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Supply chains in circular business models: processes and performance objectives

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ABSTRACT

Circular business models formulate sustainable business strategies. To evaluate sustainable business strategies, it is necessary to be able to measure the actual performance of all processes of a supply chain in a circular business model. To measure the actual performance it is required to define what performance objectives are being pursued for all processes of a supply chain in a circular business model. There is a common understanding in literature that a supply chain in a circular business model differs from a supply chain in a linear business model. However, studies on what processes and what performance objectives conceptualize a supply chain in a circular business model are currently not available. A systematic literature review is conducted to conceptualize the processes and performance objectives of a supply chain in a circular business model. The study indicates that a supply chain in a circular business model consists of eight processes: (1) Plan, (2) Source, (3) Make, (4) Deliver, (5) Use, (6) Return, (7) Recover, (8) Enable. Several processes need to be supplemented with subprocesses to enable planning of use and recovery, delivery of maintenance products and the return of end-of-use products. Furthermore, several processes need to shift their focus towards matching availability of resources (materials, water, energy) with the requirements of the supply chain, sourcing materials that minimize waste and enable returns and recovery after end-of-use, resource efficient production, sustainable packaging, waste disposal, buy-back and take back programs. The performance objectives can be classified into performance objectives for the circular economy, performance objectives that focus on the Triple Bottom Line and performance objectives that characterize a supply chain in a circular business model.

1. Introduction

A circular business model is a framework to formulate a sustainable business strategy (Bocken \textit{et al.}, 2016; Geissdoerfer \textit{et al.}, 2018). Circular business models formulate these sustainable business strategies as, for example, the 3Rs: Reduction, Reuse, Recycle (Ghisellini \textit{et al.}, 2016) or the 9Rs: Refuse (make product redundant), Rethink (intensifying the product’s use), Reduce (increase efficiency in production or use), Re-use, Repair, Refurbish, Remanufacture, Repurpose (new product with different function), Recycle and Recover (incineration of materials with energy recovery) (Kirchherr \textit{et al.}, 2017; Kravchenko \textit{et al.}, 2019; Potting \textit{et al.}, 2017; Saidani \textit{et al.}, 2019). Within these sustainable business strategies a hierarchy is assumed, a preferred order of sustainable business strategies (Ellen MacArthur Foundation, 2013a; Potting \textit{et al.}, 2017). The hierarchy of sustainable business strategies is represented in the sequence of the 9Rs. The hierarchy suggests that strategies which are positioned higher in the hierarchy, will lead to more sustainable business (Ellen Mac Arthur Foundation 2013a; Potting \textit{et al.}, 2017).

However, to date the theories suggesting that strategies positioned higher in the hierarchy indeed lead to more sustainable business, lack empirical evidence (Sehnem \textit{et al.}, 2019). On the contrary, several examples from practice indicate that recycling products is less sustainable than incinerating or landfilling them. This is because recycling requires reverse logistics to collect products from end-users and a disassembly process of the product. This will lead to the use of energy, water, chemicals, production and distribution capacity. In certain cases this will result in a larger environmental impact and more costs as compared to a situation in which virgin materials would have been used and the product is incinerated after end-of-life (Sehnem \textit{et al.}, 2019). To evaluate sustainable business strategies it is not sufficient to rely on mere assumptions on the hierarchy of sustainable business strategies. Instead, it is necessary to be able to measure the actual performance of processes following the execution of a strategy. The actual performance
occurs during value creation, value delivery and value retention which involves all processes of the entire supply chain (Bocken et al., 2018; Geissdoerfer et al., 2018; Urbinati et al., 2017). In circular supply chain literature there is a common understanding that a supply chain in circular business model differs from a supply chain in a linear business model (Batista et al., 2018; Farooque et al., 2019; Urbinati et al., 2017). However, studies on what processes conceptualize a supply chain in a circular business model are, based on the findings of this study and to the best of our knowledge, currently not available. This is remarkable, since a profound understanding of the processes of which performance should be measured is required to be able to determine the performance of any strategy. Performance measurement, rather than assumptions, is required in order to be able to make actual and factual claims on the performance of sustainable business strategies (APICS, 2017; Neely, 2002). Defining the performance objectives for processes is the first step in developing performance measurement (Bourne et al., 2000). As a consequence, to be able to measure the actual performance of a supply chain in a circular business model, it is required to define which performance objectives are being pursued for processes of a supply chain in a circular business model.

Besides the 3Rs and 9Rs other strategies are available. Other strategies are, for example, slowing (extension of a product’s lifetime), closing (recycling and narrowing (using fewer resources per product) resource loops (Bocken et al., 2016). This is supplemented by Geissdoerfer et al. (2018) with intensifying (intensifying the product’s use) and dematerializing (substitute product for service) resource loops. Furthermore, new taxonomies of circular business models are being developed (Urbinati et al., 2017). Still, for any strategy, it is a need to be able to measure its sustainable performance, for which a profound understanding of all processes of the supply chain and its performance objectives is a requirement (APICS, 2017; Bourne et al., 2000; Neely, 2002). Moreover, strategies need to be operationalized, need to be translated into action (APICS, 2017; Neely, 2002; Taticchi et al., 2013). Performance objectives are set for processes and actions are executed. The progress of actual performance towards these performance objectives is monitored, reported and controlled (Neely, 2002; Hald and Mouriisten, 2018; Taticchi et al., 2013). Incumbents that aspire a transition towards a circular business model will have to set performance objectives for processes, put strategy into action and monitor, report and control the progress of actual performance towards performance objectives. Therefore, a transition towards a circular business model requires a set of performance objectives for processes of a supply chain in a circular business model.

