other strongly regulated environments. However, since the Ministry of Defense is the only one exempted from the program Netherlands Circular 2050, generalization to other

ministries is hampered. The study is also not generalizable to other industries, since the context in which it was conducted was rather specific. Thus, the results of this study are neither generalizable to similar nor to other industries, thereby lacking external validity.

4. Results

4.1 Defense material process

A project within the Dutch Ministry of Defense is often characterized by four phases which are clustered in the Defense Material Process (DMP)[4]. The phases form a sequence which project leaders follow in case of projects over €25 million. Both the projects within the Clothing and Personal Equipment (CPE)-company, and the tent systems for deployment fall under the DMP. The PET-bottles project however is below the minimum amount, and thus does not follow the DMP but a slightly different process instead. However, since there are very few differences between the two processes, it was decided to follow the DMP for comparative reasons.

4.1.1 General DMP

The DMP consists of four phases: the requirement phase, pre-contractual phase, development phase, and the transfer phase. During the requirement phase, the Operational Command states a certain need. This need, or requirement statement, is then considered by the Chief of Staff of the Armed Forces after which a budget is linked to the project. At the start of the pre-contractual phase, the project is assigned to a project leader, who compiles a project team. Together with his team, the project leader sets-up a program of demands, based on the requirement statement and a market consultation. After presenting the program of demands to the market, suppliers can enroll in the tender. The enrollments are checked and tested for the demands and criteria, after which the tender is awarded to one supplier. Now, the development phase starts, in which the supplier needs to produce the product. When the product is approved, based on the inclusion of the demands, criteria, and quality, the production can start. The transfer phase is the final phase. Here the product is delivered, and the contract is evaluated for the coming four years, which is the maximum number of years allowed under the law.

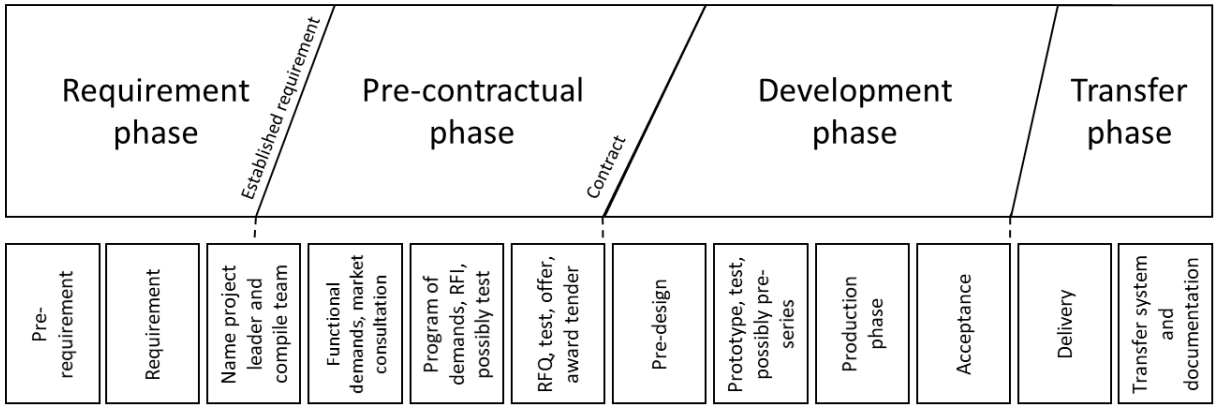


Figure 4: Defense Material Process

[4] Adapted from the AMRA (ARBO en Milieu Risico Analyse) used by Cluster VKAM

4.1.2 DMP per project

The three projects discussed in this research are all in a different DMP phase. The project at the CPE-company is currently in the transfer phase. The requirement phase started in 2015, and the tenders for both overalls and towels were awarded about a year later. Since framework agreements are allowed to last a maximum of four years according to the Dutch law, the cycle of procuring new products starts over soon.

The PET-bottles project is currently between the development and transfer phase. Though this project also has a framework agreement of four years with one specific supplier, the project is still seen as a pilot project which allows for changes during the four years agreement. Moreover, the agreement with the supplier is rather new, so there are still three more years left with this contract.

The project regarding the tent systems for deployment is currently in the pre-contractual phase. The requirement is submitted, a project leader is assigned to the project and the market is being consulted. Next, the program of demands needs to be written, followed by registrations, awarding the tender, and producing the new tent systems. These new tent systems need to be procured by 2021, so there is a relatively short deadline.

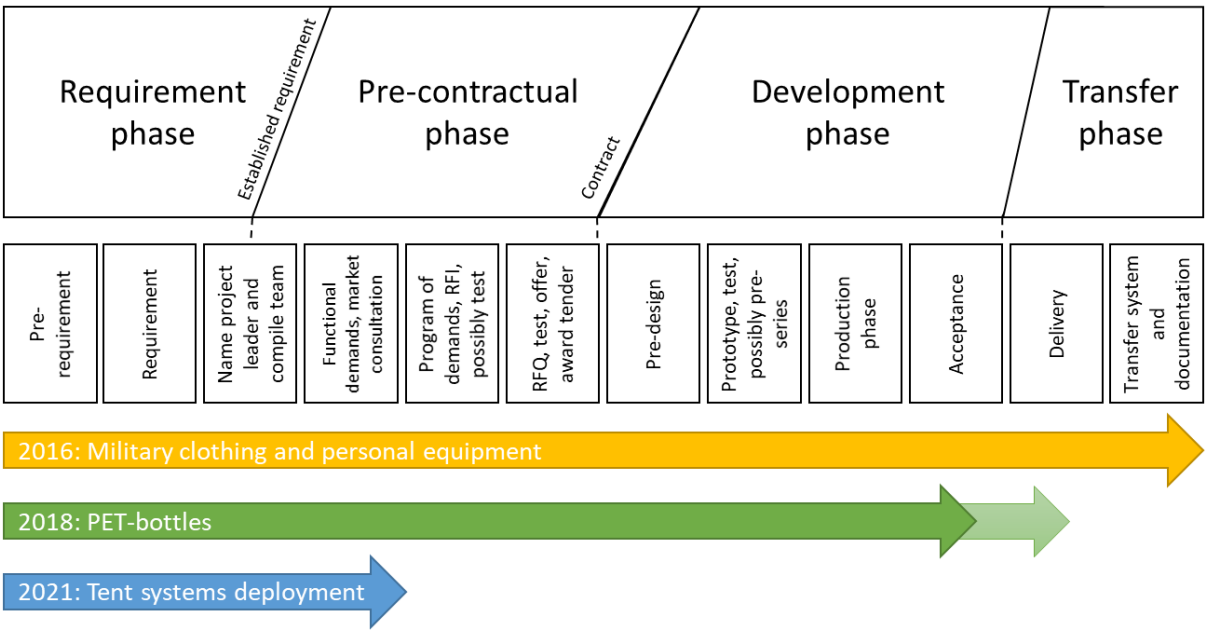


Figure 5: Defense Material Process per project

4.2 Barriers

The barriers are discussed per category and within the categories per project. There were a number of people interviewed who were not involved with the specific projects, they discussed whether the barriers were present either for their own projects, in the case of the project leader combat shirt, or within Defense. The interviewees with whom the list of barriers was discussed are marked **bold** in the tables.

4.2.1 Contextual

The contextual category entails barriers related to customers and legislation. The barriers in this category are customer resistance (Co1), perception of sustainability (Co2), the lack of awareness (Co3), and the lack of regulations, standards and support (Co4). The customers in Co1, Co2 and Co3 are in this case the soldiers of the Royal Dutch Army, this applies to all the projects as discussed below.

4.2.1.1 Clothing and personal equipment

When clothes need to be replaced, or after ending their service for the Royal Dutch Army, soldiers are required to hand-in their military clothing and personal equipment such as towels back to the CPE-company. The CPE-company can then offer these products to the market to fiberize it and make new products out of the recycled fibers. Since handing-in the military clothing and personal equipment is a procedure which is already embedded in the policy of the CPE-company, the soldiers do not have to change their behavior (Co1). Therefore, customer resistance is not seen as a barrier.

According to the purchaser, soldiers do not care about sustainability, they just need their materials to work (Co2). Thus, as long as soldiers are not made aware of the fact that they might wear recycled clothing or use recycled towels, they do not care (Co3). There is no resistance (Co1), no perception (Co2), and a lack of awareness (Co3), however this does not form barriers since soldiers learned to do as they are told.

> *"A soldier gets an assignment and executes it. As long as it works, they do not need to change their behavior, and as long as it works, they do not care." (Purchaser CPU-company)*

The fourth barrier, the lack of regulations, standards and support (Co4), is also not seen as a barrier by the project leader, purchaser and the suppliers. The project leader and purchaser stated that they were able to execute projects and procure products within the current Dutch and EU laws and regulations.

Like the project leader, purchaser, and suppliers, the expert did not feel that contextual barriers were present at projects within the CPE-company. Regarding clothing, it does not matter to a soldier whether it is circular or not, as long as it is comfortable and fulfills its function. Therefore, customer resistance (Co1), no/negative perception (Co2), and the lack of awareness (Co3) are no barriers in this case. Only when the quality of the product is lower than that of a linear product the expert expects some resistance from the soldiers, however this is not the case in current projects. Finally, the lack of regulations, standards and support was not seen as a barrier (Co4).

> *"When you look at these four, there are especially barriers if the product is not at least as good as the current version, otherwise there is no problem." (Expert)*

Overall, none of the interviewees in this project felt that there are barriers in the contextual category, therefore none of the boxes in the table below are ticked.

Table 8: Barriers contextual category clothing and personal equipment

Clothing and personal equipment				
	Co1 (Resistance)	Co2 (Perception)	Co3 (Awareness)	Co4 (Regulations)
Project leader				
Purchaser				
Supplier A				
Supplier B				
Expert				

4.2.1.2 PET-bottles

As stated in the methods section, the PET-bottle project entails the collection of whole, not crumpled PET-bottles by soldiers, which allows for reverse logistics, and eventually the shredding of bottles and the reuse of PET. The project leader found all the barriers in the contextual category to hinder the project. She received a lot of resistance from soldiers (Co1), who were not willing to change their behavior because they were used to crumpling their PET-bottles when they are empty. Moreover, soldiers often have no perception of circularity (Co2) nor awareness of circularity (Co3), which makes it harder to make them change their behavior.

These barriers are also underlined by the project associate, who stands alongside the project leader in this project. One of the main reasons why changing the behavior makes the soldiers resist the change (Co1), is because soldiers do not want it to form an obstruction for their work. Moreover, she stated that soldiers do have a perception of circularity (Co2), however this is a negative perception. This can be found in the fact that soldiers are afraid it is going to gives them more work. Moreover, soldiers are sometimes aware of the necessity for circularity (Co3), they just think that putting energy and effort in it themselves is a bridge too far. Finally, both the project leader and project associate mentioned the lack of regulations, standards and support as a barrier (Co4). They do acknowledge that current laws and regulations are not necessarily against circularity, but these laws do not facilitate it either.

> *"To be able to recycle the empty PET-bottles used on exercises by the soldiers, it was important to transport empty PET-bottles from Germany to the Netherlands. When we tried to do this, we were put on the spot by the Military Police, who wanted to give a fine for transporting waste across EU borders. There is a European law that states that you are not allowed to transport waste from one country in the EU to another. However, we contacted the Ministry of Infrastructure and Water Management, and they eventually found a loophole which states that 'if soldiers go to another country to perform their duties, they are allowed to take the stuff they used back to their own country'." (Project leader PET-bottles)*

This example shows that if the project leader had not looked into the laws of waste transport in the EU[5], the Military Police would have fined the transport of empty PET-bottles, thereby hindering the aim of the project leader to recycle the PET-bottles.

The soldiers that were in the first pilot project reflected on the project by answering various questions in a survey. From the survey followed that soldiers are not necessarily resistant to changing their behavior (Co1). They are internally motivated to take the bottles back with them, however they do realize that some soldiers have no perception of circularity (Co2) and are not aware of the necessity of it (Co3). Moreover, they mention that throwing the bottles away has been too easy for too long and that awareness needs to be created. Though they are on the right track, this still forms barriers.

> *"People need to handle the environment consciously. When we go to Germany, we take the bottles back with us although we do not get a deposit back for it. Is it purely environmental awareness that all the bottles are picked up and handed in so it does not become trash in the field. This needs to be rubbed in." (Respondent 5)*

According to the expert, the fact that the soldiers are not allowed to crumple their PET-bottles will cause resistance (Co1). They are used to not having to take the bottles back with them as a whole, and now they have to. The expert also mentions that there is a negative perception to circularity (Co2), since leaving the bottles as a whole leaves soldiers with less space in their bag. Moreover, currently there is a lack of awareness (Co3) and this thus needs to be created. Explaining to the soldiers why the bottles need to be collected as a whole can make this less of a barrier. Finally, since a loophole to the EU regulations with regards to the transportation of waste was found, the expert does not consider the lack of regulations, standards and support (Co4) to be a barrier.

Table 9: Barriers contextual category PET-bottles

PET-bottles				
	Co1 (Resistance)	Co2 (Perception)	Co3 (Awareness)	Co4 (Regulations)
Project leader	x	x	x	x
Project associate	x	x	x	x
Soldiers		x	x	
Supplier				
Expert	x	x	x	

4.2.1.3 Tent systems for deployment

In general, the project leader tent systems for deployment stated that sustainability is not a basic requirement for good equipment, it has not proven itself to be, which leads to a negative perception

[5] The European Parliament and the Council of the European Union *Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste*, 12 July 2006, under consideration 10

(Co2). Moreover, there is a lack of awareness within the organization (Co3). Though he mentioned a negative perception and the lack of awareness as barriers to circularity, they are not necessarily hindering for his project when looking at the soldiers as the customers.

The ideas regarding barriers by the project leader overlap with those of the expert. He did not expect resistance from soldiers (Co1), since tent systems probably will not look different when designed in a circular manner. Moreover, if a tent is assigned to the soldiers and they are not told that it is partially made of recycled materials, they will not experience a negative perception (Co2), since they do not know. The same goes for awareness (Co3), the soldiers do not have to be aware of circularity to use the tent systems, therefore this also does not form a barrier. Finally, the lack of regulations, standards and support also does not form a barrier (Co4).

Table 10: Barriers contextual category tent systems for deployment

Tent systems for deployment				
	Co1 (Resistance)	Co2 (Perception)	Co3 (Awareness)	Co4 (Regulations)
Project leader				
Expert				

4.2.1.4 Other

In the 'other' paragraph, a division between project specific and organization wide barriers was made. Some interviewees answered the questions based on the project they are working on, whereas others focused more on Defense as a whole. For the contextual category however, all answers provided by the interviewees were focused on the organization and not on specific projects. Therefore, all interviewees were placed in the organization wide section.

Organization wide

Here, the list of barriers was discussed with four interviewees via semi-structured interviews. Besides these interviewees, three other interviewees mentioned barriers in the contextual category. These interviewees are the Head of Environment DMO, the Head of Environment CLAS, and the project leader tent systems training.

Regarding customer resistance (Co1), the external purchaser MatLogCo and the consultants viewed this as a barrier. The latter stated that the resistance comes from incomprehension, discomfort, and a fear of change.

The second barrier, perception of sustainability (Co2), is mentioned by the project leader combat shirt, the Head of Environment CLAS, the purchaser DOSCO, the project leader tent systems training, and by the external purchaser MatLogCo. The purchaser DOSCO explained that a negative perception from soldiers can for instance be created by cleaners. In example: soldiers on barracks in The Netherlands are expected to separate their waste, however at the same time they see cleaning

personnel throw everything together in a big trash can. This then creates negative perception with the soldiers. The external purchaser MatLogCo stated that the main reason that perception is a barrier, is due to the fact that people often do not know how things can be done differently.

Furthermore, the lack of awareness (Co3) is mentioned by the project leader combat shirt, the Head of Environment DMO, the Head of Environment CLAS, the purchaser DOSCO, and the consultants. The Head of Environment CLAS proposed a fairly simple solution to reduce energy consumption, which raised questions by the units, indicating the lack of awareness.

> *"We said to a number of units, 'if you have a compressor in your workshop, put a time switch between the compressor and the power plug'. 'Why should we?' they asked us. 'That thing is turned on 24/7 and never stops pressing, so when you do not use it, let's say between 6 p.m. and 6 a.m., can you put it on a time switch so it will shut down." (Head of Environment CLAS)*

None of the interviewees mentioned the lack of regulations, standards and support (Co4) as a barrier.

Table 11: Barriers contextual category other interviewees

Other					
		Co1 (Resistance)	Co2 (Perception)	Co3 (Awareness)	Co4 (Regulations)
Organization wide	**Project leader combat shirt**		x	x	
	Head of environment DMO			x	
	Head of environment CLAS		x	x	
	Purchaser DOSCO		x	x	
	Project leader tent systems training		x		
	External purchaser MatLogCo	x	x		
	Consultancy company	x		x	

4.2.1.5 Overview

Within the contextual category, customer resistance (Co1) was mentioned a couple times by the interviewees. Noteworthy, the external purchaser MatLogCo mentioned there was little resistance. Hence, he does see it as a barrier, though it is a small one. No or a negative perception (Co2) and the lack of awareness (Co3) were mentioned the most as barriers. Overall, the lack of regulations, standards and support (Co4) was the least seen as a barrier to circularity. This is mainly due to the fact that most interviewees see possibilities to purchase in a circular manner within the current laws and regulations. The barrier as stated by the project leader tent system for deployment is focused on the standards and procedures within the organization, instead of on laws and regulations.

Table 12: Overview barriers contextual category per project

Contextual				
	Co1 (Resistance)	Co2 (Perception)	Co3 (Awareness)	Co4 (Regulations)
Clothing and personal equipment				
Expert				
PET-bottles	x	x	x	x
Expert	x	x	x	
Tent systems for deployment				
Expert				
Other – organization wide	x	x	x	

4.2.2 Cultural

The cultural category involves barriers related to the norms, values and beliefs of the Royal Dutch Army. There are two barriers within this category: risk aversion (Cu1) and resistance to new business models (Cu2).

4.2.2.1 Clothing and personal equipment

Within this category, the project leader nor the purchaser of the CPE-company mentioned any barriers. The purchaser stated that he does not believe that circular business models are riskier (Cu1). Moreover, they both stated that there is no resistance at the CPE-company (Cu2), they just look at the market, at the customers, and think in solutions.

> *"I saw a chance to secure it [circularity] in the governance. What you want is not having to ask for every tender if you have to do it, what it may cost, and how you are going to get it. No, it is fixed in advance what my focus is with every tender and what I want to achieve with it." (Project leader CPU-company)*

Both supplier A and supplier B also did not see risk aversion (Cu1) and resistance to new business models (Cu2) as barriers. Moreover, supplier B stated that sustainability has been of importance to the company for years.

According to the expert, there is always resistance to change a business model (Cu2). He expects there is some urgency and necessity to change it, especially in the top of the organization, since he feels Defense has to set an example for society. Moreover, there is a role for Defense to boost products which are not economically viable just yet. In the current situation, the CPE-company resells clothing for fibers, but there are many different circular revenue models. However, according to the expert, realizing different models is hard for now. Therefore, resistance to new business models forms a barrier.

Table 13: Barriers cultural category clothing and personal equipment

Clothing and personal equipment		
	Cu1 (Risk aversion)	Cu2 (Resistance to new BM)
Project leader		
Purchaser		
Supplier A		
Supplier B		
Expert		x

4.2.2.2 PET-bottles

The project leader PET-bottles mentioned she did not experience risk aversion (Cu1) as a barrier to the project. She did however mention that there was sometimes a bit of risk avoidant behavior. Resistance to new business models (Cu2) is a barrier she faced throughout the project a lot. Though she wanted to find a solution to the problem, higher ranked officers told her that there was already a way they handled things and that was it (see quote below). Contrary to the project leader, the project associate did not mention risk aversion (Cu1) nor resistance to new business models (Cu2) as a barrier. This difference can be explained due to the fact that she is less involved with the project than the project leader.

> *"I talked to DMO about it [the fact that the trash in Mali was picked up by contractors who dumped it a few hundred meters from the base, which eventually led to this project] with a lieutenant colonel, and he said 'we have a contract and it is in there, which makes it not our responsibility anymore'." (Project leader PET-bottles)*

The expert stated that risk aversion (Cu1) could cause a barrier, when Defense for instance starts to shred the PET-bottles themselves, which is not the core business of Defense. However, this is currently not the case and therefore not a barrier to this specific project. Resistance to new business models (Cu2) is however, since collecting PET-bottles which are not crumpled in order to shred them later on is not part of the core business of Defense.

Table 14: Barriers cultural category PET-bottles

PET-bottles		
	Cu1 (Risk aversion)	Cu2 (Resistance to new BM)
Project leader		x
Project associate		
Soldiers		
Supplier		
Expert		x

4.2.2.3 Tent systems for deployment

During the interview, risk aversion (Cu1) was not mentioned at all by the project leader tent systems for deployment, therefore this is presumed not to be a barrier. Resistance to new business models (Cu2) however, does form a barrier in his opinion. Though he sees circularity as a good cause, the most important demand in the end is optimal performance.

> *"It [circular thinking] is noble, very idealistic and I think it is good as well. What I am afraid of is that it comes at the expense of a regular demand during the regular use. So we do not look at the most environmental unfriendly product, but we seek optimal performances." (Project leader tent systems for deployment)*

Looking at tent systems the expert sees potential for more circular business models. In comparison to the other two projects, he believes this projects lends itself better for such a business model. However, he also stated that a circular business model is riskier (Cu1) than a linear one, and therefore this forms a barrier. In addition to this, the expert expects a lot of resistance from top level management (Cu2) when changing the business model. Since this project is prone to changing the business model, the second barrier is also expected to be present.

Table 15: Barriers cultural category tent systems for deployment

Tent systems for deployment		
	Cu1 (Risk aversion)	Cu2 (Resistance to new BM)
Project leader		x
Expert	x	x

4.2.2.4 Other

Project specific

The project leader combat shirt did not see risk aversion (Cu1) as a barrier. However, like the project leader PET-bottles, he did mention that there is risk avoidant behavior at some times. Regarding the resistance to new business models (Cu2), he stated that the military organization is rather conservative. The current business model is focused on delivering combat power, and does not involve circularity. Due to the conservativeness of the organization, he expected this to be a barrier.

Organization wide

From the interviewees not connected to the specific projects, only the interviewees that went discussed the list of barriers provided some input for the cultural category. These are the Purchaser DOSCO, the External purchaser MatLogCo, and the Consultancy Company.

Risk aversion (Cu1) was not seen as a barrier by any of the interviewees. The external purchaser MatLogCo stated that circular business models carry a little bit more risk. This has to do with specifying the program of demands, if this is done in a functional instead of technical way, this leaves

room for interpretation on the side of the suppliers. However, for him this is not a reason to avoid circular business models and it thus not form a barrier.

Resistance to new business models (Cu2) is experienced as a barrier. The purchaser DOSCO stated that that he keeps 'running into walls' when it comes to circularity. This thought is shared with the external purchaser MatLogCo. He stated that resistance comes from top-down, and that it is very hard to change culture and internal procedures. Hence, this forms a barrier. Opposite to this, the consultants do not view resistance to new business models as a barrier. Moreover, they do not necessarily see the need to change the business model when implementing circularity. It can have a positive influence and provide extra benefits to do so, however it is also possible to buy circular products without changing the business model.

Table 16: Barriers cultural category other interviewees

Other			
		Cu1 (Risk aversion)	Cu2 (Resistance to new BM)
Project specific	**Project leader combat shirt**		x
Organization wide	**Purchaser DOSCO**		x
	External purchaser MatLogCo		x
	Consultancy company		

4.2.2.5 Overview

Risk aversion (Cu1) was almost never mentioned as a barrier by the interviewees. The expert did however mention this to be a possible barrier with regards to the tent systems for deployment project. This was due to the fact that he believes this project lends itself more for a circular business model than the other two projects. Moreover, he stated that a circular business model inherently comes with more risk, thus forming a barrier. The other interviewees did not see risk aversion as a barrier, though two project leaders did mention there was a form of risk avoidant behavior within Defense.

Resistance to new business models (Cu2) was found to be a barrier within almost every project. In all projects, the expert mentioned it as a barrier, which makes sense since all the projects are executed within Defense. The employees of the CPE-company however, did not recognize this as a barrier. This might be due to the fact that the purchaser of the CPE-company was the only one who discussed the list of barriers.

Table 17: Overview barriers cultural category per project

Cultural		
	Cu1 (Risk aversion)	Cu2 (Resistance to new BM)
Clothing and personal equipment		
Expert		x
PET-bottles		x
Expert		x
Tent systems for deployment		x
Expert	x	x
Other – project specific		x
Other – organization wide		x

4.2.3 Financial

In the financial category, there are three barriers related to the financial aspect of circular supply chains. These are investment costs (F1), costs recycled materials (F2), and financial support (F3).

4.2.3.1 Clothing and personal equipment

The project leader of the CPE-company did not mention any financial barriers regarding projects within the CPE-company. On the contrary, he stated that he can show via business cases that he was able to make money by attaining circular products. So, instead of seeing any barriers within this category, he sees opportunities.

The purchaser of the CPE-company on the other hand, was less positive. Though he did not see investments costs (F1) as a barrier when it delivers a better, circular product, he did state that the costs for recycled materials (F2) are higher which can form a barrier. Moreover, the trade-off between price and quality might be worse than when it comes to virgin material. Regarding financial support (F3), he stated that he is not sure whether this can form a barrier. Since he did not experience any issues regarding financial support, he did not indicate this as a barrier.

Though supplier A won a tender based on a trade-off between price and percentage of recycled content, he did mention a few barriers. The investment costs (F1) to make the overalls with recycled content were high, a lot needed to be changed, as is also stated below. Moreover, the price of recycled content (F2) is higher than that of virgin material, which also makes a product more expensive and can thus form a barrier. Financial support (F3) did not pose a barrier to this supplier. He did not receive any subsidy, and was nevertheless able to make a product with more recycled content.

> *"The investment costs are high, everything has to go in a different way. Research and Development already costs a lot of money, processes needed to be changed, employees need to be trained in a different manner. This also leads to a higher unit price, since we are in the business to make a profit and our shareholders expect us to as well." (Supplier CPE-company)*

Supplier B, like supplier A, also noted the investment costs (F1) as a barrier. A lot of research needed to be done regarding the technical possibilities, moreover the optimized production process had to be

adjusted. For both of the actions, additional costs could not be excluded, and therefore formed a barrier. The costs of recycled materials (F2) also formed a barrier, since more actions needed to be taken as opposed to virgin materials. These actions involve sorting of old jeans, ripping them up, taking out zippers, and so forth.

The expert also mentioned barriers which he expected to be felt by the supplier of the CPE-company. He stated that circular products are already more expensive with the initial investment, partly due to scalability. Besides this, people tend to look only at the purchase value and not at the residual value of a product. This could lead to think that investment costs (F1) are fairly high, while it yields more when it is balanced out. Within Defense, the residual value of a product is often overlooked, thus investment costs of circular products are higher compared to linear products and therefore form a barrier. The expert also feels that the costs of recycled materials (F2) forms a barrier. He expects Defense is willing to pay ten cents more for a t-shirt which is circular produced, however he feels six euros is too much. Finally, the expert does not feel that financial support (F3) forms a barrier. On the contrary, he has the idea that banks and governments try to support sustainable initiatives and that there is money available for sustainable initiatives.

Table 18: Barriers financial category clothing and personal equipment

Clothing and personal equipment			
	F1 (Investment costs)	F2 (Costs recycled material)	F3 (Financial support)
Project leader			
Purchaser		x	
Supplier A	x	x	
Supplier B	x	x	
Expert	x	x	

4.2.3.2 PET-bottles

The project leader of the PET-bottle project mentioned investment costs (F1) as a barrier. She stated that it is important to look throughout the chain, not just at a single product. To close the chain, more investments are needed to be made, and she simply does not have the budget for it. Besides this, costs of recycled materials (F2) also forms a barrier. Following the current line of thought within Defense, she always has to purchase the cheaper bottle. According to the project leader, financial support (F3) is not a barrier.

> *"Costs is a very important subject. If there is a bottle with recycled material, or just a PET-bottle, and the PET-bottle is cheaper, than we have to buy that one. Reason we were able to fix it [not a bottle of recycled material, but a way to recycle them] for this project, is because the supplier offered us a discount which made it cheaper." (Project leader PET-bottles)*

The project associate follows the line of thinking of the project leader. She stated that making a supply chain more circular does not stop at just buying a product, because changes need to happen

throughout the chain. This is however hard to achieve, since the focus lies on purchasing products with the lowest price, thus investment costs (F1) and costs of recycled materials (F2) need to be low, otherwise these costs form barriers.

When the investment costs (F1) are justifiable, for instance by making a product more circular and thus better for the environment, the expert does not feel these are a barrier. The costs of recycled materials (F2) also do not have to form a barrier, since the bottles are shredded which leads to less or no raw materials costs, after which the fibers are used for new bottles again. Moreover, he feels there is support (F3) within Defense to invest in sustainable initiatives.

Table 19: Barriers financial category PET-bottles

PET-bottles			
	F1 (Investment costs)	F2 (Costs recycled material)	F3 (Financial support)
Project leader	x	x	
Project associate	x	x	
Soldiers			
Supplier			
Expert			

4.2.3.3 Tent systems for deployment

In the eyes of the project leader, the whole category can be seen as a barrier. Like with the PET-bottles project, he also stated that it is hard to defend a circular product if the costs are twice as high as that of a regular product. This can be either due to investment costs (F1), or due to the costs of recycled materials (F2). The costs of recycled materials can even be to such an extent, that the industry does not offer the materials at all. Finally, financial support (F3) was also seen as a barrier.

The expert has the idea that the current investment (F1) estimates for the tent systems are way too low, he expects the actual costs to be higher, even without a circular component. Therefore, it makes it even harder to make the tender circular, especially if the residual value is not taken into account. The costs of recycled materials (F2) is related to the investment costs. If the costs of recycled materials make the product more expensive, it also forms a barrier. The expert expects there is support (F3) from policy makers to make products more circular. Especially tent systems is a good case in his eyes, since it is not a highly complex or combat related product.

Table 20: Barriers financial category tent systems for deployment

Tent systems for deployment			
	F1 (Investment costs)	F2 (Costs recycled material)	F3 (Financial support)
Project leader	x	x	x
Expert	x	x	

4.2.3.4 Other

Project specific

The project leader of the combat shirt mentioned two barriers within the financial category. Though he is fine with investment costs (F1) being a little higher, he does not feel that the organization agrees, which makes it hard for him to continue acquiring a circular product. Moreover, he feels that the Dutch government should make a certain amount of money available for circularity for all the ministries (F3). The money then does not have to come from the budget of Defense, like it has to now, which currently makes it into a barrier.

> *"If higher profits from recycling creates two percent more investment costs, I'd say why not. But then we act weird because it is over budget, that two percent." (Project leader combat shirt)*

Organization wide

The costs for recycled materials (F2) is mentioned as a barrier by the purchaser DOSCO, the external purchaser MatLogCo, and the consultants. According to the purchaser DOSCO, it can form a barrier, since not every supplier can deliver recycled materials, and the ones that can, often have a higher initial price. This is also stipulated by the external purchaser MatLogCo, who stated that the costs of the recycled materials are so high, that there is no incentive to use those materials.

Table 21: Barriers financial category other interviewees

Other				
		F1 (Investment costs)	F2 (Costs recycled material)	F3 (Financial support)
Project specific	**Project leader combat shirt**	x		x
Organization wide	**Purchaser DOSCO**		x	
	External purchaser MatLogCo		x	
	Consultancy company		x	

4.2.3.5 Overview

The investment costs (F1) and the costs of recycled materials (F2) were mentioned almost the same amount of times. In most interviews, when the interviewee mentioned the one as a barrier, the other was also mentioned, indicating that there is a certain correlation between these barriers. Overall, the costs of recycled materials was mentioned two times more often than the investment costs. This difference is however not reflected in the table. Financial support (F3) was mentioned as a barrier the least amount of times, only by the project leader tent systems for deployment and the project leader combat shirts. Noteworthy, the expert did not mention the investment costs (F1) and the costs of recycled materials (F2) as a barrier in the project on PET-bottles, though he did in the other two barriers. This can be explained by the fact that no new products are created in the PET-bottle project as opposed to the other two projects.

Table 22: Overview barriers financial category per project

Financial			
	F1 (Investment costs)	F2 (Costs recycled material)	F3 (Financial support)
Clothing and personal equipment	x	x	
Expert	x	x	
PET-bottles	x	x	
Expert			
Tent systems for deployment	x	x	x
Expert	x	x	
Other – project specific	x		x
Other – organization wide		x	

4.2.4 Organizational

The organizational category consists of four barriers which are involved with the strategy of an organization. These barriers are the lack of knowledge and skills (O1), trust among suppliers (O2), no reverse supply chain in place (O3), and circular business does not align with strategy (O4).

4.2.4.1 Clothing and personal equipment

Within the organizational category, the project leader of the CPE-company only recognized the lack of knowledge and skills (O1) as a barrier to circular supply chains. He believes that people think they have to think about making a product more circular themselves, even though the industry does the thinking for them. The only thing that needs to be taken into account, is that the industry needs to be told what to do. This does require some knowledge, which might be lacking sometimes. The project leader did not mention other barriers in this category.

The purchaser of the CPE-company stated, that they have the knowledge in-house to keep doing what they are currently doing. Thus, he does not see the lack of knowledge and skills (O1) as a barrier. The purchaser did not mention trust among suppliers (O2) nor reverse logistics (O3) as a barrier. The latter does not form a barrier, since the reverse logistics is controlled by the CPE-company. Clothing worn by soldiers is taken back and offered to the market, where it is fiberized and the fibers are reused. Only circular business does not align with strategy (O4) forms a barrier in the eyes of the purchaser. It is really necessary to align circularity and strategy, because if this does not happen, it forms a barrier.

Though circularity was not part of the strategy (O4) of supplier A, they decided to get involved with it anyway. The supplier feels that the market of circular products will continue to grow in the coming years. Since it is more embedded now, they can also keep working on innovations. The alignment of the strategy with circularity in the end did not form a barrier for supplier A. For supplier B, the alignment of strategy with circularity (O4) also did not form a barrier, probably because it was already embedded in the strategy.

The expert states that there is a definite lack of knowledge and skills (O1) on circularity within Defense. He also thinks that purchasers have no clue on what circularity means for purchasing clothes, therefore this forms a barrier. Trust among suppliers (O2) is also a barrier in the eyes of the expert, though not entirely the suppliers' fault. The quality of recycled content is often less than that of virgin materials, which works against the trust in suppliers to deliver at least the same quality of circular products versus linear products. Reverse logistics (O3) is an important factor when it comes to circularity. If reverse logistics is not in place, than a circular economy does not work. Currently, the CPE-company has the reverse logistics arranged in such a way, that it does not form a barrier. Finally, the alignment of strategy with circularity (O4) is a barrier which can be present throughout Defense. However, in the case of the CPE-company, the expert feels that it is not a barrier, since the project leader of the CPE-company formed a sort of strategy on his own, including circularity.

Table 23: Barriers organizational category clothing and personal equipment

Clothing and personal equipment				
	O1 (Knowledge)	O2 (Trust)	O3 (Reverse supply chain)	O4 (Alignment)
Project leader	x			
Purchaser				x
Supplier A				
Supplier B				
Expert	x	x		

4.2.4.2 PET-bottles

Within this project, the project leader stated that all barriers from the list of barriers were present. Though she feels that the lack of knowledge (O1) is not a huge barrier, it is a barrier which is present. In this case, the barrier was not necessarily a barrier on what circularity is, but more on what the possibilities to circularity are. Trust among suppliers (O2) was also seen as a barrier, however this mainly has to do with how the quality can be measured. Regarding reverse logistics (O3), the project leader made two opposing statements, the first being that there is a form of reverse logistics, and the second that there is not (see quote below). Either way, even with the reverse logistics in place, it formed a barrier for the project due to the fact that it was very cumbersome. Finally, the alignment of circularity with the strategy (O4) also forms a barrier, since they want to become more circular, but the procedures to do so are not designed for it.

> *"They said, 'this is how it works. We have a reverse logistics location in Soesterberg. Everything has to go there and from there we distribute it again'. That requires extra actions, extra communications and more room for error. Moreover, the PET-bottles had to be transported from Bathmen to Soesterberg to distribute them to Bathmen again." (Project leader PET-bottles)*

> *"We don't really have reverse logistics. Often there is just a single line on it in a piece on logistics, and that states: 'reverse logistics is the same line as logistics but then backwards'." (Project leader PET-bottles)*

The project associate stated more or less the same about the barriers as the project leader, with the exception of the trust among suppliers (O2), which she did not believe to be a barrier. Regarding the reverse logistics (O3), she addressed the same example as the project leader. Looking at the alignment (O4), she added to the statement of the project leader by mentioning that it does not help to have a fuzzy goal as an organization, then no-one takes responsibility.

According to the expert there needs to be knowledge and skills (O1) to work with circularity, however, he does not feel that this is a barrier in this project. The trust among suppliers (O2) could in his eyes become a barrier, depending on the quality of the plastic which is recycled. At least the quality should not be worse than that of a regular bottle. Everything depends on the reverse logistics (O3). Due to the complexity of collecting the bottles, shredding them, using the fibers for new bottles, and distributing the bottles again to the soldiers, he believes that this is one of the main barriers within this project. Regarding the alignment (O4), the expert noticed that circularity is not yet embedded in the strategy of the Royal Dutch Army. There is an increase in attention and support for the PET-bottles project, however the lack of alignment between the strategy and circularity forms a barrier.

Table 24: Barriers organizational category PET-bottles

PET-bottles				
	O1 (Knowledge)	O2 (Trust)	O3 (Reverse supply chain)	O4 (Alignment)
Project leader	x	x	x	x
Project associate	x		x	x
Soldiers				
Supplier				
Expert	x	x	x	x

4.2.4.3 Tent systems for deployment

The project leader of the tent systems for deployment mentioned that there is a lack of knowledge (O1). He also mentioned that there is a certain need to break with current behaviors. Currently, people are stuck in their old behavior, which requires knowledge and skills to get out of. Since there is a lack thereof, this forms a barrier. Furthermore, the absence of alignment between circularity and strategy (O4) forms a barrier. Defense purchases are conducted according to procurement rules and these are

based on the best performances against the lowest life expectancy costs. The project leader however mentions that this is a problem which needs to be tackled top-down.