In recent years there have been several literature reviews on circular supply chains. Table 1 presents previous literature reviews on circular supply chains and their main topics.

| Author                  | Year | Main topics                                                                 |
|-------------------------|------|-----------------------------------------------------------------------------|
| Masi et al              | 2017 | Drivers, inhibitors and enabers of for circular supply chain configurations |
| Batista et al           | 2018 | Scope, focus and impact of the circular supply chain                         |
| Farooque et al          | 2019 | Definition of circular supply chain management. Drivers and barriers. Indicators and measurement tools. Integrating circular economy in supply chain functions. |
| Taghikha et al          | 2019 | Traditional, sustainable and sustainable circular supply chain               |
| Lahane et al            | 2020 | Analysis of research design, research methods, data analysis techniques, mathematical tools, theories, multi-criteria decision making and industries. |
| González-Sánchez et al  | 2020 | Greater intensity in the relationships, adaptation of logistics and organizational, disruptive and smart technologies, and a functioning environment support the development of circular supply chains |

This paper is structured as follows. Section 2 describes the theoretical background, which focuses on business models, strategy, processes and performance objectives, circular economy, supply chain, open-loop supply chain, closed-loop supply chain and circular supply chain and the SCOR framework of supply chain processes and performance objectives. Section 3 explains the methodology. Section 4 describes the results of the literature review. Section 5 presents the discussion, followed by the conclusions in section 6. Finally, section 7 presents the opportunities for further research.

2. Theoretical background

This section introduces the key concepts of this paper: business models, strategy, processes and performance objectives (2.1), circular economy (2.2), the similarities and differences between supply chain, open-loop supply chain, closed-loop supply chain and circular supply chain (2.3) and SCOR, a framework of supply chain processes and performance objectives, which is used to analyze the results of this study.

2.1. Business models, strategy, processes and performance objectives

A business model is a framework to formulate a business strategy (Bocken et al., 2016; Geissdoerfer et al., 2018; Osterwalder and Pigneur, 2010; Richardson, 2008). A strategy is an approach to outperform competitors and gain competitive advantage (Barney and Hesterly, 2010; Richardson, 2008). A strategy defines the value proposition (which needs of which customer segments to satisfy), value creation (resources and processes required to create value including the relationships with suppliers and customers), value delivery (resources and processes required to deliver value to customers) and value capture (cost structure and revenue streams) (Bocken et al., 2018; Osterwalder and Pigneur, 2010; Richardson, 2008). Value proposition,
value creation, value delivery and value capture must form a coherent system and strategy represents the logic of this coherence (Richardson, 2008).

A strategy needs to be translated into action (Barney and Hesterly, 2010; Kaplan and Norton, 1996; Osterwalder and Pigneur, 2010; Richardson, 2008). For a strategy to become action, it is determined which key processes are required to create and deliver value and which performance objectives need to be accomplished to execute the strategy (APICS, 2017; Gunasekaran et al., 2004; Richardson, 2008). The key processes and performance objectives should contain multiple levels of connected hierarchy (APICS, 2017). These levels enable to translate the strategy into decision making on a strategic, tactical and operational level in the organization (Bourne et al., 2000; Neely et al., 1995). Furthermore, these levels enable all levels to report, monitor and control their progress towards the performance objectives and their contribution to strategic success (Gunasekaran et al., 2004; Jensen and Sage, 2000).

2.2. Circular economy

Although there is not a unified definition of circular economy (Kirchherr et al., 2017), the definition of the Ellen MacArthur Foundation is renowned: “an industrial economy that is restorative or regenerative by intention and design.” (Ellen MacArthur Foundation, 2013a). The circular economy focuses on the efficient use of materials, reduction of waste and recycling of materials (Kirchherr et al., 2017) and strives to improve the Earth’s ecosystem via profitable business models (Aminoff and Kettunen, 2016; Geissdoerfer et al., 2018; Lewandowski, 2016).

Various authors have made important contributions to literature on circular economy. The work by Pearce & Turner (1990) is often referred to as a key contribution to the concept of circular economy (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Govindan and Hasanagic, 2018). Pearce and Turner (1990) present the circular economy as a closed-system. The natural environment provides resources (materials, water, energy) which are the input of production. Production converts these resources into products and services for consumption. The natural environment, production and consumption create waste. Waste is any resource not used for production or consumption. Waste is either recycled into resources or disposed into the natural environment. The natural environment has assimilative capacity. Assimilative capacity is the capability of nature to absorb waste and convert this into harmless or useful resources. As long as waste is disposed within the assimilative capacity, the environment retains its capability to convert this waste into resources. However, if the waste that is disposed exceeds the assimilative capacity, the capability of the environment to provide resources is damaged. This will lead to a decrease of resources. Finally, extraction of resources which exceeds its yield will also lead to a damaged capability of the environment. This will also lead to a decrease of resources (Pearce and Turner, 1990) (Fig. 1).

A linear economy is an open system in which the environment is being ignored. The environment consists of extraction and yield of resources, waste, assimilative capacity and recycling (Pearce and Turner, 1990). On the other hand, a circular economy is a closed system. In a closed system the environment is part of the system. The extraction of resources compared to its yield is taken into consideration. Waste, via recycling, is input for the creation of new resources (Boulding, 1966; McDonough and Braungart, 2010; Pearce and Turner, 1990). Subsequently, we can draw a parallel between the circular economy and supply chains by considering supply chains as a system. A linear supply chain then is an open system which ignores the environment of extraction and yield of resources, waste, assimilative capacity and recycling. A circular supply chain is a closed system in which the environment is part of the system. A circular supply chain takes into consideration the extraction and yield of resources, waste, assimilative capacity and recycling (Batista et al., 2018; De Angelis et al., 2018).