The expert also sees a barrier when it comes to the lack of knowledge and skills (O1). This also has to do with the fact that the project leader is currently looking to purchase a linear tent system, since that is what they know. Trust among suppliers (O2) also forms a barrier in this project, since the question is to what extent the quality of the tent systems can be guaranteed. The reverse logistics (O3) of the tent systems does not have to form a barrier. The expert thinks that the only difference is, that these tent systems are taken back to the Netherlands instead of leaving them in the country of deployment. However, this does raise the question if the refurbishment of the tent systems outweighs the costs and the emissions involved in retrieving the tent systems. Like with the other two projects, the expert also expect the alignment of circularity with strategy (O4) to be a barrier. This is due to the fact that circularity is new within the Royal Dutch Army, and even though there is more attention and support for it, it is not yet embedded in the strategy which can hinder procurements.

Table 25: Barriers organizational category tent systems for deployment

Tent systems for deployment				
	O1 (Knowledge)	O2 (Trust)	O3 (Reverse supply chain)	O4 (Alignment)
Project leader	x			x
Expert	x	x		x

4.2.4.4 Other

Project specific

The project leader combat shirt noticed within his team that there is very little knowledge (O1) on circularity. Moreover, he also stated that his team does not have the right skill set to look at circularity within a program of demands. Therefore, the lack of knowledge and skills forms a barrier for this project. Furthermore, he is trying to sign multiple contracts at the same time with one company, which is chosen based on delivered quality, thus indicating a build-up of trust (O2). This trust is however based on the quality of linear products, and it there is no guarantee the quality of circular products is equally good, therefore this can form a barrier. Reverse logistics (O3) is hampered according to the project leader combat shirt, due to the fact that Defense currently wants to remain owner of the procured products. The lack of alignment between circularity and strategy (O4) is also a barrier according to the project leader. He states that the current vision of Defense is focused on NATO, and that it would be useful if circularity also was incorporated.

Organization wide

The lack of knowledge and skills (O1) was mentioned as a barrier by seven interviewees. According to the head of environment DMO, one of the reasons is that very little room is made available within the

organization to create more knowledge on circularity. The head of environment CLAS stated that, in order to influence the so-called C-systems, they need MatLogCo to generate certain files. However, at MatLogCo there is too little knowledge, quality and capacity to make this happen. Moreover, the purchaser DOSCO stated that to make people more knowledgeable on this subject, still a lot of steps that need to be taken. Regarding these steps, the project leader water treatment stated that it is important to figure out if projects involving circularity are feasible, however to do this knowledge is needed and currently there is a lack thereof. Furthermore, the project leader tent systems for training stated that the concept of circularity is currently not well known within the organization, and that more information and knowledge needs to be provided to make this happen. Another reason the lack of knowledge forms a barrier, according to the consultants, is that it is uncertain when something is a success. Because of this, purchasers might not know how to consider whether a circular product is a success or not.

The only other barrier mentioned by these interviewees is mentioned by the external purchaser MatLogCo and involves the reverse logistics (O3). Regarding this, he stated that Defense is not a specialist regarding products, like suppliers are, therefore the current reverse logistics lines might not work or are not optimal, which thus forms a barrier.

Table 26: Barriers organizational category other interviewees

Other					
		O1 (Knowledge)	O2 (Trust)	O3 (Reverse supply chain)	O4 (Alignment)
Project specific	**Project leader combat shirt**	x	x	x	x
Organization wide	Head of environment DMO	x			
	Head of environment CLAS	x			
	Purchaser DOSCO	x			
	Project leader tent systems training	x			
	Project leader water treatment	x			
	External purchaser MatLogCo	x		x	
	Consultancy company	x			

4.2.4.5 Overview

The lack of knowledge and skills (O1) was mentioned most often as a barrier by the interviewees. All but the CPE-purchaser and supplier pointed this out as a barrier, some even stating that this is a huge barrier. The fact that there is no alignment between circularity and strategy (O4) was also seen as a barrier by many interviewees. The trust among suppliers (O2) was mainly seen as a barrier by the expert, and the reverse logistics (O3) were only seen as a barrier within the PET-bottles project and with the interviewees who are not involved with one of the three projects.

Table 27: Overview barriers organizational category per project

Organizational				
	O1 (Knowledge)	O2 (Trust)	O3 (Reverse supply chain)	O4 (Alignment)
Clothing and personal equipment	x			x
Expert	x	x		
PET-bottles	x	x	x	x
Expert	x	x	x	x
Tent systems for deployment	x			x
Expert	x	x		x
Other – project specific	x	x	x	x
Other – organization wide	x		x	

4.2.5 Technological

This category contains the most barriers. These barriers are focused on the technical aspects involved with supply chains. Lack of technical skills (T1), limited availability of recycled materials (T2), design to reuse/recycle (T3), quality control of reused/recycled material (T4), and lack of new materials and processes (T5).

4.2.5.1 Clothing and personal equipment

According to the project leader of the CPE-company, the market is often not ready to use recycled content in products due to the fact that certain standards need to be met. Therefore, quality control of reused/recycled material forms a barrier (T4). The purchaser of the CPE-company disagrees with this however. He states that there are no quality issues when it comes to cotton, even ripped outfits can be used for new fibers. The lack of technical skills (T1), limited availability of recycled materials (T2) and the lack of new processes (T5) do however form barriers in his eyes. Regarding the limited availability of recycled materials (T2), he stated that more and more materials become available every day, the amount is just not adequate enough. The recycled materials consist in this case of short threads which are spun from fibers. These need to be mixed with long, virgin threads in order to get a strong thread. In order to do this, new machines or processes (T5) need to be developed sometimes to make sure both long and short threads go in easy, this costs however money and can thus form a barrier.

Supplier A indicated a few barriers as well. The first being the lack of technical skills (T1), which is correlated with the lack of new materials and processes (T5). In order for the employees to be able to work with the new process, they need to get extra training and to be trained differently. This is both cost and time intensive, which thus requires an investment from the supplier, and can therefore form a barrier. Though the design (T3) of the overalls needed to change, and the quality of recycled material is less than that of virgin material (T4), this does not form a barrier according to the supplier. The input

used for the overalls, is old jeans. However, there is still little availability of jeans (T2), and though the input is increasing, it still forms a barrier.

Like supplier A, supplier B also mentioned the lack of technical skills (T1) and the lack of new materials and processes (T5) as barriers. Regarding the availability of recycled materials, supplier B states that these materials are available at all times, therefore this does not pose a barrier. The design of the product (T3) did not have to be changed in order to produce it with recycled content. Finally, the quality of the materials (T4) did also not pose a barrier to the supplier.

> *"The quality of the materials does not form a barrier, however recycled jeans are supplemented with new cotton to be able to guarantee the strength of the towel. The final product is an equivalent of 'regular' towels." (Supplier B)*

The expert believes that there are no barriers within this category. Suppliers already have the technical skills (T1) needed to use recycled content in clothes, since they buy the material to begin with. The clothing is also designed (T3) in such a way that it easy to recycle them after it has been used. Finally, he mentioned that the necessity for new processes (T5) might be a stimulus for suppliers to switch old machines with new ones.

Table 28: Barriers technological category clothing and personal equipment

Clothing and personal equipment					
	T1 (Technical skills)	T2 (Availability materials)	T3 (Design)	T4 (Quality)	T5 (New processes)
Project leader				x	
Purchaser	x	x			x
Supplier A	x	x			x
Supplier B	x				x
Expert					

4.2.5.2 PET-bottles

The project leader and the project associate did not state any barriers regarding this category. This has to do with the fact that they believe the barriers in this category all have to do with the knowledge of the market, which they do not have, since they are not the suppliers.

The supplier of the PET-bottles does however mention a few barriers in this category. These barriers have to do with the availability of recycled materials (T2) and the quality of the materials (T4), and seem to be correlated. Though her own technical background is too limited to state whether there is a lack of technical skills (T1) or there are new processes (T5) needed to process the recycled PET, the supplier has never heard within her company that this formed a barrier.

"Currently, there is a lot of fuzz regarding the availability of so-called R-PET [recycled PET]. The quality has to be good, which means that the stream of R-PET should be clean. It is often very hard to keep this stream clean, which cause the quality of R-PET to decline, which then leads to less availability of recycled materials." (Supplier PET-bottles)

The quality (T4) of the PET-bottles could form a barrier according to the expert. If the quality of the recycled materials diminishes, then virgin materials should always be added, otherwise it is not strong enough. The other barriers from the list were not mentioned by the expert as hindering for this project.

Table 29: Barriers technological category PET-bottles

PET-bottles					
	T1 (Technical skills)	T2 (Availability materials)	T3 (Design)	T4 (Quality)	T5 (New processes)
Project leader					
Project associate					
Soldiers					
Supplier		x		x	
Expert				x	

4.2.5.3 Tent systems for deployment

Despite the fact that the project leader does not see the lack of technical skills (T1) and quality control of reused/recycled material (T4) as hindering for himself, he did mention that this can cause barriers for the industry/suppliers.

The expert does however not see the lack of technical skills as a barrier. He stated that there are probably no additional skills (T1) needed when producing a circular tent system versus a linear tent system. Furthermore, he does not feel that the design (T3) of a circular tent system forms a barrier, one way to do this for instance is by designing it in a modular way. Nor did he mention the lack of new materials and processes (T5) as a barrier.

Table 30: Barriers technological category tent systems for deployment

Tent systems for deployment					
	T1 (Technical skills)	T2 (Availability materials)	T3 (Design)	T4 (Quality)	T5 (New processes)
Project leader	x			x	
Expert					

4.2.5.4 Other

Project specific

The project leader combat shirt did not mention specific barriers within this category. He did however state that he called his supplier, asking him to incorporate circularity in the product. The supplier replied by asking why they should do that. Here, he showed a lot of resistance and incomprehension.

The project leader noted about this, that the industry needs to be stimulated to change the product technically.

Organization wide

In this category, barriers were only mentioned by the external purchaser MatLogCo and the consultants. Since this category is, in their opinion, focused on the industry, the barriers were not discussed extensively. Both interviewees mentioned the lack of technical skills (T1), and the consultants stated this felt like a challenge.

The limited availability of reused/recycled material (T2) also formed a barrier for both interviewees. The external purchaser MatLogCo stated that the amount of recycled material available, depends on the supply and demand of certain product groups. According to the consultants, this barriers was formed due to the robustness of the design of products (T3). Hence, this also forms a barrier for the consultants.

The quality control of reused/recycled products (T4), as well as the lack of new materials and processes (T5) only form barriers in the eyes of the external purchaser MatLogCo. The quality of the products sometimes does not live up to the standard, and in many cases, suppliers work with old machines which are not fit for purpose.

Table 31: Barriers technological category other interviewees

Other						
		T1 (Technical skills)	T2 (Availability materials)	T3 (Design)	T4 (Quality)	T5 (New processes)
Project specific	**Project leader combat shirt**					
Organization wide	**Purchaser DOSCO**					
	External purchaser MatLogCo	x	x		x	x
	Consultancy company	x	x	x		

4.2.5.5 Overview

The quality control of reused/recycled materials (T4) is mentioned most often by the interviewees as a barrier. This barrier was followed by the lack of technical skills (T1) and the limited availability of reused/recycled materials (T2). Some interviewees mentioned that the limited availability of materials also correlated with the quality control. The design to reuse/recycle (T3) was only mentioned by the consultants as a barrier. There were a number of interviewees that felt they did not have the knowledge to state whether the barriers within this category were hindering. Moreover, they mentioned that this category was up to the industry to discuss.

Table 32: Overview barriers technological category per project

Technological					
	T1 (Technical skills)	T2 (Availability materials)	T3 (Design)	T4 (Quality)	T5 (New processes)
Clothing and personal equipment	x	x		x	x
Expert					
PET-bottles		x		x	
Expert				x	
Tent systems for deployment	x			x	
Expert					
Other – project specific					
Other – organization wide	x	x	x	x	x

4.2.6 Additional barriers

In addition to the barriers presented in the framework, the interviewees also mentioned some other barriers to circular supply chains. The first additional barrier, **preconditions**, was mentioned by nine interviewees and revolves around the idea that the main aim of the Royal Dutch Army is to be operational. This means that soldiers in the first place need to be able to fight, which leaves little room to even think about circularity. Additionally, there are often concerns surrounding the quality of products and whether a circular product will not slow soldiers down or require them to do extra actions, which stands in the way of meeting the preconditions of the Royal Dutch Army. This barrier is placed in the cultural category, since preconditions are deeply rooted in the customs and traditions of the Royal Dutch Army (Cu3), and the current business model is focused on delivering combat power.

> *"It is difficult to decide when you can consider something like a sustainable solution. It cannot be that you decide to go with a sustainable solution, you can on deployment and then the products do not work. It could costs peoples' lives, we're still talking about the army here." (Project leader tent systems deployment)*

> *"We just don't think it is that important. In stating priorities, if you just do something regarding environment or sustainable, fine, but it cannot hinder the operational employability." (Head of environment DMO)*

The second barrier was mentioned by five interviewees, and involves the job description of the interviewees. Integrating circularity within projects requires time, which is often not included in the job description of project leaders. This can for instance be seen in the PET-bottles project, a project executed 'on the side', next to regular work. Though this project is closely related to the regular work of the project leader, it takes up time which is not given for the project, which thus means working extra hours. The project leader combat shirt also identifies this a barrier, and states that circularity is currently a side issue which should be upgraded to a main issue. The barrier **time constraints** is placed in the organizational category (O5), since implementing circular supply chains is involved with the strategy of an organization.

> *"There were a few interviews with suppliers, all on a location in Stuttgart. Those took at least a day, maybe more, and we just can't free up the time to go there next to our regular work." (Project associate PET-bottles)*

A final additional barrier was found in the measurability of circularity, which was mentioned by four interviewees. By scoring the enrollments from different suppliers for a certain tender, a buyer can easily and justifiably choose which supplier is the best. However, interviewees find it hard to make circularity quantifiable, which makes it harder to justify a certain choice to the suppliers that did not win the tender. This could then lead to lawsuits from suppliers that lost the tender, which will cost a lot of time and money. This barrier, **measurability**, is placed in the organizational category (O6), since it is also part of an organization's strategy how this is embedded in procedures.

> *"We were asked to write the program of demands as specific as possible. As measurable as possible. So no one could interpret it in another way. […] If person X offers a certain cardboard and person Y offers PET-bottles which are unsustainable, but the cardboard is. However the cardboard is three times as expensive. How are you going to compare?" (Project leader PET-bottles)*

4.2.7 Overview

The table below contains an overview of all the barriers mentioned by the interviewees per project and within all the categories. Besides the original barriers, three additional barriers were added. In the table these can be found in ***bold, italic and with an asterisk (*)***. These additional barriers were not discussed with the expert.

All the barriers from the framework came forward in the interviews. Most barriers mentioned are barriers from the financial and organizational category. Risk aversion (Cu1) and the design to reuse/recycle (T3) are mentioned the least. These barriers from the cultural and technological category were only mentioned once, risk aversion (Cu1) by the expert and design to reuse/recycle (T3) by the consultancy company. Since these barriers were not mentioned by interviewees involved in the projects, it leads to wonder how important these barriers are. An in-depth analysis focused on the differences and similarities between the three projects, is discussed in 4.3.2.

From the table also follows that the interviewees that discussed the barriers based on Defense as an organization, mentioned more barriers than interviewees that discussed specific projects. This might be due to the fact that the interviewees who looked organization wide, mentioned barriers they expected to occur, instead of what they actually ran into. Moreover, the organization wide group contains more interviewees than the different projects and the project specific group, and thus contains more opinions, which could also lead to a higher amount of barriers.

Table 33: Overview barriers all categories per project

	Contextual				Cultural			Financial			Organizational						Technological				
	Co1	Co2	Co3	Co4	Cu1	Cu2	***Cu3****	F1	F2	F3	O1	O2	O3	O4	***O5****	***O6****	T1	T2	T3	T4	T5
Clothing and personal equipment							x	x	x		x			x			x	x		x	x
Expert						x		x	x		x	x									
PET-bottles	x	x	x	x		x	x	x	x		x	x	x	x	x	x		x		x	
Expert	x	x	x			x					x	x	x	x						x	
Tent systems for deployment						x	x	x	x	x	x			x	x		x			x	
Expert					x	x		x	x		x	x		x							
Other – project specific						x		x		x	x	x	x	x	x	x					
Other – organization wide	x	x	x			x	x		x		x		x		x	x	x	x	x	x	x

4.3 Dimensions

In this paragraph, the barriers are discussed based on three dimensions, namely the actor groups, the complexity of the projects, and the timelines. For the dimensions, only the three projects under study (CPE-company, PET-bottles, and tent systems for deployment) are looked at.

4.3.1 Actor groups

In this research, three actor groups were taken into account: project leaders (), customers (), which are in this case the soldiers of the Royal Dutch Army, and suppliers (). During the research, another actor group surfaced which has also been taken into account, namely the purchaser (). Alongside the project leader PET-bottles, is the project associate, who functions at the same level and is therefore grouped with the project leaders for this dimension. Besides the actors, the expert was also asked to indicate which categories of barriers he expected per actor group.

4.3.1.1 Project leaders

As expected based on the literature, the project leaders mentioned barriers in the contextual, cultural, financial and organizational category. Barriers in the contextual category were mainly mentioned by the project leader PET-bottles, which can be explained by the fact that soldiers needed to change their behavior and the project leader had to make an effort to make this happen. Within the cultural category, the project leaders from the PET-bottles and tent systems for deployment mentioned resistance to new business models (Cu2), as well as preconditions (Cu3) as barriers. The financial barriers the project leaders indicated were focused mostly on investment costs (F1) and the costs of recycled materials (F2). These barriers were mentioned by all the project leaders, whereas financial support (F3) was only mentioned by one project leader. Barriers in the organizational category were also mentioned by all the project leaders, here the focus mainly was on the lack of knowledge and skills (O1), reverse logistics (O3) and the lack of alignment between strategy and circularity (O4). Though two project leaders did mention some barriers within the technological category, they explained that these barriers specifically belong to the industry or suppliers, therefore these are not seen as barriers the project leaders are involved with.

The expert indicated that he expected the barriers experienced by the project leaders to mainly be in the financial, organizational and technological category. This thus deviates from the expectations based on the literature, and from the experiences by the project leaders. The financial barriers the expert indicated are linked to the quality of the product (T4), which can form a technological barrier. Moreover,

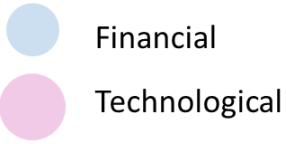
the project leader requires knowledge (O1) to be able to integrate circularity in a project. When there is a lack of knowledge however, this can form an organizational barrier. Regarding the contextual and cultural category the expert did not mention any barriers for the project leaders.

4.3.1.2 Soldiers

Following the literature, it was expected that the soldiers perceived barriers in the contextual and organizational category. Based on secondary data from the PET-bottles project, the soldiers only mentioned barriers in the contextual category. Here, they either had no or a negative perception (Co2), and they lacked awareness (Co3) regarding the importance and necessity of circularity. From the secondary data, no other categories of barriers followed. However, there is a possibility that soldiers indicated some barriers in the organizational category such as the lack of knowledge and skills (O1), or the lack of alignment between strategy and circularity (O4), if the data was retrieved first hand.