2.3. Supply chain, open-loop supply chain, closed-loop supply chain and circular supply chain

Supply chains in a circular economy are often referred to as open-loop supply chains, closed-loop supply chains as well as circular supply chains (Geissdoerfer et al., 2018). There are several similarities and differences between supply chains, open-loop supply chains, closed-loop supply chains and circular supply chains. These concepts are clarified by describing their origins and relate these origins to the development of the SCOR framework in the same era. SCOR is a framework used by practitioners and academics alike to describe the processes, performance, practices and required skills within a supply chain (APICS, 2017; Schrödl and Simkin, 2014; Ntobe et al., 2015).

The management of supply chain, open-loop supply chain, closed-loop supply chain and circular supply chain originated in different eras in response to different challenges and opportunities. Supply chain management has for long been focused on coordinating a network of organizations that supply, produce and deliver goods to end-users (Croom et al., 2000). This is referred to as the linear model, take-make-consume-dispose or the forward supply chain (Geissdoerfer et al., 2017). This approach is also apparent from the first SCOR model, introduced in 1996, which included four business processes: Plan, Source, Make and Deliver (Lambert et al., 2005). Around the turn of the century, supply chain management was faced with a new challenge. The rise of e-commerce led to an increased reverse flow of goods from end-

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**Fig. 1.** Circular Economy model, redrawn after Pearce & Turner (1990)
users to producers, also referred to as reverse logistics. Following this development, the Return process was introduced in SCOR in 2001, in version 5.0 (Lambert et al., 2005). Initially this reverse flow of goods was considered to be a burden and the focus was on cost minimization. Later companies recognized how forward flow and reverse flow are interconnected and how both flows can be optimized simultaneously. In addition, a distinction was made between a reverse flow in the same sector and a reverse flow to another sector. In case of a reverse flow in the same sector, this is referred to as a closed-loop supply chain. In case of a reverse flow to another sector, this is called an open-loop supply chain (Batista et al., 2018; Farooque et al., 2019; Genovese et al., 2017; Guide et al., 2003). With the transition towards a circular economy, supply chains take into consideration their impact on the environment and the attention increases for opportunities to create value by reducing, maintaining and recovering natural resources. This is also referred to as the circular model, make-use-return or the circular supply chain (Geissdoerfer et al., 2017).

2.4. SCOR

SCOR is a framework of supply chain processes, performance objectives and metrics, best practices and skills (APICS, 2017). In this study, SCOR is used to analyze the results. SCOR was chosen for a variety of reasons. Although, various supply chain frameworks are available in literature, practitioners and academics alike, consider SCOR as the de facto standard framework for supply chains (Huan et al., 2004; Lambert et al., 2005; Ntabe et al., 2015; Schrödl and Simkin, 2014). SCOR has a proven track record in practice and literature in a variety of sectors throughout many years (APICS, 2017; Huan et al., 2004; Ntabe et al., 2015; Schrödl and Simkin, 2014). Since its origin, SCOR has continuously evolved by adapting to changing requirements of its users (APICS, 2017; Lambert et al., 2005). Furthermore, SCOR is able to support strategic decision making and changing management, relevant in a transition towards a circular business model (Huan et al., 2004). Finally, the latest version of SCOR includes performance measures focused on sustainable supply chain management (APICS, 2017).

SCOR consists of six processes (Plan, Source, Make, Deliver, Return and Enable) subdivided into various pre-defined subprocesses that serve as building blocks to describe any supply chain. The process Plan represents the planning and control activities. The process Source represents the identification and selection of sources of supply, scheduling deliveries and receipt of products and transfer of the product. The process Make represents the conversion of materials into products or services. The process Deliver represents the fulfilment of orders: picking, packing, shipment and invoicing. The process Return represents the reverse flow of goods from the end-user. The process Enable describes the activities associated with management of the supply chain.

Furthermore, SCOR consists of an extensive set of performance objectives that are subdivided into five different performance attributes: reliability, responsiveness, agility, cost and asset management efficiency. A performance attribute is a group of performance objectives that can be used to express a supply chain strategy (APICS, 2017). Performance metrics measure the ability to achieve performance objectives and thus to execute the supply chain strategy (APICS, 2017) (Fig. 2).

3. Methodology

The objective of this study is to define the concepts of processes and performance objectives of supply chains in a circular business model. To achieve this objective, a systematic literature review will be conducted. A systematic literature review enables to report descriptive results and thematic results (Denyer and Tranfield, 2009). Reporting descriptive results is focused on the number of publications per year, per journal or per research method. However, literature on supply chains in a circular business model is still in its infancy and few articles have appeared over the years (Geissdoerfer et al., 2018). Reporting descriptive results seems to offer little insight in this stage of theory development (Edmondson and McManus, 2007). Therefore, the review conducted in this study will focus on the thematic results. The thematic results aim to identify and describe the processes and performance objectives of supply chains in a circular business model and thereby defining these concepts. The approach of Denyer and Tranfield (2009) is commonly used for systematic literature reviews in the field of circular supply chain management (Batista et al., 2018; Bressanelli et al., 2018; De Angelis et al., 2018; Govindan and Hasanagic, 2018; Masi et al., 2017). The approach consists of five steps: 1. Question formulation, 2. Locating studies, 3. Study selection and evaluation, 4. Analysis and synthesis and 5. Reporting and using the results. In the subsequent sections these steps will be described in more detail.