The barriers in the contextual category are substantiated by the expert as well. For the soldiers involved with the PET-bottles project, he believes, the main barriers can be found in this category, since they have to adjust their way of working. Since there are no changes necessary from soldiers for the projects at the CPE-company, no barriers for soldiers are expected here. The same goes for the tent systems for deployment, as long as a circular product is equally as good as a linear product, there are no barriers expected for the soldiers.

4.3.1.3 Suppliers



The category of barriers most mentioned by the suppliers from the CPE-company and the supplier of the PET-bottles project is the technological category. This is also consistent with the expectations from the theoretical framework. Suppliers are in charge of the technical specifications of a product, therefore barriers in this category can for instance be found in the lack of technical skills (T1), the limited availability of recycled materials (T2), and the quality of recycled products (T4). Though it was expected, the suppliers did not mention any barriers in the organizational category, such as reverse logistics (O3). Both suppliers from the CPE-company did note that the financial category contained some barriers. These barriers are involved with the investment costs (F1) and the costs of recycled materials (F2). For the tent systems for deployment, no supplier has been selected just yet, therefore this project is not taken into account when it comes to this actor group.

The expert also mentioned that he expected the financial and technological category to contain barriers for the suppliers. He stated that suppliers are willing to deliver a circular product, but they do

need a certain financial compensation for it, since it requires more money. Moreover, the quality of the circular product needs to be as good as that of a linear product, this can also cause a barrier sometimes.

4.3.1.4 Purchasers

Besides the project leader, the purchaser of the CPE-company was also interviewed, since he procures certain products at the CPE-company. He mentioned barriers in the financial, organizational, and technological category. Within the financial category, he stated that the costs of recycled materials (F2) was a barrier, which is linked to the limited availability of recycled materials (T2), a barrier within the technological category. In the organizational category he mentioned the lack of alignment between strategy and circularity (O4) as a barrier.

The barriers the expert mentioned for this actor group more or less correspond with the barriers mentioned by the purchaser himself. The expert believes that the financial category causes the main barriers, since a purchaser gets a certain budget assigned for a project. Moreover, the expert sees a barrier within the organizational category since he believes that the purchaser, like the project leader, needs to be aware of the concept of circularity in order to be able to take it into account.

4.3.1.5 Overview

Below figure 8 can be found, which presents the categories of barriers per actor groups based on the literature. Next to it, in figure 9, the categories are presented which were mentioned by the different actor groups. In the latter figure, a difference in the size of the actor groups can be spotted based on the amount of projects the actor groups were in. Overall, the project leaders mentioned the most categories, which was also expected based on the literature. The soldiers mentioned the least categories, this might however be due to the use of secondary data.

It was expected that the organizational category would be mentioned by most actor groups, instead it was the financial category which was mentioned. This category was mentioned by three out of four actor groups, namely the project leaders, purchaser, and the suppliers. The organizational category was mentioned by two actor groups, the project leaders and the purchaser, instead of by all actor groups which was expected. The technological category was also mentioned by two actor groups, the suppliers and the purchaser. Here, it was expected that only the suppliers would mention this category, however in the expectation the purchaser was not taken into account. Completely in line with the expectations are the contextual and cultural category. The contextual category formed barriers for the project leaders and soldiers, and the cultural category formed barrier solely for the project leaders.

Figure 6: Legend categories

Figure 7: Legend actor groups

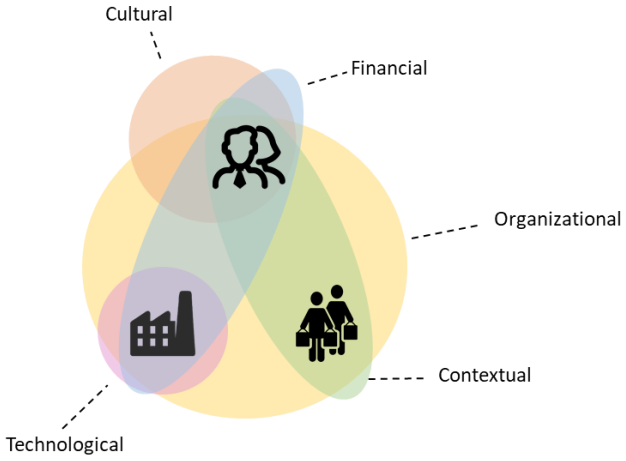


Figure 8: Expected categories per actor group

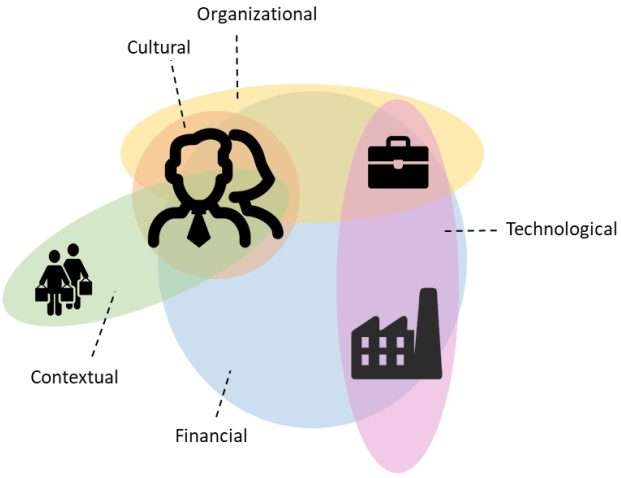


Figure 9: Actual categories per actor group

4.3.2 Complexity

Based on the interview with the expert, the three projects are classified from least complex to most complex. He states that the project at the CPE-company is least complex, followed by PET-bottles and tent systems for deployment, which are equally complex but in a different way. PET-bottles is for instance a project which is just one kind of product, whereas tent systems are made up of more materials. However, with the PET-bottle project more actor groups are involved, as compared to tent systems for deployment.

In the table below, between the brackets and in *italic*, the expectation regarding the classification as created based on the literature can be found. This is done to show the differences and similarities between the expectations and the empirical data. The numbers between the brackets behind the categories of barriers indicate the number of barriers within the category, this is including the additional barriers.

Table 34: Overview complexity per category

			Categories of barriers				
Complexity			Contextual (4)	Cultural (3)	Financial (3)	Organizational (6)	Technological (5)
	Less	CPE	Low *(Low)*	Low *(High)*	Medium *(High)*	Low *(Low)*	High *(Medium)*
	More	PET-bottles	High *(High)*	Medium *(High)*	Medium *(High)*	High *(High)*	Medium *(Medium)*
		Tent systems	Low *(High)*	Medium *(High)*	High *(High)*	Medium *(High)*	Medium *(Medium)*

4.3.2.1 Less complex project

The less complex project showed a partially similar image in the empirical data as in the expectation. The contextual and organizational category overlap with the expectation. The cultural category shows the biggest difference with the expectation. For this category, it was expected that all the barriers were present, however the only barrier present was preconditions (Cu3), which was not part of the original framework but added after the interviews. For the financial category there is a slight difference between the expectation and the empirical data. It was expected for this category that all barriers were present, however the lack of financial support (F3) was not mentioned by the interviewees as a barrier. Finally, the technological category shows a slight difference. It was expected that based on the product, a few barriers would be present. However, for the products of the less complex project, a number of adjustments needed to be made. These adjustments resulted in the presence of all but one barrier of the technological category.

4.3.2.2 More complex projects

Regarding the more complex projects there is no unambiguous pattern between the categories of barriers present for the PET-bottles project and the tent systems for deployment. For the PET-bottles project, the contextual, organizational, and technological category correspond with the expectation. Though it was expected that all barriers would be mentioned for the cultural and financial category, risk aversion (Cu1) and the lack of financial support (F3) were not mentioned as barriers, and therefore do not correspond with the expectation.

Two categories regarding tent systems for deployment correspond with the expectation, namely the financial and technological category. The cultural and organizational category show a slight difference between the empirical data and the expectation, in the cultural category two barriers were mentioned, and in the organizational category three. The biggest difference can be found in the contextual category, here it was expected that all barriers would be present, however none were. This can be explained by the fact that circularity in tent systems does not have to change anything for soldiers, and therefore does not pose any barriers.

4.3.2.3 Overview

Overall, a difference between categories of barriers for less complex versus more complex project is present. This can be seen in the table below, in which the two more complex projects are taken together. For some categories, two classifications are present, this is due to the fact that the two projects both had a different classification.

Table 35: Overview complexity per project, more complex projects merged

		Categories of barriers				
		Contextual	Cultural	Financial	Organizational	Technological
Complexity	Less	Low *(Low)*	Low *(High)*	Medium *(High)*	Low *(Low)*	High *(Medium)*
	More	Low-High *(High)*	Medium *(High)*	Medium-High *(High)*	Medium-High *(High)*	Medium *(Medium)*

This table shows that a project which is less complex faces less barriers, as was expected. The contextual category stands out in this table, since there is a big difference between the two more complex projects. Here, the PET-bottles project corresponds with the expectation, whereas the tent systems for deployment does not. In the cultural category, the less complex project nor the more complex projects correspond with the expectation. This can partially be explained due to the fact that risk aversion was mentioned by none of the interviewees, thereby eliminating the possibility of a *high* classification, since all barriers in this category need to be present for that. Within the financial category, there is a slight difference between the less complex and more complex projects, however this difference is just one barrier. As expected, organizational barriers are present for the more complex projects, albeit to varying degrees. Finally, the technological category shows a slight difference with the expectation when it comes to the less complex project.

4.3.3 Time

The time dimension indicates in what order the categories of barriers (are expected to) occur. The project leaders of the three projects, the project associate of the PET-bottles project, and the purchaser of the CPE-company were asked to put the categories of barriers in order. All but one of them did, only the project leader of the CPE-company refrained from putting the categories barriers in order of occurrence. The purchaser of the CPE-company, the project leader of the PET-bottles project and the project associate of the PET-bottles project were able to put the categories in order of occurrence. The project leader tent systems for deployment attempted to put the categories in order of occurrence, however he realized that he was not able to this, which is further explained in 4.3.3.3.

4.3.3.1 Clothing and personal equipment

The purchaser of the CPE-company was asked to put the different categories of barriers in order of occurrence for projects at the CPE-company. Though the purchaser originally did not mention the contextual barriers, he did include this category in the timeline, however after consulting him again, he eliminated the category from the timeline. The financial category presents the main barriers and is hardest to overcome. These barriers can be found at the start of the project and take a long time to overcome. The barriers which can be easiest overcome originate somewhere in the middle of the project. The technological barriers can be found more at the end of the project, when the suppliers come in. Finally, the purchaser stated that the cultural category did not form barriers at all, therefore this category is also not placed on the timeline.

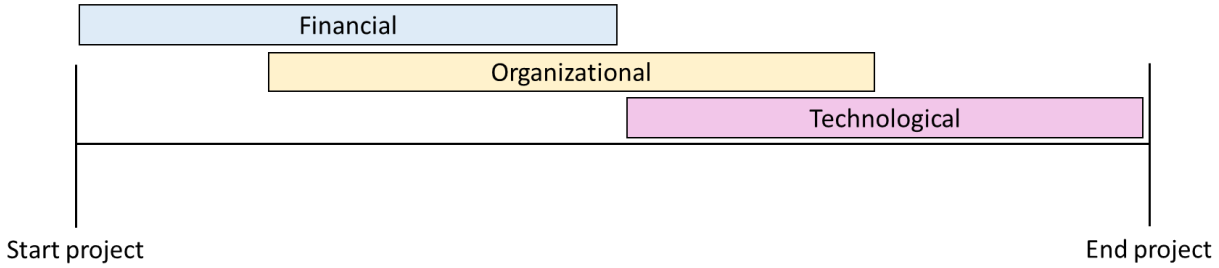


Figure 6: Timeline clothing and personal equipment according to purchaser

4.3.3.2 PET-bottles

Like the purchaser of the CPE-company, the project leader of the PET-bottles projects was asked to put the categories of barriers she expected to run into within the project in order. She mentioned that the first thing that comes up are barriers regarding resistance (Co1), perception (Co2), awareness (Co3), and knowledge and skills (O1). Therefore, she placed the contextual and organizational category at the beginning of the timeline. After these categories are tackled, there still might be some barriers within the organization regarding resistance to new business models (Cu2). Moreover, preconditions (Cu3) is an important barrier. The financial category also occurs after the contextual and organizational category, since this is the moment investments costs (F1) and costs of recycled materials (F2) start to form barriers. During the cultural and financial category, the organizational category occurs again. The barriers in this category present at this place on the timeline are reverse logistics (O3) and no alignment of circularity and strategy (O4). Finally, she placed the technological barrier throughout the timeline. This has to do with the interaction the project leader feels there is between the contextual, organizational and technological category. For instance, the easier the technological barriers are to overcome, the easier it will be to tackle the resistance and lack of knowledge and skills as barriers, and vice versa.

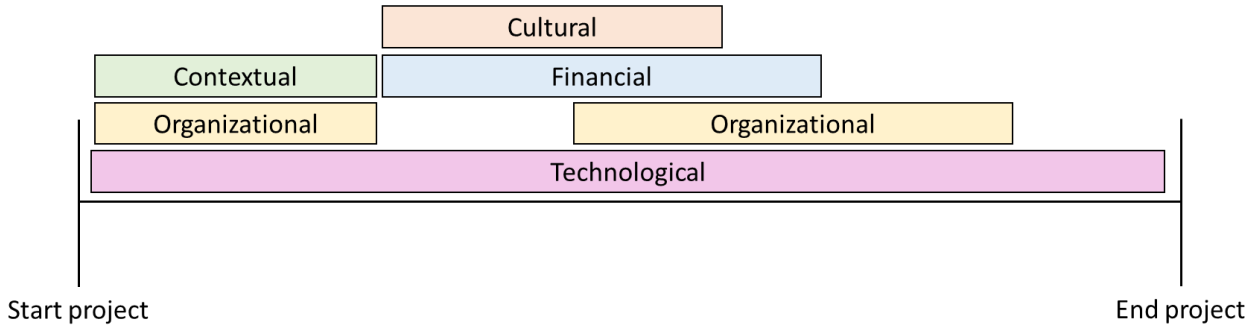


Figure 7: Timeline PET-bottles according to project leader

The project associate proposed a slightly different timeline than the project leader. She mentioned that at the start of the project, they ran into barriers from the contextual, cultural, and organizational category instantly. Convincing soldiers did not take long, however the barrier on the lack of regulations, standards and support (Co4) formed a barrier for the project for a rather long time. The cultural category was not easy to overcome, however with the help of the right people (higher ranked soldiers), it was fairly quickly that this category of barriers was resolved. The barriers from the organizational category also lasted for a long time, since the reverse supply chain (O3) was also involved here, even longer than the contextual category. During the presence of the contextual and organizational category, the financial category also started to play a role. This was followed by the barriers from the technological category, which she expected are relatively easy to overcome.

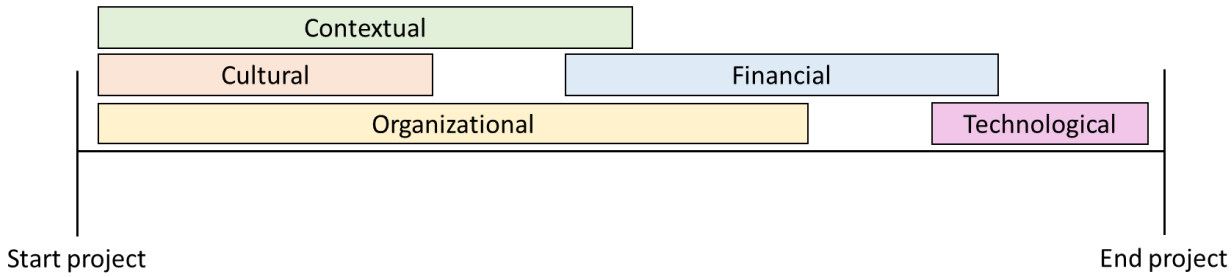


Figure 8: Timeline PET-bottles according to project associate

4.3.3.3 Tent systems for deployment

The project leader tent systems for deployment explained that he could not provide a clear timeline for his project. He mentioned that it is important for him that all barriers are tackled at the start of the project, so during the requirement phase or even during the pre-requirement phase. Here, he explained, needs to be looked at a certain form of prioritizing, logistical demands, sustainability, finances, and available technologies. Thus, all the categories should occur at the beginning in order for them to be tackled.

4.3.3.4 Overview

The timelines as created by the purchaser of the CPE-company and the project leader and project associate of the PET-bottles project, differ from each other in a number of ways. The timeline of the CPE-company does not include the contextual and cultural category, whereas the timelines of the PET-bottles project do include these categories. Moreover, the purchaser of the CPE-company placed the financial category at the start of the project, whereas it is placed more in the middle and towards on the timelines regarding the PET-bottles project. The organizational category is placed in the middle of all the timelines, however for the project associate of the PET-bottles project it occurred at the beginning of the timeline, and for the project leader of the PET-bottles project the category even occurred twice. Besides the differences, there is also a category they all agree on, namely the technological category. Though the occurrence of the category differs per timeline, the purchaser, project leader, and project associate do expect this category to present barriers until the end of the project.

Based on the literature, it was expected that the cultural and financial category occurred at the start of a project. This is followed by the organizational and technological category, of which the latter is expected to run a bit longer. At the end of the organizational and technological category, it is expected that the contextual category occurs.

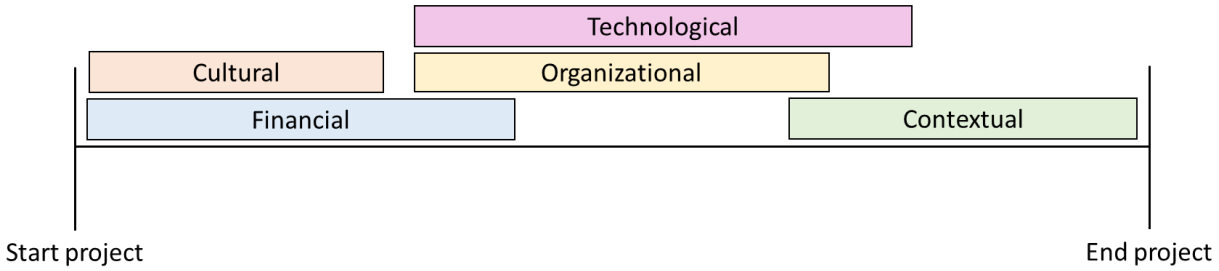


Figure 9: Expected timeline

This expectation has some similarities with the timelines created by the interviewees, however there are mainly differences. The main similarity can be found in the organizational category, like for the timelines from the interviewees, this category is mainly present in the middle of the project. The financial category corresponds in terms of occurrence with the timeline of the purchaser of the CPE-company, and the cultural category with the timeline of the project associate. Based on the timelines for the PET-bottles project, the contextual category occurs at the beginning of the project instead of at the end. Moreover, for all the timelines the technological category entails barriers until the end of the project, which is not the case in the expectation.

Overall, there is a lot of difference between the timelines themselves, and between the timelines and the expectations. However, based on the interviews, a pattern is constructed which is presented in the figure below. Important to note here, is that this timeline is created based on the suggestions of three interviewees and is specific to this empirical context.