3.1. Question formulation

As described and motivated in the first section of this paper, the structured literature review will focus on the research questions as described in section 1.

3.2. Locating studies

To be able to define the concepts of processes and performance objectives of supply chains in a circular business model, this study aims to bring together two research streams: circular economy and supply chains. Based on this objective a search string was formulated per research stream. For circular economy the search string was ‘circular’ to locate the widest possible set of articles related to ‘circular’, such as circular economy, circular business models, circular supply chain. For supply chain the search string was ‘supply chain’ to locate the widest possible set of articles related to supply chain, such as supply chain management, closed-loop supply chain, reverse supply chain, sustainable supply chain, green supply chain and circular supply chain.

In May 2020 a search was executed in the Scopus literature database with the search string “circular” AND “supply chain” in the article title, abstract and keywords. This resulted in a total set of 576 articles.

3.3. Study selection and evaluation

To enable study selection and evaluation a set of inclusion and exclusion criteria of articles has been compiled. The inclusion and exclusion criteria and the motivation to apply these criteria are described in the following table.

The abstract of all articles in the set of 576 articles was read and articles were selected based on the exclusion and inclusion criteria.
described in the next section. The inclusion and exclusion criteria are applied for study selection in the order described in the following table (Table 2).

The original set of 576 articles contained 515 articles, reviews and conference papers. Conference papers were included to be able to review the latest development in the field which seems appropriate since the field of supply chains in circular business model is still in its early stages of development (Geissdoerfer et al., 2018). Furthermore, 82 articles presented results on the development of a circular economy in a specific country or region. 163 articles presented results on the development of a circular economy in a specific sector, such as buildings, construction, forestry, hospitals, universities, educational programs, plastics, retail, mining, agri/food, waste treatment and waste to energy. The motivation for this exclusion is that the aim of this paper is to develop concepts that enable generalization rather than to report country specific or sector specific results. A large part of the original set of articles did not focus on the key topic of this review: processes and performance objectives of a supply chain in a circular business model. 242 articles were excluded because of its topic which was not relevant for this study, such as circular economy in relation to technology, regulations, governance, life cycle assessment and leasing. The result was a set of 28 articles. However, 3 articles were not accessible and were therefore excluded from analysis and synthesis. Finally, during reading and evaluating the articles, 10 other relevant articles were identified (APICS, 2017; Elia et al, 2017; Ellen Mac Arthur Foundation, 2013a; Ellen Mac Arthur Foundation, 2015a; Ellen Mac Arthur Foundation, 2015b; Morseletto, 2020; Potting et al., 2017; Saidani et al., 2019; van der Velden and Vogtländer, 2017; Vogtländer et al., 2001). These articles were added to the set for analysis and synthesis. As a result, the set of articles after study selection and evaluation contained 35 articles (Table 3).

3.4. Analysis and synthesis

The articles were studied to find information that indicated processes or performance objectives of supply chains in circular business models. The information found on processes and performance objectives was classified according to SCOR. SCOR is a framework used to conceptualize a supply chain in a circular business model: (1) Plan (2) Source (3) Make (4) Deliver (5) Use (6) Return (7) Recover (8) Enable. The processes and subprocesses in bold, italic marked with * are additional processes for a supply chain in a circular business model compared to a supply chain in a linear business model. The other processes listed are already part of a supply chain in a linear business model (APICS, 2017) and remain part of a supply chain in a circular business model. However, these processes require a shift of focus to

| Table 2 | Inclusion and exclusion criteria for this literature review |
| --- | --- |
| Criteria | Inclusion | Exclusion | Motivation |
| Publication language | Articles written in English | Articles written in other languages | English is the common language for practitioners as well as academics in this field |
| Document type | Articles, reviews, and conference papers | Books, book chapters and editorials | Conference papers to include the latest developments |
| Focus | Articles that describe country specific or sector specific results | The purpose of this literature review is of a more general nature, focused on defining concepts rather than reporting country or sector specific results |
| Topic | Articles that focus on the processes, activities, performance of supply chains in circular business models or circular supply chains | Articles that focus on other topics in relation to circular economy | Processes and performance objectives of supply chains in circular business models is the key topic of this literature review |

3.5. Reporting and using the results

The processes that conceptualize a supply chain in a circular business model are described in section 4.1 until 4.9. Finally, the performance objectives that characterized a supply chain in a circular business model are described in section 4.10 until 4.16.

4. Results

The results of the literature review indicate two key amendments for processes of a supply chain to enable a transition towards a circular business model. First, two processes and fourteen subprocesses should be added to the supply chain to support a transition towards a circular business model. Second, certain existing processes of the supply chain should shift their focus.