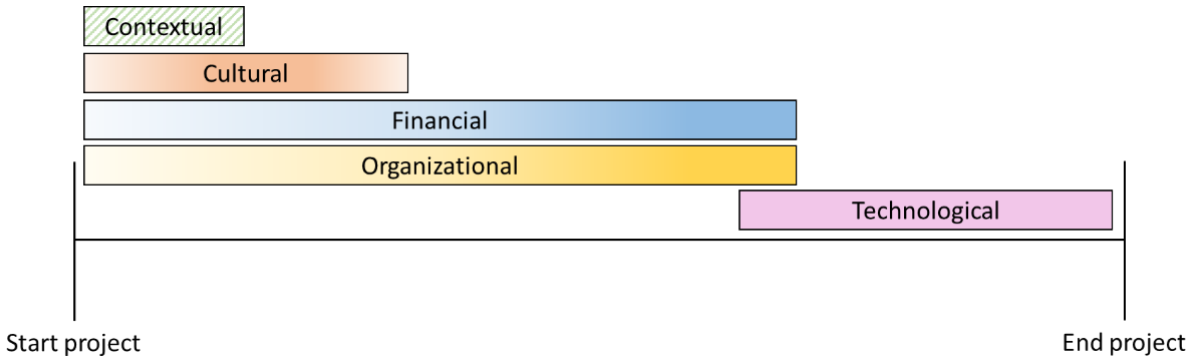


Figure 10: Timeline based on the proposed timelines by interviewees

The expert was also asked to provide his insights regarding the timelines, however these did not correspond with the timelines of the interviewees nor with the expectation. Therefore, in order to avoid confusion, it was decided not to present the timelines created by the expert.

5. Discussion

Having presented the results, this chapter addresses an interpretation of the findings, the theoretical implications, limitations to this research, and suggestions for future research.

5.1 Interpretation of the findings

In the theory section, a framework of barriers was created based on literature was presented. This framework was discussed in a general manner with interviewees throughout Defense, as well as in a more detailed manner with interviewees who are involved with three projects within the Royal Dutch Army. Moreover, open interviews were conducted in which the framework was not discussed, to get a more general idea of Defense as an organization. Additionally, during the interviews regarding the projects under study, the framework was discussed along three dimensions.

5.1.1 Framework

In the framework five categories were identified, containing eighteen barriers. The interviews show that all categories come back to a greater or lesser extent. The first category is the contextual category. This category is mainly focused on individual soldiers and the necessity for a change within the behavior of these soldiers (Moktadir et al., 2018; Sajjad et al., 2015). This study shows that for some projects a change in the behavior of soldiers is not necessary. Moreover, the lack of regulations, standards and support (Co4) (Al Zaabi et al., 2013) was only hindering for one project. This thus shows that this category is not applicable to all projects, and is rather case specific.

The second category is the cultural category, which was expected to contain two barriers. Noteworthy, one of the two barriers was only mentioned by one interviewee. Ritzén and Sandström (2017) stated that organizations tend to avoid circular business models since these are perceived to have higher risks, which thus leads to risk aversion (Cu1). The absence of risk aversion can be explained by the fact that there is a certain urgency for circularity in the Netherlands. Governments and public and private organizations are encouraged to make their business more circular, regardless of the risk. Though this barrier does not seem applicable for the Netherlands, it is kept in the framework, since it can be hindering in countries where there is less urgency for circularity. The name is however changed from risk aversion to risk avoidance, to make it more clear what is meant by this barrier. Contrary to risk aversion, the resistance to change to a new business model (Cu2) (Pheifer, 2017) was mentioned very often by interviewees. The resistance came from different angles, i.e. from high-up in the organization or because of the highest demand being optimal performance and not circularity. A third barrier is added to this category. This barrier, preconditions (Cu3), indicates that an organization has certain preconditions which it must meet, and circularity is not part of those conditions. Due to the preconditions, circularity might be

overlooked since making supply chains circular is not necessary to meet the conditions. Though this could form a serious barrier, there is a possibility that, in the Netherlands, this barrier is only applicable in the case of Defense. This has to do with the fact that all other Dutch ministries have to comply with the program Netherlands Circular 2050, however due to its operational character the Ministry of Defense is exempted of this vision. Other countries however, do not have such a vision set out by the government, and therefore have the ability to hold on to their preconditions, which can thus form a barrier.

The financial category is important in all three projects. Based on previous literature, it was stated that transitioning to a circular supply chain initially leads to more investment costs (F1) (Jia, Zuluaga, Bailey, & Rueda, 2018; Narayanan et al., 2018). In this study, investment costs form a major barrier due to several reasons. One of these reasons corresponds with the literature and involves costs due to changes that need to be made in the design, manufacturing, and return processes (Narayanan et al., 2018). This barrier is often mentioned in line with costs of recycled materials, indicating an interaction between the two barriers. As Sarkis et al. (2010) stated, the cost price of recycled materials (F2) can sometimes be higher than that of virgin material. Due to these higher costs, more money needs to be invested, thus leading to higher investment costs. To conclude this category, the barrier involving a lack of financial support (F3) was barely mentioned. Though within Defense there is no money freed-up specifically for sustainability, almost no interviewees felt this hindered them. Moreover, Moktadir et al. (2018) stated that less money tends to be given by banks and governments to sustainable initiatives. However, in the case of the Netherlands, the Dutch government offers thirty-six subsidies just for sustainable initiatives (RVO, n.d.). This thus shows that the lack of financial support does not form a barrier for the Royal Dutch Army nor for other organizations in the Netherlands, since a sufficient amount of sustainable subsidies are available. Since other countries might not have sustainable initiatives, this barrier stays included in the framework.

In the initial framework, the organizational category contained four barriers, however after the interviewees two more barriers are added to this category. Some barriers in this category are mentioned very often, like the lack of knowledge and skills (O1) (Pheifer, 2017). Regarding this barrier Moktadir et al. (2018) stated that a lack of knowledge can lead to a lock-in in the current model, which was also emphasized by the interviewees. Since the interviewees all referred to this barrier as the lack of knowledge, and did not emphasize the importance of *skills*, the name of the barrier is revised. Opposite to the lack of knowledge, the trust among suppliers (O2) is mentioned very little. The reason for this can be found in the context specificity of Defense. Here, every new tender is open for every supplier, meaning that it is not guaranteed that a supplier who is known and won the tender before, will win it again. Though it does not form a barrier in the case of Defense, it is recognized that the context is rather specific,

therefore the barrier is kept in the framework. The two barriers added to the organizational category are time constraints (O5) and measurability (O6). The first might have an interaction with the lack of alignment and entails the lack of time to include circularity in projects. Since circularity is not yet part of the core business of Defense, there is little to no time to work on it. This hinders employees who do want to incorporate circularity in a project, but have to do it besides their regular job. This barrier is also found in literature on volunteering to formal organizations (Sundeen, Raskoff, & Garcia, 2007), an activity for which time needs to be freed-up like for incorporating circularity. In their article, it is explained that the lack of time due to a full-time job, might discourage other activities such as volunteering (Sundeen et al., 2007), or in this case delve into circularity. The second additional barrier is focused on making circularity quantifiable. This is necessary, since it allows project leaders to justify the choice for a certain supplier based on the registrations. However, if they are not able to explain to suppliers why another supplier won a tender based on circularity, a lawsuit might follow. Such a lawsuit costs time, money, and can even damage the image of the organization. Hence, forming a barrier to circular supply chains.

The framework is concluded by the technological category. In this category, five barriers were discussed. Following from the interviews, none of these barriers stood out, except for the design to reuse/recycle (T3). It was expected that this would form a barrier, since robustness of products makes it harder to disassemble them (Al Zaabi et al., 2013; Narayanan et al., 2018), and therefore to reuse or recycle them. In this study it was only mentioned once to be a barrier, which could stem from the fact that the recycled products as well as the created products are all built-up from few materials. However, if a product contains more different materials, this might be harder. Thus, the barrier is kept in the framework since it can form a barrier for other products, though it does not really form a barrier for this study.

Below, the revised framework is presented. The barriers regarding which changes are made are marked grey. If a name is changed, the previous name is crossed out and the new name is marked by underlining it. Barriers which are *italic* and have an asterisk (*) behind are not important for this study, however should remain in the framework since it can apply to other contexts. Finally, the barriers which are underlined and **bold** are the newly added barriers. Moreover, the actor groups for which the categories are present can be found on the right hand side of the table. This is further discussed below.

Table 36: Revised framework of barriers

	Code	Barrier	Context	Actor groups
Contextual	**Co1**	Customer resistance	Customers want to keep doing what they are doing	
	Co2	Perception	Customers have no/negative perception of circularity	
	Co3	Lack of awareness	Customer awareness on the importance of circularity is limited	
	Co4	Lack of regulations	Current laws and regulations stand in the way of a circular economy	
Cultural	**Cu1**	*Risk ~~aversion~~ avoidance**	Circular BMs have higher/more risks and are therefore avoided	
	Cu2	Resistance to new business models	Top level management resistance to change the current business model to a circular business model	
	Cu3	**Preconditions**	It is necessary the preconditions are met, this does not include circularity	
Financial	**F1**	Investment cost	To shift to a circular business model major investments are needed	
	F2	Costs of recycled materials	Recycled materials are often more expensive than raw materials	
	F3	*Lack of financial support**	There is a lack of financial support for circularity by the government	
Organizational	**O1**	Lack of knowledge ~~and skills~~	There is little knowledge on circularity	
	O2	*Trust among suppliers**	Circular suppliers are expected to deliver the same performance/quality than linear suppliers	
	O3	No reverse supply chain	Organizations lack the processes to take back products	
	O4	Circular business does not align with strategy	Circularity is not in alignment with the current strategy of the organization	
	O5	**Time constraints**	There is little to no time to invest in circularity besides the core business	
	O6	**Measurability**	In order to justify circularity it has to be made measurable/quantifiable	
Technological	**T1**	Lack of technical skills	There is a lack of technical capabilities and competencies	
	T2	Limited availability of recycled materials	Recycling often leads to downcycling, thus there will always be a need for virgin materials	
	T3	*Design to reuse/recycle**	Products are built without considering the reparability and reusability of parts or materials	
	T4	Quality control of reused/recycled material	Recycled material is in bad shape, therefore it is not possible to reuse/remanufacture the materials	
	T5	Lack of new processes and machines	Current processes and machines are not designed for circularity and thus need to be redesigned	

5.1.2 Dimensions

Actor groups

In the theory section it was stated that every supply chain consists of at least three individuals (Mentzer et al., 2001). In this study, three actor groups were distinguished: project leaders, customers (in this case soldiers), and suppliers. However, during the interviews it became apparent that in the case of Defense another actor group plays an important role, namely the purchaser. At the end of this section, the role of the purchaser is discussed. The visualization of which actor group mentioned which categories of barriers can be found in the table 36.

Based on the literature, it was proposed that the project leader experiences barriers in four different categories. The categories in which barriers were expected to be found are the contextual (Clifford Defee & Stank, 2005), cultural, financial (Kirchherr et al., 2018; Torstensson, 2016) and organizational category. The results show that barriers experienced by the project leaders were found in these categories; the literature thus corresponds with the empirical data.

The customers, in this case soldiers, were expected to experience barriers in the contextual (Moktadir et al., 2018; Xue et al., 2010) and organizational category (Mont et al., 2017; Pheifer, 2017). For the contextual category, the barriers were found, though not for all projects. This has to do with the context of a project, for some project a change of behavior from the soldiers is not necessary. Barriers in the organizational category were not found for the soldiers, which can be explained by two reasons. First, hierarchy is very important in the Royal Dutch Army. Every soldier does what he/she is ordered to do, which makes it less important if a soldier for instance has the knowledge of circularity or if the strategy is aligned with circularity. The second reason regards the data collection in this study. The data collected was secondary data, in which no specific questions regarding the organizational category were asked. Though it is not the case in this study, a study in a different context and with a different kind of data collection might show barriers in the organizational category.

In line with the literature, the empirical data showed barriers for the suppliers in the financial (Moktadir et al., 2018) and technological (Al Zaabi et al., 2013; Narayanan et al., 2018) category. Though the organizational category was also expected to present barriers for the suppliers (Mont et al., 2017), this was not the case. This can be explained by the fact that the interviewed suppliers have been working towards circularity for some time now. Thus, the necessary knowledge is already present, the reverse logistics is already in place and the circularity is already taken up in the strategy. Suppliers which are still at the start of becoming more circular might however face barriers in this category. Therefore, it is useful to consider this category for suppliers in another empirical context.

A fourth role found during the interviews is that of the purchaser. This role is expected not just within Defense but in other organizations as well. Stores, wholesalers, other governments and healthcare institutions for instance employ people to execute the purchasing policy. Within Defense, the purchaser is responsible for procuring products based on a program of demands. He does not have to deal with the final implementation of a product with the customers, therefore the contextual category does not form barriers. Nor does the cultural category, since the project leader is expected to overcome these barriers. The purchaser only carries out the program of demands: he needs to stay within budget (financial category), he needs knowledge regarding circularity and the reverse logistics needs to be arranged (organizational category), and finally the quality of the products needs to be no less than that of linear products (technological category). Thus, in this context the financial, organizational and technological category present barriers. Besides these categories however, the addition of the cultural category is also expected for different empirical contexts. If the purchaser has the possibility to procure in a circular manner while this is not laid down in the purchasing policy, he might also suffer some resistance from top level management. The contextual category is however not expected here, since purchasers in other context also do not have to deal with customers.

Complexity

It was expected that less complex projects would present less categories of barriers than the more complex projects. This is confirmed by the empirical data, in which less categories of barriers for the less complex project are identified than for the more complex projects. Regarding the two more complex projects, there is a differentiation which was not expected. Here, there was no unambiguous pattern which categories came forward. The differentiation shows that, at least for the more complex projects, the categories of barriers which come forward are rather case specific. Thus, the complexity dimension does not show as clear a pattern as originally expected.

Time

In the theory section, a report by IMSA Amsterdam containing steps to transition to a circular economy (2013) was discussed. Since no other literature was found regarding a timeline for categories of barriers, the timeline was constructed based solely on this report. The timeline differentiates from the timelines presented by the interviewees in a number of ways. Moreover, the timelines by the interviewees differentiate amongst each other as well. Therefore, it was more complicated than expected to analyze the different timelines. Some categories did not come forward at all for specific projects (contextual category), whereas other came forward in all the projects but at different moments in time (financial and organizational category).

5.2 Theoretical implications

The literature gap identified in this study involves barriers to circular supply chains. To fill this gap, literature on barriers to circular economy and barriers to sustainable supply chain management was brought together. The literature showed that supply chains are important for the implementation of circularity, which strengthens the use of these concepts to create a framework of barriers to circular supply chains. By applying the framework of barriers to the empirical context of the Royal Dutch Army, it was discovered that, in this context, some barriers are more important to CSC than others. Moreover, some barriers which were not initially in the framework were also found to be important. Based on these results, the initial framework was adjusted, which led to a revised framework of barriers to CSC. This framework is believed to be applicable in a wider context, as opposed to the one created by Mangla et al. (2018), which can only be applied to developing countries. Moreover, the framework by Mangla et al. (2018) presented individual barriers, whereas in the framework used in this study the barriers are clustered into five categories. The revised framework can be found in table 36.

Moreover, to gain a broader understanding of barriers to circular supply chains, the framework was also discussed in relation to the dimensions actor groups, complexity and time. Regarding the actor groups, it was expected that different categories were present for different actor groups. This also followed from the empirical data, thereby adding to the understanding how these actors groups relate to the categories of barriers. Regarding the dimension complexity, it was expected that more complex projects show more categories of barriers than less complex projects. Though this was also found in the results, there was no clear indication when specific categories were present other than that it was case specific. For the dimension time, it was expected that categories of barriers occur at a specific moment during a project. Since there were only three interviewees who were able to provide a timeline, it was hard to research this specific dimension and to draw conclusions from it.

This study contained too little projects and interviewees to be able to draw conclusions regarding the dimensions complexity and time. Despite this, it is believed that these dimensions are promising and can add to the understanding of barriers to circular supply chains. Important to note here is that there might also be some coherence between complexity and time. If for instance a project is less complex, less categories of barriers are expected to be present and therefore less categories of barriers occur on a timeline. The same holds for more complex projects, there it is expected that more categories of barriers are present and thus more categories need to be placed on a timeline. This way, the complexity of a project can thus have an influence on the timeline of a project.

5.3 Limitations and future research

Every research has its limitations, and this study is no exception to that rule. However, limitations also offer possibilities for future research and should therefore be embraced. A first limitation to this study is the comparability of the dimensions, here it is important to keep in mind that the projects in the study were the only ones currently available at Defense. The three projects under study are all in different phases of the DMP. This has an influence on the barriers interviewees expect to occur or which they have already faced, thereby making it harder to compare the projects. Hence, for future research it is suggested that projects are selected from the same phase. The comparability of the projects is also challenged by the fact that projects are all in a different department of the organization. These different departments all have different procedures, objectives, and a different culture, making it more difficult to compare them. Though this is not a limitation to this study, it reflects Defense as an organization, it is suggested for future research to enhance comparability by focusing on projects which are in the same department of an organization. Moreover, the comparability can also be enhanced by including a lot more projects, this way multiple departments of an organization as well as different phases projects are in can be taken into account.

Overall, twenty people were interviewed and for one actor group, the soldiers, secondary data in the form of a survey was used. Seven of the interviewees are involved with the projects under study and one interviewee was the expert, who also provided an insight in these projects. For the projects, no more interviewees were available, however the most important people in the projects, such as the project leaders, have been interviewed. Furthermore, eight interviewees provided an overview of circularity within Defense and three interviewees gave insights in how Defense works. The table in appendix XI gives an overview of which barriers are mentioned by whom. The table shows that there is a big difference between the numbers of barriers mentioned by interviewees who did see the list, on average eight barriers, versus interviewees who did not see the list, on average three barriers. This forms an important limitation, since it indicates that if a list is shown, people are more susceptible to mentioning barriers. The data regarding the barriers was aggregated both for the projects and the 'other' group and there was always at least one interviewee who had seen the list of barriers. Therefore, this limitation does not form a major issue for the interpretation of the barriers in the framework. For the dimensions on the other hand, it is more of an issue since the list of barriers was discussed with none of the suppliers.

Besides the fact that people are more susceptible to mentioning barriers after seeing the list, different barriers were mentioned by interviewees who did see the list and who did not. Resistance to new business models (Cu2) and circularity does not align with strategy (O4), two of the most mentioned

barriers by interviewees who saw the list, are not mentioned at all by interviewees who did not see the list. Thus, these might be barriers which people are only prone to mention when they have seen the list. Furthermore, the cultural category was only mentioned by interviewees who did see the list. On the other hand, the lack of knowledge and skills (O1) is mentioned most often by interviewees who did see the list and interviewees who did not. The difference in the amount of times the barriers were mentioned can partially be explained by the fact that some interviewees are less involved with the concept circularity. Based on this limitation, it is suggested for future research to present all interviewees with a list of barriers. This way, differences in the number of times a barriers is mentioned cannot be attributed to whether or not the interviewee has seen the list of barriers.

The generalizability of this study forms a final limitation. The empirical context of the organization under study is namely part of the government and strictly regulated in the sense that the only operative is to deliver combat power. The fact that Defense is part of the government should initially not form a limitation since the government has committed itself to the program Netherlands Circular 2050. This program requires all departments of the government to work towards a circular economy. However, due to the operative of the Ministry of Defense it is exempted from the program, which limits the generalization to other departments of the Dutch government. Moreover, departments of the government uphold different rules and procedures than organizations not bound to the government. Therefore, it is hard to generalize the findings of this research to the general industry. For future research it is suggested that either an organization not bound to the government is under study, or a government bound organization which is not exempted from Netherlands Circular 2050 is under study.

Throughout this study, a possible link between different barriers has been noted a few times, such as between investments costs (F1) and the costs of recycled materials (F2). Since some barriers seem to be linked to one another, it might be useful to research the interaction between these barriers and what this means for the framework. Can these barriers for instance stand on their own? Or is it always the case that the presence of one of the two barriers leads to the presence of the other? And is this one-way around or vice versa? Questions like these can be addressed in future research.

6. Conclusion

This study aimed to provide an answer to the following question: "*How do different barriers influence the implementation of circularity in supply chains in the Royal Dutch Army?*" To answer this question, a framework was created which was applied to three projects within the Royal Dutch Army and via general interviews with employees of Defense. Based on the data from the interviews, the framework of barriers was adjusted. For some barriers the name changed, whereas other barriers were completely new to the framework. The revised framework can be found in table 36.

For the Royal Dutch Army, it followed from the empirical data that barriers in all five categories were present. Not all barriers from the framework were found to hinder circularity in supply chains in the Royal Dutch Army, and besides the initial barriers, three additional barriers were found. It differed not only per project which barriers were present, differences were also found depending on the actor group. An overview of the barriers to circularity in supply chains in the Royal Dutch Army can be found below, in table 37, per category. The barriers mentioned the most are made **bold**, these are: no/negative perception (Co2, mentioned 9 times), lack of awareness (Co3, mentioned 9 times), preconditions (Cu3, mentioned 9 times), costs of recycled materials (F2, mentioned 11 times), and lack of knowledge (mentioned 11 times).

Table 37: Barriers to circularity in supply chains in the Royal Dutch Army

Categories	**Barriers**				
Contextual	Customer resistance	**No/negative perception**	**Lack of awareness**	Lack of regulations	
Cultural	Resistance to new business models	**Preconditions**			
Financial	Investment costs	**Costs of recycled materials**			
Organizational	**Lack of knowledge**	No reverse supply chain in place	Circular business does not align with strategy	Time constraints	Measurability
Technological	Lack of technical skills	Limited availability of recycled materials	Quality control of reused/recycled material	Lack of new processes and machines	

In conclusion, this study showed that there are a number of barriers to circularity in supply chains in the Royal Dutch Army. These barriers can be case specific, and thus do not necessarily have to apply to all projects. Moreover, depending on the actor group an employee is in, different (categories of) barriers can be experienced. The presence of categories of barriers is influenced by the complexity of a project, however the specifics of a project are important to determine which categories are hindering in more complex projects. Thus, when assessing the barriers to a circular supply chain, it is important to look at the specifics of the project or supply chain and check which actor groups are involved, in order to determine the barriers.

7. Recommendations to the organization

Based on this study, it is shown that the transition to circular supply chains in the Royal Dutch Army is being hindered by a number of factors. The topics addressed came forward during the interviews, and were used as a point of departure to provide some practical recommendations. The four topics form a roadmap, which should eventually lead to more circular supply chains. Important to note here is that three topics contain sub-steps, for *knowledge* and the *program of demands* these should be followed consecutively. The topic on *measurement* however shows different ways to measure circularity and just one of these steps should be chosen to follow. The roadmap is presented below, an explanation of the different steps is provided later in this chapter.

Table 38: Roadmap to circular supply chains in the Royal Dutch Army

	Steps	**Explanation**	
Context	Step 1	Describe the context	
Knowledge	Step 2	Provide a definition of circular economy for the Royal Dutch Army	
	Step 3	Create an information point/help desk for information and questions	
Program of demands	Step 4	Consult the market to see where the suppliers are currently at	
	Step 5	Write a functional program of demands	
	Step 6	Include a part on circularity in the program of demands	
Measurement	Step 7	Think of how circularity should be measured and be transparent about this to the market	
		a	Tool
		b	Price valuation
		c	Conversation with the market
Decision time	Step 8	Choose the best option	

By following these recommendations, the Ministry of Defense and the Royal Dutch Army not only take part in making the Netherland more circular, but also set an example for other organizations who are exempted from the program Netherlands Circular 2050.

7.1 Context

Firstly, it is important to realize where the opportunities lie for the Royal Dutch Army. Since the main function of the Dutch Ministry of Defense is to deliver combat power, it is recommended to start introducing circularity into non-weapon supporting systems. The projects covered in this study also fall under this sort of system, and have no direct effect on the deployability of weapons, trucks, et cetera. These projects can be carried out and tested first in the Netherlands, before being translated to mission areas. This provides time and space for project leaders to incorporate circularity into their products in a way that the quality does not fall short to linear products.

7.2 Knowledge

7.2.1 Definition

The second step is understanding what is meant by a circular economy. There are currently over a hundred definitions (Kirchherr, Reike, & Hekkert, 2017) regarding circular economy, however a specific definition for the Royal Dutch Army needs to be created. Thus, the question what a circular economy means for the Royal Dutch Army needs to be answered.

7.2.2 Information point

The definition provides a starting point to gain more knowledge on circular economy and circular supply chains. It is useful to create a central information point or help desk, which consists of at least one person who is specialized in the circular economy. This person or these people can provide project leaders with information on circularity, how it can be incorporated in the program of demands, what it may cost, and what can be gained by it. Moreover, if a project leader runs into specific issues, they can direct their questions to this information point.

Besides creating awareness with project leaders, it is also of importance to involve the purchasers in the process. They are the ones that have to procure products and thus have to ask suppliers about circularity. To help purchasers explain circularity to suppliers, why they ask for it in their program of demands, and how it is scored, workshops throughout the organization can be facilitated.

The most important actors for the Royal Dutch Army are the soldiers. With implementing circularity into supply chains, sometimes a change in behavior is necessary. However, there can be resistance to this change due to a lack of awareness or a negative perception of sustainability. Therefore, it is important to guide the soldiers and to connect circularity to their day-to-day business. This can be done by showing that it can be rather easy to change the behavior, and that it has benefits for the work they do.

7.3 Program of demands

7.3.1 Market consultation

Before giving the purchaser a program of demands with which he can start a tender, it is important to consult the market to find out what suppliers are capable of on the topic of circularity. Following from the interviews and different meetings, it is established that this can be done in two different ways: invite all suppliers at the same time, or invite them one by one. Both options have their advantages and disadvantages. By inviting all suppliers at the same time and asking them where they stand, there is transparency between the suppliers. However, since the suppliers are then in a room filled with their competition, they will possibly not uncover where they are truly at. On the other hand, inviting them one

by one can ensure that the suppliers are more willing to share what they are capable off, however this makes the process less transparent. After receiving information on where the suppliers stand, the program of demands can be specified.

7.3.2 Specification

Currently, a program of demands is specified in a technical way. However, for circular supply chains it is important to specify the program in a functional way. This means that suppliers are for instance asked to come up with something from which soldiers can drink, instead of specifically asking them for a bottle made out of PET. This gives suppliers the space to come up with innovative ideas, like a cardboard packet with a certain coating which ensures that the packet does not leak.

7.3.3 Include circularity

When specifying the program of demands, a special part for circularity can be added. In this part of the program, questions can be asked which give the purchaser an insight in how the supplier thinks of circularity and what he plans to do with it. These questions can range from what a supplier understands under a circular economy, what his vision is on circularity, and how he plans to make the whole supply chain more circular.

7.4 Measurement

When the program of demands is concluded, the final step is to set out the tender and choose the supplier who has the best enrollment. Measuring circularity is however easier said than done; a purchaser cannot say ‘whomever I think is most circular will win the tender’. To make it easier, multiple ways to make circularity measurable are identified via interviews, meetings and conversations. These different ways are explained below, and form different options instead of a sequence contrary to the earlier topics in the blueprint. Note that it is important to be transparent to the suppliers which measurement is used.

7.4.1 Tool

One way to measure it is by using a tool. There is a tool which allows a purchaser to score suppliers based on what he thinks is most important. Beforehand the consulting company deliberates with the project leader and/or purchaser what part of the circular economy is most important to them, and what it may cost. Based on this, the consulting company can set up the tool and suppliers can put in their enrollments.

For example: if the project leader/purchaser values recycled content highest, then the supplier with the most recycled content will receive the most points. However, if he finds it most important that a product can be reused at the end-of-life, than this is valued highest. A combinations of recycled content

and reusability can also be made, then the supplier which scores best one both of these will receive the most points.

7.4.2 Price valuation

Another way of measuring circularity can be found if it is already clear what the project leader/purchaser wants from suppliers. If they are for instance looking for recycled content in a product, an equation can be made regarding how much it costs versus the amount of recycled content in the product. For such a price valuation a minimum of recycled content needs to be taken as a starting point, otherwise the product does not fulfill the demands and the enrollment will be rejected. Moreover, a limit needs to be set to the calculation as well, otherwise the prices set by suppliers can become unacceptably high.

For example: the demand is at least 10% recycled content, any enrollment with less recycled content is rejected immediately. The extra price valuation runs up to 50%, so if a supplier puts in more than 50%, they will not receive extra rewards for this. It is important to note here that a supplier with more recycled content in the product does not necessarily win the tender. Instead, a supplier who has a lower price for the product but also less recycled content, might have a better price valuation than a supplier with more recycled content and a higher price.

7.4.3 Conversation with the market

Using a measurement tool or price valuation as a way to make circularity measurable is not always necessary. Sometimes having a conversation between the purchaser and the market is sufficient enough. If it is clear to the market what the purchaser is looking for, and it is thoroughly discussed with all suppliers, the choice a purchaser makes based on the enrollments will likely be accepted. The benefit of this is that the purchaser can in this way refrain from comparing products which might not be comparable at all.

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Appendix

Appendix I: Overview articles on CSC

	Article	Author	Year	Aim	Database
1	Strategic framework towards measuring a circular supply chain management	Jain, Jain & Metri	2018	Develop a strategic framework for measuring CSCM	Scopus
2	Business models and supply chains for the circular economy	Geissdoerfer, Morioka, de Carvalho, & Evans	2018	Propose a framework to integrate circular business models and CSCM towards sustainable development	Scopus, Web of Science
3	In search of a circular supply chain archetype–a content-analysis-based literature review	Batista, Bourlakis, Smart, & Maull	2018	Understand circularity in supply chain configurations that support restorative and regenerative processes	Scopus, Web of Science
4	Barriers to effective circular supply chain management in a developing country context	Mangla, Luthra, Mishra, (…), Dora, Dwivedi	2018	Generate relevant barriers to CSCM adoption in India; ISM-MICMAC-based model is suggested to analyze the barriers; prove a benchmarking framework to assist mangers/government bodies	Scopus, Web of Science
5	Product-service systems business models for circular supply chains	Yang, Smart, Kumar, Jolly, & Evans	2018	Explore the relationship between business model innovation and circularity in supply chains	Scopus
6	Circular supply chains and renewable chemical feed stocks: a network configuration analysis framework	Srai, Tsolakis, Kumar, & Barn	2018	Provide a comprehensive decision-making process and a framework for exploring the commercial viability of supply chains arising from renewable feed stocks	Scopus
7	Supply chain management and the circular economy: towards the circular supply chain	De Angelis, Howards, & Miemczyk	2018	Examine link between tradition SCM, SSCM, and CE; highlight the sources of value creation in a CE; discuss implications for SCM in terms of opportunities and challenges in transition towards CSCs	Scopus, Web of Science
8	Value creation from circular economy-led closed loop supply chains: a case study of fast-moving consumer goods	Mishra, Hopkinson, & Tidridge	2018	Assess how and why the four examples created value, for whom, and to explore some of the key issues in the delivery of those new value propositions within the context of a multi-national FMCG	Scopus, Web of Science
9	Supply chain operations for a circular economy	Batista, Bourlakis, Liu, Smart, & Sohal	2018	Editorial piece: identifies future research directions that seek to develop knowledge and understanding about CE operations, principles, praxis and theoretical advances	Scopus, Web of Science
10	Creating loops with value recovery: empirical study of fresh food supply chains	Vlajic, Mijailovic, & Bogdanova	2018	Focus: reuse, remanufacture and recycling as key recovery processes, and that way indicate possibilities for resource reduction in further research	Scopus
11	On the circular supply chain's impact on revenue growth for manufacturers of assembled industrial products – A conceptual development approach	Larsen, Knudby, Van Wonterghem, & Jacobsen	2018	Identify links between the circular supply chain and the firm's revenue using revenue growth theory developed for the forward supply chain	Scopus
12	Towards the circular supply chain: A literature review of challenges	Bressanelli, Perona, & Saccani	2018	Systematic literature review about the challenges companies face when supply chain is redesigned for CE	Scopus
13	Comparing linear and circular supply chain: A case study from the construction industry	Nasir, Genovese, Acquaye, Koh, & Yamoah	2017	Assess the environmental impacts associated with the two supply chains, also understanding additional dynamics and implications that could arise by the implementation of circular production systems	Scopus
14	Support Circular Economy through Use-Based Business Models: The Washing Machines Case	Gnoni, Mossa, Mummolo, Tornese, & Verriello	2017	Evaluate the potential impacts and benefits of CE tools, in particular combining business model innovation through product-service systems and closed-loop schemes, on the CCC sector on a supply chain level, identifying the main actors involved and the challenges related to such a strategy	Scopus
15	New environmental supplier selection criteria for circular supply chains: Lessons from a consequential LCA study on waste recovery	Prosman & Sacchi	2016	Develop a generic E-SSC for circular supply chains by considering the constrained nature of the supply, the competition of waste handling activities for discarded products as well as the processing of the discarded products in the receiving product system	Scopus, Web of Science

Appendix II: Barriers CE

Authors	Article	Industry	Objective study	Barriers
Ritzén & Sandström, 2017	Barriers to the Circular Economy – Integration of Perspectives and Domains	Large manufacturing companies with technically complex products including forestry, gardening and manufacturing equipment	Report on the initial results of a study on organizational barriers to CE for traditional manufacturing firms having a product-oriented focus and following the dominant linear economy.	- Financial - Structural - Operational - Attitudinal - Technological
Torstensson, 2016	Internal barriers for moving towards circularity – An industrial perspective	Large mature industrial B2B company	To identify barriers that large mature organizations face when applying CE, to open up possibilities and opportunities to overcome them	- Financial - Cultural - Technological - Structural - Contextual
IMSA Amsterdam, 2013	Unleashing the Power of the Circular Economy	The Netherlands	This report was written at the request of Circle Economy (CE), a non-profit organization based in the Netherlands with the aim to accelerate the transition to a circular economy.	- Financial - Institutional - Infrastructural - Societal - Technological
Liu & Bai, 2014	An exploration of firms' awareness on circular economy development in China: an empirical research in China	Manufacturing (beverages, textile, leather, furniture, chemical fibers, transportation equipment, synthetic material, etc.) in China	Research the "gap" existing between a firm's awareness and its actual behavior in developing a circular economy	- Structural - Cultural - Contextual
Kirchherr et al., 2018	Barriers to the Circular Economy: Evidence From the European Union (EU)	Businesses, policy-makers and academics in the EU [since CE has been argued to be "multi-actor"]	What are the main barriers that derail or slow down the transition towards a CE in the EU?	- Cultural - Regulatory - Market - Technological
Van Eijk, 2015	Barriers & Drivers towards a Circular Economy	Different environmental agencies/councils throughout the EU	This literature review has confirmed the gaps that act as barriers to the development of a circular economy, and therefore where further consideration of policy action may be beneficial in promoting the circular economy	- Institutional/Organizational - Cultural/Awareness - Policy & Regulation - Financial - Technological/Infrastructural/Economical

Mont et al., 2017	Drivers and Barriers for the Swedish Industry: The Voice of REES Companies	Swedish companies and organizations interested/in process of innovating business models for a circular economy	This report aims to help supporting the idea of business model innovation for a circular economy among companies in Swedish manufacturing industries and beyond by offering an introduction into the basic concepts and principles of what is called circular business models	- Coercive - Business model - Financial - Value chain - Market - Customer - Organizational - Technological
Vanner et al., 2014	Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains		To provide an initial scoping assessment of potential priorities and policy options to support the transition to a circular economy in the EU	- Lack of skills and investment Lack of enablers - Lack of consumer and business acceptance - Lack of know-how and economic incentives - Lack of consumer information - Lack of waste separation at source - Lack of sustainable procurement incentives - Lack of investment and innovation - Weaknesses in policy coherence - Widespread planned obsolescence in products
Ranta et al., 2018	Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US and Europe	Institutional environments in China, the US and Europe	Analysis of the general and region-specific institutional drivers of and barriers to CE initiatives across China	- Regulative - Normative - Cultural-cognitive
Pheifer, 2017	Barriers & Enables to Circular Business Models		To identify, from a range of current leading CE business practitioners, the key barriers and opportunities that prevent or help them to adapt their current 'linear' business to a 'circular' business	- Incorrect design of products, not designed for longevity, easy maintenance, disassembly and reuse - Not fully understanding the holistic approach of the circular economy

				- Not integrated in the strategy, mission, vision, goals & key performance indicators - Availability of circular economy knowledge and - Financing of circular business propositions (internal & external) - Existence of organizational silos and poor collaboration - No sense of urgency, company culture and people opposed of changing current way of working - Focus on short term Return on Investment (ROI) and costs reduction - Processes and quality management systems are organized in a linear way - Strong hierarchical organization prevents awareness & recognition CE-opportunities at C-level - Culture & behaviour of consumers; price is nr.1 driver in the buying decision - No reverse supply-chain in place - Lack of data and insufficient transparency in the supply-chain - Focus on the end of the product lifecycle - Current governmental (waste) legislation & ruling is designed for linearity - Current linear system in place / Institutional barriers - No financial incentives for circularity, while there is for linearity - Cost of degradation of ecology and society not taken into cost price

Rizos et al., 2015	The Circular Economy: Barriers and Opportunities for SMEs	SMEs: Up-Shirt (textile) and Fairphone (electronic)	To identify key barriers and enablers to adopting circular economy business practices	- Financial - Lack of government support and effective legislation - Lack of information - Administrative burden - Lack of technical skills - Lack of support from the supply and demand network
Xue et al., 2010	Survey of officials' awareness on circular economy development in China: Based on municipal and county level	Cities from northwest China	Gain insight into the awareness of municipal government officials with respect to the promotion process of CE	- Weakness of public awareness - Lack of financial support

Appendix III: Barriers CE explained and classified

Authors	Category	Barriers	Classification
Ritzén and Sandström (2017)	Financial	Measuring financial benefits of circular economy Financial profitability	Financial
	Structural	Missing exchange of information Unclear responsibility distribution	Organizational
	Operational	Infrastructure/Supply chain management	Infrastructural
	Attitudinal	Perception of sustainability Risk aversion	Cultural
	Technological	Product design Integration into production processes	Technological

Authors	Category		Barriers	Classification
Torstensson (2016)	Financial	Primary	Initial investment Inventory Pricing models Quantify Benefits Secure financial flow – relate to refurbishing	Financial
		Secondary	Profit driven company with high profit goals	
	Cultural	Primary	Resistance for new BMs from inside the Company Capital cautious company culture Measuring success/company goals	Cultural
		Secondary	Resources and priorities Promise too much Attitude to selling second-hand Attitude towards leasing	
		Identified by author	Measuring success Risk averse Product oriented Holy profit level within company Discussions are if the customer can be more sustainable – not the company To be based on outsourcing	