Section 4.1 presents the processes of a supply chain in a circular business model. Subsequently, the results per process will be described in section 4.2 until 4.9. Finally, the performance objectives that characterize a supply chain in a circular business model are presented in section 4.10 until 4.16

4.1. Processes of a supply chain in a circular business model

The results are presented according to the eight processes that conceptualize a supply chain in a circular business model: (1) Plan (2) Source (3) Make (4) Deliver (5) Use (6) Return (7) Recover (8) Enable. The processes and subprocesses in bold, italic marked with * are additional processes for a supply chain in a circular business model compared to a supply chain in a linear business model. The other processes listed are already part of a supply chain in a linear business model (APICS, 2017) and remain part of a supply chain in a circular business model. However, these processes require a shift of focus to
| Process Level 1 | Process Level 2 | Remarks | Sources |
|----------------|----------------|---------|---------|
| Plan Source | | | APICS, 2017 |
| Plan Make | | | Blomma & Brennan, 2017; |
| Plan Deliver | | | Farooque et al, 2019; |
| **Plan Use** | | | Genovese et al, 2017; |
| | | | Jain et al, 2018; |
| | | | Koh et al, 2017; |
| | | | APICS, 2017 |
| Source Stocked Product | | The supply chain in a circular business model should focus on sourcing of materials that enable return, disassembly and recovery and minimize waste. Selection of biodegradable and easily returned and recovered materials. | APICS, 2017; |
| Source Make-to-Order Product | | | Ellen MacArthur Foundation, 2013a; |
| Source Engineer-to-Order Product | | | Farooque et al, 2019; |
| **Make** | | The supply chain in a circular business model should focus on resource efficient production. Furthermore, within the process Make there should be more focus on: - Packaging of the product for storage or delivery to end-users - Waste disposal: collection and disposal of waste during production and testing | Jain et al, 2018 |
| Deliver Stocked Product | | Delivery of spare parts for maintenance and repair during Use | De Angelis et al, 2018; |
| Deliver Make-to-Order Product | | | Kalmykova et al, 2018; |
| Deliver Engineer-to-Order Product | | | Koh et al, 2017; |
| Deliver Retail Product | | | APICS, 2017 |
| *MRO* = Maintenance, Repair, Overhaul | | | |
| **Use** | | the process of using the product by the end-user | Govindan & Hasanagic, 2018; |
| | | | Kalmykova et al, 2018; |
| | | | Kirchherr et al, 2017; |
| | | | Koh et al, 2017; |
| | | | APICS, 2017 |
| **Maintenance** | | the process required to retain the product in the state necessary for fulfilment of its function (Gits 1992; Kothamasu et al, 2006) | De Angelis et al, 2018; |
| | | | Ellen Mac Arthur Foundation, 2013a |
| **Repair** | | the process required to restore the product in the state necessary for fulfilment of its function (Gits 1992; Kothamasu et al, 2006) | De Angelis et al, 2018; |
| | | | Ellen Mac Arthur Foundation, 2013a |
| Return Stocked Product | | End-users are a source of products after end-of-life Develop buy back and take back programs | Di Maio et al., 2017; |
| Return Defective Product | | | Jain et al, 2018; |
| Return MRO Product | | | Kalmykova et al, 2018; |
| Return Excess Product | | | APICS, 2017 |
| **Source Return End-of-Use Product** | | Products after end-of-life need to be collected and delivered to a facility for waste processing and/or recovery. | Jain et al, 2018; |
| | | | Kalmykova et al, 2018; |
| | | | Koh et al, 2017; |
| | | | Geisdoerfer et al, 2018; |
| | | | Yang et al, 2018 |
| **Recover** | | the process of reinserting the end product into the supply chain after none or minimal treatment of the end product. Redistribute is a synonym of reuse the process of recovering components from the end product and combining them with new components into a new end product with equal or higher performance than the original end product | Ellen Mac Arthur Foundation, 2013a; |
| | | | Geisdoerfer et al, 2018; |
| | | | Yang et al, 2018 |
| **Remanufacturing** | | process of converting materials into new materials of higher quality and increased functionality | Ellen Mac Arthur Foundation, 2013a |
| **Refurbishing** | | process of good working condition by replacing or repairing major components that are faulty or close to failure, and making 'cosmetic' changes to update the appearance of the end product, such as cleaning, changing fabric, painting or reconditioning | Ellen Mac Arthur Foundation, 2013a |
| **Upcycling** | | the process of converting materials into new materials of higher quality and increased functionality | Ellen Mac Arthur Foundation, 2013a |
| **Recycling** | | the process of recovering materials for the original purpose or for other purposes, excluding energy recovery | Ellen Mac Arthur Foundation, 2013a |
| **Downcycling** | | the process of converting materials into new materials of lesser quality and reduced functionality | Ellen Mac Arthur Foundation, 2013a |
| Enable | | Communication with organizations and private-persons. Buy back and take back programs | (Di Maio et al., 2017) (Jain et al, 2018). |
support a circular business model. This shit of focus is described in the column ‘Remarks’ (Table 4).

4.2. Plan

The process Plan aims to identify supply chain requirements and balance them with available resources and supply chain assets (APICS, 2017). Traditionally there was little to no attention for boundaries in the use of natural resources., as long as they were available to meet supply chain requirements. However, a circular business model requires supply chains to consider environmental boundaries, such as the assimilative capacity of the environment and the extraction of resources compared to its yield (Boulding, 1966; Pearce and Turner, 1990; Urbinati et al., 2017). Therefore, a supply chain in a circular business model will focus more on the availability of natural resources and on the influence supply chain requirements have on the availability of natural resources (Blomsma and Brennan, 2017; Farooque et al., 2019; Genovese et al., 2017; Koh et al., 2017; Pearce and Turner, 1990; Schrödland Simkin, 2014). Circular economy has its origins in industrial ecology (Genovese et al., 2017), is embedded in natural ecosystems (Farooque et al., 2019; Genovese et al., 2017) wherein the health of the eco-system is a key topic (Ellen Mac Arthur Foundation, 2015b). Therefore, the availability of natural resources should be part of a circular business model to which the process Plan provides a key contribution (Blomsma and Brennan, 2017).