	Technological	Primary	Quality compromising when constructing for CE Hard/work-intense/expensive to disassemble the products Quality control of recycled/reused material Uncertainties if remanufacture/reuse would save energy & resources	Technological
		Secondary	Complication with remanufacture and reuse	
		Identified by author	Design to reuse/recycle	
	Structural	Primary	Implementation of new strategy (CE) in a decentralized company Environmental aspects have low priority in R&D projects	Organizational
		Secondary	Involving suppliers in take-back Change long standing contracts Trusting new suppliers No volume benefit with suppliers	
		Identified by author	Being decentralized – related barriers: • Communication gap • Hard to align • Tension between divisions Lack of knowledge and organizing skills Lack of knowledge regarding how to organize for sustainability/CE Changing mature/established firms	
	Contextual	Primary	Material flows systems for take-back	Contextual
		Secondary	Offer global solutions Complexity with large market presence Customer maturity Customer resistance towards leasing Environmental aspects have a low priority at the customer Raw material Regulations regarding batteries Lack of regulations	
		Identified by author	Eco systems & dominant design	

Authors	Category	Barriers	Classification
IMSA Amsterdam (2013)	Financial	Major up-front investment costs Environmental costs (externalities) are not taken into account Shareholders with short-term agenda dominate corporate governance Recycled materials are often still more expensive than virgin Higher costs for management and planning	Financial
	Institutional	Unlevel playing field created by current institutions Financial governmental incentives support the linear economy Circularity is not effectively integrated in innovation policies Competition legislation inhibits collaboration between companies Recycling policies are ineffective to obtain high quality recycling Governance issues concerning responsibilities, liabilities and ownership	Institutional
	Infrastructural	Limited application of new business models Lack of an information exchange system Confidentiality and trust issues hamper exchange of information Exchange of materials is limited by capacity of reverse logistics	Infrastructural
	Societal	Lack of awareness and sense of urgency, also in businesses GDP does not show the real progress or decline of our society Resistance from powerful stakeholders with large interests in status quo	Cultural
	Technological	Limited attention for end-of-life phase in current product designs Limited availability and quality of recycling material New challenges to separate the bio- from the techno-cycle Linear technologies are deeply rooted	Technological

Authors	Category	Barriers	Classification
Liu and Bai (2013)	Structural	Employment term limits imposed on managers affect long-term CE strategies Staff must demonstrate to boss ways in which new recommendations are consistent with past ways No incentives are built into the budgetary system that stimulates circular economy innovation Hierarchical systems inhibits flexibility and innovation	Organizational
	Cultural	Silos exist between planning and production Strong risk aversion of mangers	Cultural
	Contextual	Competing priorities inhibit commitment to circular economy Uncertainty about the market place	Contextual

Authors	Category	Barriers		Classification

Kirchherr et al. (2018)	Cultural	Lacking awareness and/or willingness to engage with CE	Hesitant company culture Limited willingness to collaborate in the value chain Lacking consumer awareness and interest Operating in linear system	Cultural
	Regulatory	Lacking policies in support of a CE transition	Limited circular procurement Obstructing laws and regulations Lacking global consensus	Institutional
	Market	Lacking economic viability of circular business models	Low virgin material prices Lacking standardization High upfront investment costs Limited funding for circular business models	Financial
	Technological	Lacking (proven) technologies to implement CE	Lacking ability to deliver high quality remanufactured products Limited circular designs Too few large-scale demonstration projects Lack of data, e.g. on impacts	Technological

Authors	**Barriers**	**Classification**
Van Eijk (2015) and Vanner et al. (2014)	The lack of internalization of externalities through policy or other measures and the lack of resource pricing, which lead to economic signals that do not encourage the efficient use of or a transition to a circular economy	Contextual
	The lack of skills and investment in circular product design and production	Organizational
	The lack of enablers to improve cross-cycle and cross-sector performance due inter alia to non-alignment of power and incentives for transformation between actors within and across value chains	Organizational
	The lack of consumer and business acceptance regarding consumer-as user, and performance-based payment models	Contextual
	The lack of know-how and economic incentives including for repair and reuse	Organizational
	The lack of consumer information on origins and perishability of products	Cultural
	The lack of waste separation at source (especially for food waste and packaging)	Technological
	The lack of sustainable procurement incentives for public authorities	Institutional
	The lack of investment and innovation in recycling and recovery infrastructure and technologies	Financial
	The lack of harmonization of transport flows systems between municipalities, which leads to confusion among shippers and transporters	Organizational
	Weaknesses in policy coherence (e.g. bioenergy and waste policies)	Institutional
	Widespread planned obsolescence within product chains	Technological

Authors	**Category**	**Barriers**	**Classification**

Mont et al. (2017)	Coercive	Policies that incentivize recycling/incineration over other circular strategies like reuse and refurbishment Regulatory frameworks that target export of waste streams may also hinder circular business models by preventing cross-border movement of products for reuse Difficulty, high cost and long time to gain 'secondary material' status over 'waste' status under the existing environmental permit system Absence of defined targets for resource efficiency in policy Lack of governmental incentives for resource efficiency Legacy product liabilities	Institutional
	Business model	Difficulty to internalize legal risks of extending responsibility beyond point of sale Lack of supply of returned products or resources Difficult to organize takeback logistics Risks with product performance, increased liabilities for reconditioned products or materials	Organizational
	Financial	Liquidity risks as cash flows spread over longer periods of time High upfront investment costs associated with products with longer lifetimes Increased capital needs for pre-financing in the case of leasing models, and relatively lower returns on investment in these models Potential increase of cost of capital as assets are retained on the companies' balance sheets creating a financing demand and thus decrease overall liquidity of the company's asset Risk of not achieving cost-effective repair, reuse, or remanufacturing High costs associated with takeback of products High labor costs related to product disassembly and source separation of waste	Financial
	Value chain	Existing supply chain dependencies and relationships prevent circularity Difficult to cooperate/collaborate with other companies and/or stakeholders More risks from being dependent on market-unstable suppliers compared to being dependent on traditional global commodity markets for virgin materials OEMs may risk damaging relationships with their retailers and dealers by offering repair or refurbishment Component producers and other non-OEMs may have limited or unclear opportunities to adopt circular business models because of their position in the value chain	Organizational
	Market	Products have low residual value at the end of life Low price of many virgin materials is a barrier, especially when the costs of recycled materials are higher Current infrastructure does not support circular offerings, i.e. locked-in infrastructure Lack of supply chains for disassembled products and components, recycled materials (reverse logistics) High labor costs	Infrastructural/ Technological

		Lack of design tools for circular business models and circular products	
	Customer	Lack of consumer awareness about refurbishment, reuse, servicing, performance sales, etc. Lack of and/or uncertainty about consumer acceptance and/or demand for circular offers/products about product or service acceptance Pre-conceived notions that refurbished products are inferior to new products Mishandling of products by customers Data security (IP) concerns from customers	Cultural
	Organizational	Circular business does not align strategically within organization Lack of expertise in the company Lack of expertise within organization and increased demand for company resources	Organizational
	Technological	Products are not designed for circular business models Concerns about technical reusability of materials or lower material quality after reuse Hygienic/safety issues associated with reused or repaired products Lack of spare parts, repair tools, repair guidelines	Technological

Authors	**Barriers**		**Indicators barriers**	**Classification**
Ranta et al. (2018)	Regulative	Institutional environment specific	China: Low-level regulation and its enforcement	Institutional
			US: Lack of national laws supporting CE	
		General institutional	Manufacturer: Regulatory support toward increasing reuse activities is low	
			Integrator: Inconsistent regulation and its enforcement in China and the US	
	Normative	Institutional environment specific	China: It is normatively valuable that many gain their livelihood from informal recycling activities	x
		General institutional	Manufacturer: Lack of indications for normative support for CE outside recycling	x
			Integrator: Reuse of materials considered as waste lacks normative support	Technological
	Cultural-cognitive	Institutional environment specific	China: Tradition of the informal sector collecting valuable recyclables, and food-heavy waste streams	Organizational
			US: Low level of source-separation for recyclables in residential waste	Technological
		General institutional	Manufacturer: Customers prefer new products	Contextual
			Integrator: Low perceived role in activities of reuse and reduce	Contextual

Authors		Barriers	Classification
Pheifer (2017)	Micro	Incorrect design of products, not designed for longevity, easy maintenance, disassembly and reuse	Technological
		Not fully understanding the holistic approach of the circular economy	Organizational
		Not integrated in the strategy, mission, vision, goals & key performance indicators	Organizational
		Availability of circular economy knowledge and skills	Organizational
		Financing of circular business propositions (internal & external)	Financial
		Existence of organizational silos and poor collaboration	Organizational
		No sense of urgency, company culture and people opposed of changing current way of working	Cultural
		Focus on short term Return on Investment (ROI) and costs reduction	Financial
		Processes and quality management systems are organized in a linear way	Infrastructural
		Strong hierarchical organization prevents awareness & recognition CE-opportunities at C-level	Cultural
		Culture & behavior of consumers; price is nr.1 driver in the buying decision	Cultural
	Meso	No reverse supply-chain in place	Organizational
		Lack of data and insufficient transparency in the supply-chain	Infrastructural
		Focus on the end of the product lifecycle	Technological
	Macro	Current governmental (waste) legislation & ruling is designed for linearity	Institutional
		Current linear system in place / Institutional barriers	Institutional
		No financial incentives for circularity, while there is for linearity	Financial
		Cost of degradation of ecology and society not taken into cost price	Financial

Authors	Barriers	Classification
Rizos et al. (2015)	Financial	Financial
	Lack of government support and effective legislation	Institutional
	Lack of information	Organizational
	Administrative burden	x
	Lack of technical skills	Technological
	Lack of support from the supply and demand network	Contextual

Authors	Barriers	Classification
Xue et al. (2010)	Weakness of public awareness	Cultural
	Lack of financial support	Financial

Appendix IV: Barriers SSCM

Authors	Article	Industry	Objective study	Barriers
Sajjad et al., 2015	Sustainable Supply Chain Management: Motivators and Barriers	New Zealand business context	To contribute to an improved understanding of the motivators of and barriers to SSCM implementation	Internal - Lack of awareness and understanding - Behavioral - Psychological External - Lack of suppliers' capability to deliver desired services/products - Higher prices by suppliers - Lack of customer interest - Lack of government leadership
Narayanan et al., 2018	Analyzing the interactions among barriers of sustainable supply chain management practices	Rubber products manufacturing industry in India	Identify, model, analyze and prioritize the barriers in implementing sustainable practices in rubber products manufacturing industry in a state in South India	25 internal and external barriers, of which 11 are researched more in-depth
Al Zaabi et al., 2013	Analysis of interaction between the barriers for the implementation of sustainable supply chain management	Two fastener manufacturing industries that are located in the southern part of India	To determine the relationship between the barriers and to identify the most influential barriers from the recommended barrier list with the help of interpretive structural modeling	13 barriers are considered from extensive literature review of 10 articles
Tay et al., 2015	A Review on Drivers and Barriers towards Sustainable Supply Chain Practices	Literature review	To identify the barriers and drivers towards the implementation of the sustainable supply chain management	Internal - People issues - Strategic issues - Functional issues External - Government - Competitors - Customers - Media

				- Sectoral - Organization - Technology
Jia, Zuluaga, Bailey, & Rueda, 2018	Sustainable supply chain management in developing countries: An analysis of the literature	Literature review, in context of developing countries	To present an analysis of the academic literature addressing SSCM practices in developing countries	- Lack of political support - Lack of knowledge and awareness - Lack of infrastructure - Social barriers and unsupportive culture - High economic cost - Corruption and mock compliance
Moktadir et al., 2018	Modeling the interrelationships among barriers to sustainable supply chain management in the leather industry	Leather industry in Bangladesh	To identify most influential barriers to SSCM practices, particularly in context of developing economies, and examine the causal relationships between them with an aim to facilitate the effective implementation of SSCM in the Bangladeshi leather processing industry	- Environmental - Technology - Knowledge & support - Social - Financial

Appendix V: Barriers SSCM explained and classified

Authors		Barriers	Classification
Sajjad et al., 2015	Internal	Lack of awareness and understanding	Cultural
		Behavioral (people are not willing to change)	
		Psychological (negative perception about sustainability)	
	External	Lack of suppliers' capability to deliver desired services/products	Infrastructural
		Higher prices by suppliers	Financial
		Lack of customer interest	Cultural
		Lack of government leadership	Contextual

Authors		Barriers	Classification
Narayanan et al., 2017	Internal	Poor organizational culture	Cultural
		Lack of commitment by top level management	Cultural
		High initial cost of implementation	Financial
		Lack of policies and practices for the retention of skilled and experienced employees in the organization	Contextual
		Lack of knowledge and training in SSCM	Organizational
		Fear of failure	Cultural
		Lack of clear policies and practices	Contextual
		Lack of budget for SSCM implementation	Financial
		Inconsistent and inadequate performance measures	Cultural
		Complexity of design to reuse/recycle the used products	Technological
		Lack of infrastructure facilities for SSCM implementation	Infrastructural
		Lack of motivation in adopting SSCM	Cultural
		Lack of strategic planning	Organizational
		High cost of hazardous waste disposal	Financial
	External	Lack of government initiatives	Institutional
		Lack of proper rewards and acceptance from the government	Contextual
		Lack of monitoring and control	Cultural
		Lack of benchmark in India	x
		Lack of supply chain support	Organizational
		Lack of markets for recycled materials	Contextual
		Lack of experts in providing expert opinion about sustainable practices	Organizational

		Negative attitude of suppliers toward supplying sustainable raw materials	Cultural
		Lack of mutual trust among the supply chain members	Organizational
		Lack of supply chain partners' performance	Organizational
		Lack of new technology, materials and processes	Technological

Authors	**Barriers**	**Classification**
Al Zaabi et al., 2013	Too high costs for disposal of hazardous waste	Financial
	Cost for environmentally friendly packaging	Financial
	Lack of clarity regarding sustainability	Organizational
	Cost of sustainability and economic conditions	Financial
	Lack of sustainability standards and appropriate regulations	Contextual
	Misalignment of short-term and long-term strategic goals	Organizational
	Lack of effective evaluation measures about sustainability	Cultural
	Complex in design to reduce consumption of resources and energy	Technological
	Inadequate facility for adoptions of reverse logistic practices	Contextual
	Lack of IT implementation	Organizational
	Inadequate industrial self-regulation	Contextual
	Lack of top management commitment to initiate sustainability efforts	Cultural

Authors		**Category**	**Barriers**	**Classification**
Tay et al., 2015	Internal	People issues	Lack of management commitment	Cultural
		Strategic issues	Resources	Cultural
			Performance measurement	
			Organizational size	
			Financial, technical, information, managerial and organizational	
		Functional issues	Purchasing and supply function - Lack of training - Lack of understanding of how to incorporate in purchasing - Other SCM priorities	Organizational
			Lack of corporate structures and processes	Organizational
	External	Government	Regulation	Institutional
		Competitors	Competitive pressures	Organizational

		Customers	Consumer desire for lower prices Poor supplier commitment	Contextual
		Media	Green wash	x
		Sectoral	Less regulated industries	Contextual
		Organization	Policy and market issues	Contextual
		Technology	ICT	Technological

Authors	Barriers	Classification
Jia et al., 2018	Lack of political support	Institutional
	Lack of knowledge and awareness	Cultural
	Lack of infrastructure	Infrastructural
	Social barriers and unsupportive culture	Cultural
	High economic cost	Financial
	Corruption and mock compliance	x

Authors	Category	Barriers	Classification	Main classification
Moktadir et al., 2018	Environmental	Lack of eco-literacy amongst supply chain partner	Structural	Organizational
		Lack of environmental requirement	Contextual	
		Lack of practice on reverse logistics	Structural	
		Lack of awareness of local customers in green product	Cultural	
	Technology	Lack of technical expertise	Structural	Technological
		Resistance to change and adopt innovation	Cultural	
		Lack of cleaner technology	Technological	
		Outdated machineries	Technological	
	Knowledge & Support	Information gap	Structural	Organizational
		Lack of commitment from top management	Cultural	
		Lack of training and education about sustainability	Structural	
		Limited access to market information	Structural	
	Social	Lack of government support & guideline to adopt SSCP	Institutional	Contextual
		Absence of society pressure	Contextual	
		Lack demand & pressure for lower price	Contextual	
		Less of business friendly policy	Institutional	
	Financial	Cost of sustainability & economic condition	Financial	

		Capacity constraints	Financial	Financial
		Lack of funds for SSCP	Financial	
		Green power shortage		

Appendix VI: Barriers classified in 7 categories

Contextual

	CE
Torstensson (2016)	Material flow systems for take-back Offer global solutions Complexity with large market presence Customer maturity Customers resistance towards leasing Environmental aspects have a low priority at the customer Raw material Regulations regarding batteries Lack of regulations Eco systems & dominant design
Liu and Bai (2013)	Competing priorities inhibit commitment to circular economy Uncertainty about market place
Van Eijk (2015) and Vanner et al. (2014)	The lack of internalization of externalities through policy or other measures and the lack of resource pricing, which lead to economic signals that do not encourage the efficient use of or a transition to a circular economy The lack of consumer and business acceptance regarding consumer-as user, and performance-based payment models
Rizos et al. (2015)	Lack of support from the supply and demand network
Ranta et al. (2018)	Customers prefer new products Low perceived role in activities of reuse

	SSCM
Sajjad et al., (2017)	Lack of government leadership
Narayanan et al. (2017)	Lack of policies and practices for the retention of skilled and experienced employees in the organization Lack of proper rewards and acceptance from the government Lack of markets for recycled material
Al Zaabi et al. (2013)	Lack of sustainability standards and appropriate regulations Inadequate facility for adoptions of reverse logistic practices Inadequate industrial self-regulation
Tay et al. (2015)	Consumer desire for lower prices

	Poor supplier commitment Less regulated industries Policy and market issues
Moktadir et al. (2018)	Lack of government support & guideline to adopt SSCP Absence of society pressure Lack demand & pressure for lower price Less of business friendly policy Lack of environmental requirement

Cultural

	CE
Ritzén and Sandström (2017)	Perception of sustainability Risk aversion
Torstensson (2016)	Resistance for new BMs from inside the Company Capital cautious company culture Measuring success/company goals Resources and priorities Promise too much Attitude to selling second-hand Attitude towards leasing Measuring success Risk averse Product oriented Holy profit level within company Discussions are if the customer can be more sustainable – not the company To be based on outsourcing
IMSA Amsterdam (2013)	Lack of awareness and sense of urgency, also in businesses GDP does not show the real progress or decline of our society Resistance from powerful stakeholders with large interests in status quo
Liu and Bai (2013)	Silos exist between planning and production Strong risk aversion of managers
Kirchherr et al. (2018)	Hesitant company culture Limited willingness to collaborate in the value chain

	Lacking consumer awareness and interest Operating in linear system
Van Eijk (2015) and Vanner et al. (2014)	The lack of consumer information on origins and perishability of products
Mont et al. (2017)	Lack of consumer awareness about offerings or misunderstandings about refurbishment, reuse, servicing, performance sales Lack of and/or uncertainty about consumer acceptance and/or demand for circular offers/products about product or service acceptance Pre-conceived notions that refurbished products are inferior to new products or lack in their thrill of 'newness' Mishandling of products by customers Data security (IP) concerns from customers
Pheifer (2017)	No sense of urgency, company culture and people opposed of changing current way of working Strong hierarchical organization prevents awareness & recognition CE-opportunities at C-level Culture & behavior of consumers; price is nr. 1 driver in the buying decision
Xue et al. (2010)	Weakness of public awareness

	SSCM
Sajjad et al. (2015)	Lack of awareness and understanding Behavioral (people are not willing to change) Psychological (negative perception about sustainability) Lack of customer interest
Narayan et al. (2017)	Poor organizational culture Lack of commitment by top level management Fear of failure Inconsistent and inadequate performance measures Lack of motivation in adopting SSCM Lack of monitoring and control Negative attitude of suppliers toward supplying sustainable raw materials
Al Zaabi et al. (2013)	Lack of effective evaluation measures about sustainability Lack of top management commitment to initiate sustainability efforts
Tay et al. (2015)	Lack of management commitment Resources Performance measurement Organizational size

Moktadir et al. (2018)	Lack of awareness of local customers in green product Resistance to change and adopt innovation Lack of commitment from top management

Financial

	CE
Ritzén and Sandström (2017)	Measuring financial benefits of circular economy Financial profitability
Torstensson (2016)	Initial investment Inventory Pricing models Quantify benefits Secure financial flow – relate to refurbishing Profit drive company with high profit goals
IMSA Amsterdam (2013)	Major up-front investment cost Environmental costs are not taken into account Shareholders with short-term agenda dominate corporate governance Recycled materials are often still more expensive than virgin Higher costs for management and planning
Kirchherr et al. (2018)	Low virgin material prices Lacking standardization High upfront investment costs Limited funding for circular business models
Van Eijk (2015) and Vanner et al. (2014)	The lack of investment and innovation in recycling and recovery infrastructure and technologies
Mont et al. (2017)	Liquidity risks as cash flows spread over longer periods of time High upfront investment costs associated with products with longer lifetimes Increased capital needs for pre-financing in case of leasing models and relatively lower returns on investment in these models Risk of not achieving cost-effective repair, reuse, or remanufacturing High costs associated with takeback of products High labor costs related to product disassembly and source separation of waste
Pheifer (2017)	Financing of circular business propositions (internal & external) Focus on short term Return on Investment and costs reduction

	No financial incentives for circularity, while there is for linearity Cost of degradation of ecology and society not taken into cost price
Rizos et al. (2015)	Financial
Xue et al. (2010)	Lack of financial support

	SSCM
Sajjad et al. (2015)	Higher prices by suppliers
Narayanan et al. (2017)	High initial cost of implementation Lack of budget for SSCM implementation High cost of hazardous waste disposal
Al Zaabi et al. (2013)	Too high costs for disposal of hazardous waste Cost for environmentally friendly packaging Cost of sustainability and economic conditions
Jia et al. (2018)	High economic cost
Moktadir (2018)	Cost of sustainability & economic condition Capacity constraints Lack of funds for SSCP Green power shortage

Organizational

	CE
Ritzén and Sandström (2017)	Missing exchange of information Unclear responsibility distribution
Torstensson (2016)	Implementation of new strategy (CE) in a decentralized company Environmental aspects have low priority in R&D projects Involving suppliers in take-back Change long standing contracts Trusting new suppliers No volume benefit with suppliers Being decentralized – related barriers: • Communication gap • Hard to align • Tension between divisions

	Lack of knowledge and organizing skills Lack of knowledge regarding how to organize for sustainability/CE Changing mature/established firms
Liu and Bai (2013)	Employment term limits imposed on managers affect long-term CE strategies Staff must demonstrate to boss ways in which new recommendations are consistent with past ways No incentives are built into the budgetary system that stimulates circular economy innovation Hierarchical systems inhibits flexibility and innovation
Van Eijk (2015) and Vanner et al. (2014)	The lack of skills and investment in circular product design and production The lack of know-how and economic incentives including for repair and reuse The lack of harmonization of transportation flow systems between municipalities, leads to confusion The lack of enablers to improve performance due inter alia to non-alignment of power and incentives for transformation
Mont et al. (2017)	Difficulty to internalize legal risks of extending responsibility beyond point of sale Decreased sales of new products due to increased sales of repaired, reconditioned and remanufactured products Lack of supply of returned products or resources Difficult to organize takeback logistics Unpredictability of volume of returned products can make it difficult for companies to plan and financially forecast
	Existing supply chain dependencies and relationships prevent circularity Difficult to cooperate/collaborate with other companies and/or stakeholders More risks from being dependent on market-unstable suppliers compared to being dependent on traditional global commodity markets for virgin materials OEMs may risk damaging relationships with their retailers and dealers by offering repair or refurbishment Component producers and other non-OEMs may have limited or unclear opportunities to adopt circular business models
	Circular business does not align strategically within organization Diversification of product-oriented businesses with service-focused offerings and lack of expertise in the company Lack of expertise within organization and increased demand for company resources
Pheifer (2017)	Not fully understanding the holistic approach of the circular economy Not integrated in the strategy, mission, vision, goals & key performance indicators Availability of circular economy knowledge and skills Existence of organizational silos and poor collaboration No reverse supply-chain in place
Rizos et al. (2015)	Lack of information
Ranta et al. (2018)	Tradition of informal sector collecting valuable recyclables, and food-heavy waste streams

	SSCM

Narayanan et al. (2017)	Lack of knowledge in SSCM Lack of strategic planning Lack of supply chain support Lack of mutual trust among the supply chain members Lack of experts in providing expert opinion about sustainable practices
Al Zaabi et al. (2013)	Lack of clarity regarding sustainability Misalignment of short-term and long-term strategic goals Lack of IT implementation
Tay et al. (2015)	Purchasing and supply function - Lack of training / Lack of understand of how to incorporate in purchasing - Other SCM priorities Lack of corporate structures and processes
Moktadir et al. (2018)	Lack of eco-literacy amongst supply chain partner Lack of practice on reverse logistics Information gap Lack of training and education about sustainability Limited access to market information

Technological

	CE
Ritzén and Sandström (2017)	Product design Integration into production processes
Torstensson (2016)	Quality compromising when constructing for CE Hard/work-intense/expensive to disassemble the products Quality control of recycled/reused material Uncertainties if remanufacture/reuse would save energy & Resources Complication with remanufacture and reuse Design to reuse/recycle
IMSA Amsterdam (2013)	Limited attention for end-of-life phase in current product designs Limited availability and quality of recycling material New challenges to separate the bio- from the technocycle Linear technologies are deeply rooted

Kirchherr et al. (2018)	Lacking ability to deliver high quality remanufactured products Limited circular designs Too few large-scale demonstration projects Lack of data, e.g. on impacts
Van Eijk (2015) and Vanner	The lack of waste separation at source (especially food waste and packaging) Widespread planned obsolescence within product chains
Mont et al. (2017)	Products have low residual value at the end of life Low price of many virgin materials is a barrier, especially when the costs of recycled materials are higher Lack of design tools for circular business models and for circular products
	Products are not designed for circular business models, i.e. for easy disassembly, repair, refurbishment and remanufacturing and thus physical product attributes make it difficult to reuse products Concerns about technical reusability of materials or lower material quality after reuse Hygienic/safety issues associated with reused or repaired products Lack of spare parts, repair tools, repair guidelines
Pheifer (2017)	Incorrect design of products, not designed for longevity, easy maintenance, disassembly and reuse
Rizos et al. (2015)	Lack of technical skills
Rante et al. (2018)	Reuse of materials considered as waste lacks normative support Low level of source-separation for recyclables in residential waste

	SSCM
Narayanan et al. (2017)	Complexity of design to reuse/recycle the used products Lack of new technology, materials and processes
Al Zaabi et al. (2013)	Complex in design to reduce consumption of resources and energy
Tay et al. (2015)	ICT
Moktadir et al. (2018)	Lack of cleaner technology Outdated machineries

Infrastructural

	CE
Ritzén and Sandström (2017)	Infrastructure/Supply chain management

IMSA Amsterdam (2013)	Limited application of new business models Lack of an information exchange system Confidentiality and trust issues hamper exchange of information Exchange of materials is limited by capacity of reverse logistics
Kirchherr et al. (2018)	Current infrastructure does not support circular offerings, i.e. locked-in infrastructure Lack of networks and/or supply chains for disassembled products and components and recycled materials (reverse logistics) High labor costs
Pheifer (2017)	Lack of data and insufficient transparency in the supply-chain Process and quality management systems are organized in a linear way

	SSCM
Sajjad et al. (2015)	Lack of suppliers' capability to deliver desired services/products
Narayanan et al. (2017)	Lack of infrastructure facilities for SSCM implementation

Institutional

	CE
IMSA Amsterdam (2013)	Unlevel playing field created by current institutions Financial governmental incentives support the linear economy Circularity is not effectively integrated in innovation policies Competition legislation inhibits collaboration between companies Recycling policies are ineffective to obtain high quality recycling Governance issues concerning responsibilities, liabilities and ownership
Kirchherr et al. (2017)	Limited circular procurement Obstructing laws and regulations Lacking global consensus
Van Eijk (2015) and Vanner	The lack of sustainable procurement incentives for public authorities Weaknesses in policy coherence (e.g. bioenergy and waste policies)
Mont et al. (2017)	Policies that incentivize recycling, incineration, or disposal over other circular strategies such as reuse and refurbishment Regulatory frameworks that target export of waste streams may also hinder circular business models by preventing cross-border movement of products for reuse Difficulty, high cost and long time to gain 'secondary material' status over 'waste' status under the existing environmental permit system Absence of defined targets for resource efficiency in policy

	Lack of governmental incentives for resource efficiency Legacy product liabilities
Pheifer (2017)	Current governmental (waste) legislation & ruling is designed for linearity Current linear system in place
Rizos et al. (2015)	Lack of government support and effective legislation
Ranta et al. (2018)	Low-level regulation and its enforcement Lack of national laws supporting CE Regulatory support toward increasing reuse activities is low Inconsistent regulation and its enforcement in China and the US

	SSCM
Narayanan et al. (2017)	Lack of government initiatives
Tay et al. (2015)	Regulation
Moktadir et al. (2018)	Lack of government support & guideline to adopt SSCP Less of business friendly policy

Appendix VII: Sources framework of barriers

	Article	Author	Year	CE/SSCM
1	Analysis of interaction between the barriers for the implementation of sustainable supply chain management	Al Zaabi, Al Dhaheri & Diabat	2013	SSCM
2	Unleashing the Power of the Circular Economy	IMSA Amsterdam	2013	CE
3	Sustainable supply chain management in developing countries: An analysis of the literature	Jia, Zuluaga, Bailey & Rueda	2018	SSCM
4	Barriers to the Circular Economy: Evidence from the European Union	Kirchherr, Pscicelli, Bour, Kostense-Smit, Muller, Huibrechtse-Truijens & Hekkert	2018	CE
5	An exploration of firms' awareness and behavior of developing circular economy: An empirical research in China	Liu & Bai	2014	CE
6	Modeling the interrelationships among barriers to sustainable supply chain management in leather industry	Moktadir, Ali, Rajesh & Paul	2018	SSCM
7	Drivers and Barriers for the Swedish Industry: The Voice of REES Companies	Mont, Plepys, Whalen & Nußholz	2017	CE
8	Analyzing the interactions among barriers of sustainable supply chain management practices	Narayanan, Sridharan & Ram Kumar	2018	SSCM
9	Barriers & Enables to Circular Business Models	Pheifer	2017	CE
10	Barriers to the Circular Economy – Integration of Perspectives and Domains	Ritzén & Sandström	2017	CE
11	The Circular Economy: Barriers and Opportunities for SMEs	Rizos, Behrens, Kafyeke, Hirschnitz-Garbers & Ioannou	2015	CE
12	Sustainable Supply Chain Management: Motivators and Barriers	Sajjad, Eweje & Tappin	2015	SSCM
13	A Review on Drivers and Barriers towards Sustainable Supply Chain Practices	Tay, Rahman, Aziz & Sidek	2015	SSCM
14	International barriers for moving towards circularity – an industrial perspective	Torstensson	2016	CE
15	Survey of officials' awareness on circular economy development in China: Based on municipal and country level	Xue, Chen, Geng, Guo, Lu, Zhang & Lu	2010	CE

Appendix VIII: Interview guide semi-structured interview

(Translated from the Dutch version)

- Introduction self (name/study/research)
- Introduction interviewee (name/function)
- Circular economy
    - Definition – familiar with it?
    - Importance why looking at it – link to Netherlands Circular 2050
- Project (skipped for general interviews)
    - Explain the project
    - What is the interviewees role within the project
- Barriers
    - Which you can think of?
    - Discuss based on the list of barriers extensively
        - Current vs. expected
    - Place the categories of barriers on a timeline (skipped for general interviews)
- Questions/remarks

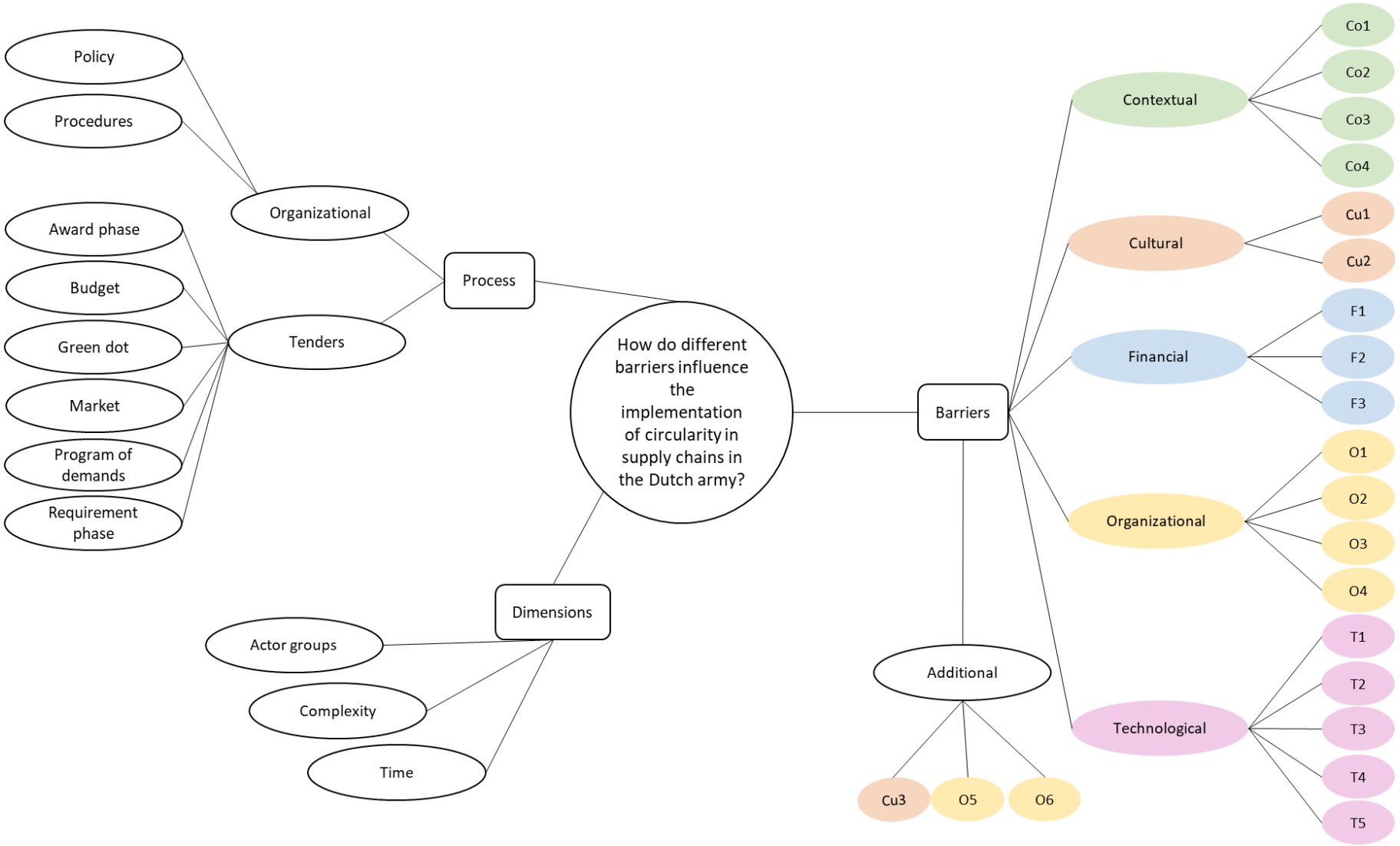
Appendix IX: Interview guide semi-structured interview expert

(Translated from the Dutch version)

This interview is a little different than the other interviews, since the three projects under study are discussed in this interview and the expert is asked to give his opinion on all of them.

- Project 1
    - Discuss list of barriers
    - Place categories of barriers on a timeline
- Project 2
    - Discuss list of barriers
    - Place categories of barriers on a timeline
- Project 3
    - Discuss list of barriers
    - Place categories of barriers on a timeline
- Complexity of the projects
    - Which are more or less complex, comparison between the projects
- Actor groups
    - Which actors face which categories of barriers
- Questions/remarks

Appendix X: Coding tree



Appendix XI: Barriers mentioned by actors

		Co1	Co2	Co3	Co4	Cu1	Cu2	***Cu3***	F1	F2	F3	O1	O2	O3	O4	***O5***	***O6***	T1	T2	T3	T4	T5	Total
CPE	Project leader							x				x									x		3
	Purchaser[6]									x					x		x	x	x			x	**6**
	Supplier A								x	x								x	x			x	5
	Supplier B								x	x								x				x	4
	Expert						x		x	x		x	x										**5**
PET	**Project leader**	x	x	x	x		x	x	x	x		x	x	x	x	x	x						**14**
	Project associate	x	x	x	x			x	x	x		x		x	x	x	x						**12**
	Soldiers[7]		(x)	(x)																			2
	Suppliers																		x		x		2
	Expert	x	x	x			x					x	x	x	x						x		**9**
Tent	**Project leader**						x	x	x	x	x	x			x	x		x			x		**10**
	Expert					x	x		x	x		x	x		x								**7**
Other	**Project leader Combat**		x	x			x	x			x	x	x	x	x	x	x						**11**
	Head Environ. of DMO			x				x				x				x							4
	Head Environ. of CLAS		x	x				x				x											4
	Purchaser DOSCO		x	x			x			x		x											**5**
	PL tent training		x					x				x											3
	PL water treatment											x											1
	Ext. Purch MatLogCo	x	x				x	x		x		x		x				x	x		x	x	**11**
	Consult. Comp.	x		x						x		x						x	x	x			**7**
	List	4	5	5	2	0	5	5	3	7	2	7	2	4	5	4	4	4	3	1	2	2	
	No list	0	2	2	0	0	0	4	2	2	0	5	0	0	0	1	0	2	2	0	2	2	
	Expert	1	1	1	0	1	3	0	2	2	0	3	3	1	2	0	0	0	0	0	1	0	
	Total	**5**	**9**	**9**	**2**	**1**	**8**	**9**	**7**	**11**	**2**	**15**	**5**	**5**	**7**	**5**	**4**	**6**	**5**	**1**	**5**	**4**	

[6] Actors made **bold** are actors with whom the list of barriers was discussed

[7] Barriers mentioned by soldiers come from secondary data, therefore these barriers are not taken into account in the 'no list' group