This paper claims that a supply chain should be supplemented with the processes Use and Recover to support a transition towards a circular business model. As a consequence, these processes should also be planned and therefore the process Plan should be supplemented with the subprocesses Plan Use and Plan Recover. Plan Use focuses on planning the balance between the requirements of end-users during the lifetime of the product with available resources for maintenance, repair and use. Plan Recover focuses on planning the balance between the requirements to recover products after end-of-life with available resources for recovery. In a supply chain in a circular business model, recovery is an input to the process Make. This input is uncertain with regard to the quantity, timing and location of products returned for recovery (Di Maio et al., 2017), which will affect the planning activities. Planning has a great influence on the performance of supply chains (Farooque et al., 2019).

4.3. Source

The process Source aims to schedule product deliveries, receive and verify the product, transfer the product and authorize supplier payment (APICS, 2017). The supply chain in a circular business model focuses on alternative materials to be sourced. Materials that have a low environmental impact, are easily returned, disassembled and recovered and minimize waste become more important (Farooque et al., 2019; Jain et al., 2018; Prieto-Sandoval et al., 20182018).

4.4. Make

The process Make aims to schedule production activities, issue materials, produce and test, stage product and release products to deliver (APICS, 2017). The process Make consists of the subprocesses Packaging and Waste disposal (APICS, 2017) which is expected to gain importance in a circular business model (Ellen Mac Arthur Foundation 2013a; Farooque et al., 2019). For packaging the focus will be on packaging materials from resources that protect the product not only during delivery but also during return, with low cost and low impact on the environment.

Collection of waste is a characteristic of a supply chain in a circular business model (Batista et al., 2018). Waste arises during the extraction of raw materials from nature, during production when materials do not end up in the product for consumption and after consumption when the product itself is no longer needed. Waste is important as it closes the loop with the environment (Urbinati et al., 2017).

The process Make refers to any process that converts materials into products, which includes activities for maintenance and recovery. Maintenance and recovery have a more prominent place in circular business models (Ünal et al., 2019; Urbinati et al., 2017). Maintenance aims to prolong the lifetime of the product and recovery aims to reuse materials. Therefore, this paper claims that in a supply chain in a circular business model, maintenance and recover should be added as two separate processes. Maintenance will be described in the section on the process Use. Recover will be described in the section on the process Recover.

4.5. Deliver

The process Deliver consists of (amongst others): build loads, route shipments, select carriers, receive product, pick, pack, document, ship and install product and is subdivided into the subprocesses Deliver Stocked Product, Deliver Make-to-Order Product, Deliver Engineer-to-Order Product and Deliver Retail Product (APICS, 2017). Deliver is considered to be a key component of a supply chain in a circular business model (Kalmikova et al., 2018). Deliver will not only focus on shipping products to end-users, it will also organize the delivery of spare parts for maintenance during use of the product to extend the lifetime of the product (Kalmikova et al., 2018). Therefore, the processes of Deliver needs to be supplemented with a subprocess Deliver MRO (Maintenance, Repair, Overhaul) Product.

4.6. Use

Literature on circular economy and circular supply chains describe that consumption is part of the supply chain in a circular business model (Kalmikova et al., 2018; Kirchherr et al., 2017; Koh et al., 2017; Pearce and Turner, 1990). This motivates the addition of the process Use in the supply chain of a circular business model. The process Use consists of the use or consumption of the product by the end-user and the maintenance and repair to prolong the lifetime of the product (De Angelis et al., 2018). The end-user can be a private person in a Business-to-Consumer market as well as an organization in a Business-to-Business market. A circular business model requires end-users to return their products end-of-life as these products are – after recovery – inputs for the process Make. Given the current uncertainty of the quantity, quality and location of these returns, it may be expected that supply chains will include the process Use. Including the process Use enables a better control of the quantity, quality and location of the input of returns. Moreover, end-users can be motivated to use the product as long as possible and stimulated to preserve the quality of the materials. Furthermore, the process Use provides interesting opportunities to collect information about the use of the product. This information may be used to improve the lifetime, sustainability or profitability of the product.

4.7. Return

The process Return aims to move material from the end-user back through the supply chain. Returns are an important part of supply chains and therefore described as one of the primary processes (APICS, 2017). Furthermore, a circular business model requires take-back after end-of-life (De Angelis et al., 2018) and returns are considered to be a key component of any circular business model (Lewandowski, 2016). Therefore, Return is a key process of a supply chain in a circular business model (Urbinati et al., 2017).

Products can be returned because of defects, MRO (Maintenance, Repair and Overhaul) or Excess (APICS, 2017). In a circular business model, products can also be returned because they are at end-of-use.
Therefore, a supply chain in a circular business model should be supplemented with the processes Return End-of-Use.

4.8. : Recover

The importance of recovery activities in a circular business model, motivates that its supply chain should include the process Recover. Possible recovery processes distinguished in this paper are: Reuse, Remanufacturing, Refurbishing, Upcycling, Recycling and Downcycling. The definitions of the processes are described in table 4.

Some authors also refer to upgrading, reconingition or cannibilization (Ellen Mac Arthur Foundation, 2013a; World Economic Forum, 2014). Upgrading is an option in which out-dated modules or components are replaced with technologically superior ones (Ellen Mac Arthur Foundation, 2013a; World Economic Forum, 2014). Upgrading is not used in this article because its defintion overlaps the definition of remanufacturing. Reconingition is restoring parts to a functional and/or satisfactory condition by surfaceing, painting and sleeving (Ellen Mac Arthur Foundation, 2013a; World Economic Forum, 2014). This overlaps with the definition of reuse. Therefore, reconingition is not used in this article. Cannibilization is the selective retrieval of parts from end products (Ellen Mac Arthur Foundation, 2013a; World Economic Forum, 2014). The situation of cannibilization is covered with the definitions of remanufacture or recycle and this term is therefore not used.

4.9. : Enable

The process Enable refers to the management process of the supply chain in a circular business model. Management of a supply chain in a circular business model is faced with a number of specific challenges which were not apparent in a linear business model.

Sourcing of materials will not only focus on suppliers, but also on end-users that dispose their end-of-life products (Di Maio et al., 2017). After return and recovery, these end-of-life products can prove to be a valuable source of materials. To enable the return of end-of-life products, buy back and take back will have to be managed (Jain et al., 2018). The traceability of materials through multiple recovery flows, cost effficient work and minimizing enironmental impact is important (Prieto-Sandoval et al., 2017), while the quality and quantity of returns is uncertain (Guide et al., 2003). Following these developments, the management of supply chains in a circular business model will become more complex and more difficult to organize in an efficient way (Prieto-Sandoval et al., 2018).

Moreover, including the process Use in the supply chain implies that a supply chain in a circular business model includes the end-user. Wherein a supply chain in a linear business model is formed solely by organizations and not private persons, a supply chain in a circular business model may be formed by organizations and private persons. A different composition of actors in the supply chain will place different demands on the organization and communication of management within a supply chain in a circular business model.

The next sections describe the performance objectives that characterize a supply chain in a circular business model.

4.10. : Performance objectives that characterize a supply chain in a circular business model

Literature describes various performance objectives that can be classified into three groups: an overall performance objective of the circular economy, performance objectives that focus on economic, environmental and social benefits and performance objectives that characterize a supply chain in a circular business model.

The overall performance objective of a circular economy is to decouple economic growth from resource depletion (Bresanelli, 2018, De Angelis et al., 2018, Ghisellini et al., 2016; Howard et al., 2019 Koh et al., 2017, Masi et al., 2017). A supply chain is a way to accomplish three performance objectives in parallel, the so-called Triple Bottom Line or 3P (People, Planet, Profit) (Carter and Rogers, 2008). These performance objectives are:

| Economic benefits | Minimize costs and maximize revenues (Kazancoglu et al., 2018) |
|-------------------|---------------------------------------------------------------|
| Environmental benefits | Minimize resource depletion, carbon footprint, toxicity and pollution (Azevedo et al., 2017; Bresanelli 2018; Di Maio et al., 2017; Ellen Mac Arthur Foundation, 2013a; Genovese et al., 2017; Ghisellini et al., 2016, GRI 305, Koh et al., 2017; Howard et al., 2019, Masi et al., 2017, Vogtländer et al., 2001) |
| Social benefits | Maximize employment; Maximize occupational safety & health; Minimize excessive working hours; Minimize extreme poverty and child labor; Maximize social equity; Maximize life expectancy and Maximize education (Azevedo et al., 2017; Ellen Mac Arthur Foundation, 2013a; Geissdoerfer et al., 2017; Kirchherr et al., 2017; Koh et al., 2017; Potting et al., 2017; van der Velden & Vogtländer, 2017; Vogtländer et al., 2001) |

These performance objectives can be pursued by any supply chain. The literature review indicates that a supply chain in a circular business model distinguishes itself by pursuing a specific set of performance objectives. The supply chain in a circular business model is characterized by the following performance objectives:

1 Minimize the use of materials, water and energy
2 Minimize inventory
3 Maximize the efficient use of Supply Chain Assets (trucks, warehouses, machines, equipment)
4 Minimize waste
5 Maximize the availability of the product
6 Maximize the number of recovery flows

These performance objectives will be subsequently described (Table 5).

4.11. : Minimize the use of materials, water and energy

Several authors have described this performance objective in various ways. Geissdoerfer et al (2018) describe the power of dematerialization, via which the use of materials, water and energy is minimized through a shift from physical to virtual goods and services. Potting et al (2017) describe a circular strategy to make the product redundant. Ghisellini et al (2016) describe the reduction principle, which aims to minimize the input of primary energy, raw material and waste.

Ellen Mac Arthur Foundation (2013a) refers to the power of inner circle, which aims to minimize the amount of materials used in end products. Bocken et al (2016) describe this performance objective as narrowing resource loops which aims to use fewer materials, water and energy per product. Ellen Mac Arthur Foundation 2013a (2013a) refers to the power of pure input which aims to minimize the quantity of contaminated end products, components and raw materials in the supply chain.

The performance objective to minimize the use of materials, water and energy applies to every process of the supply chain and includes the process Recover. Recovery of a product, so that is available for subsequent consumption, will have to be accomplished using as less materials, water and energy as possible.

4.12. : Minimize inventory

Inventory should not be available without demand from the end-user in the supply chain of a circular business model. Supply and
| Performance objective | Process | Description | Source |
|------------------------|---------|-------------|--------|
| Overall Circular Economy | Decoupling economic growth from resource depletion | The goal of the circular economy is to decouple economic growth from natural resources depletion | Bresanelli 2018 De Angelis et al, 2018 Ghisellini et al, 2016 Koh et al, 2017 Howard et al, 2019 Masi et al, 2017 |
| Triple Bottom Line (TBL) | Economic (TBL) | Cost | Kazancoglu et al, 2018 |
| | Revenues | Kazancoglu et al, 2018 |
| | Profit | Genovese et al, 2017 Howard et al, 2019 Azevedo et al, 2017 Bresanelli 2018 Koh et al, 2017 Howard et al, 2019 Masi et al, 2017 Vogtländer et al, 2001 APICS, 2017 – GRI 305 Ellen Mac Arthur Foundation, 2013a Genovese et al, 2017 Koh et al, 2017 Di Maio et al., 2017 Ghisellini et al, 2016 Vogtländer et al, 2001 |
| | Environmental (TBL) | Resource depletion | Azevedo et al, 2017 Ellen Mac Arthur Foundation, 2013a Ghisellini et al, 2016 Vogtländer et al, 2001 Carbon footprint or CO2- emissions | APICS, 2017 – GRI 305 Ellen Mac Arthur Foundation, 2013a Genovese et al, 2017 Koh et al, 2017 Di Maio et al., 2017 Ghisellini et al, 2016 Vogtländer et al, 2001 |
| | Toxicity (acidification, eutrophication, heavy metals) | | Azevedo et al, 2017 Ellen Mac Arthur Foundation, 2013a Ghisellini et al, 2016 Vogtländer et al, 2001 |
| | Pollution (carcinogens, summer and winter smog, fine dust) | | Ellen Mac Arthur Foundation, 2013a Vogtländer et al, 2001 |
| Social (TBL) | Employment | Ellen Mac Arthur Foundation, 2013a Geissdoerfer et al, 2017 Potting et al, 2017 Azevedo et al, 2017 Koh et al, 2017 |
| | Occupational safety & health | Azevedo et al, 2017 Koh et al, 2017 |
| | Excessive working hours | van der Velden & Vogtländer, 2017 |
| | Extreme poverty | Koh et al, 2017 |
| | Child labor | van der Velden & Vogtländer, 2017 |
| | Minimum acceptable wage/ Social equity | Kirchherr et al, 2017 Koh et al, 2017 van der Velden & Vogtländer, 2017 |
| | Health/Life expectancy | Koh et al, 2017 |
| | Education | van der Velden & Vogtländer, 2017 |
| Supply chain in a circular business model | Minimize use of materials, water and energy | Minimize use of materials, water and energy Resource efficiency Power of inner circle | Bocken et al, 2016 De Angelis et al, 2018 Di Maio et al., 2017 Ellen Mac Arthur Foundation, 2013a Faroque et al, 2019 Geissdoerfer et al, 2017 APICS (2017) – GRI 301; GRI 302; GRI 303 Azevedo et al, 2017 Di Maio et al., 2017 Ellen Mac Arthur Foundation, 2013a Faroque et al, 2019 Geissdoerfer et al, 2017 Ghisellini 2017 Jain et al, 2018 Kalmykova et al, 2018 Potting et al, 2017 De Angelis et al, 2018 Ghisellini 2017 Parchomenko et al, 2019 |
| Make | Minimize input of use of materials, water, energy in production process | APICS (2017) – GRI 301; GRI 302; GRI 303 Azevedo et al, 2017 Di Maio et al., 2017 Ellen Mac Arthur Foundation, 2013a Faroque et al, 2019 Geissdoerfer et al, 2017 Ghisellini 2017 Jain et al, 2018 Kalmykova et al, 2018 Potting et al, 2017 De Angelis et al, 2018 Ghisellini 2017 Parchomenko et al, 2019 |
| Deliver | Regional networks to reduce transport | “Reproducible and adaptive manufacturing. A transparent and scalable production technology that can be emulated at other places using indigenously available resources and skills.” Optimized package design. Efficient package design. | Kalmykova et al, 2018 |
| **Performance objective** | **Process**                          | **Description**                                                                                                                                 | **Source** |
|---------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Use                       | Goods are sold as services         | Dematerialization                                                                                                                                   | Batista et al. 2018 |
|                           |                                     |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Potting et al. 2017 |
|                           | Maintenance and repair to retain    | products at their desired level of performance                                                                                                   | Batista et al. 2018 |
| Return                    | Improved after-use collection      |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Potting et al. 2017 |
|                           | Improve redistribution efficiency   |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Potting et al. 2017 |
| Recover                   | Products that can easily be        | disassembled and reassembled                                                                                                                        | Bocken et al. 2016 |
|                           |                                     |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ghisselini 2017 |
|                           | Pure inputs, exclusion of toxic     | materials, avoidance of contamination, pure waste streams to improve efficiency of recovery Power of pure circles | Batista et al. 2018 |
|                           |                                     |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Potting et al. 2017 |
|                           | Efficiency of recovery              |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Yang et al. 2018 |
|                           | Reuse with little or no change      | (Reuse is preferred over refurbish is preferred over recycle)                                                                                     | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Ghisselini 2017 |
| Minimize inventory        | Make                                | Make-to-Order or Engineer-to-Order production Prevent overproduction due to its risk of obsolescence                                               | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Kalmykova et al. 2015 |
|                           | Improve flow and reduce stock of    | a material                                                                                                                                         | Lewandowski, 2016 |
|                           |                                     |                                                                                                                                                    | Franklin-Johnson, 2016 |
| Maximize efficient use of | Higher utilization of assets        |                                                                                                                                                    | De Angelis et al. 2018 |
| supply chain assets        |                                     |                                                                                                                                                    | Geissdoerfer et al. 2018 |
| (trucks, warehouses,      |                                     |                                                                                                                                                    | Howard et al. 2019 |
| machines, equipment)      |                                     |                                                                                                                                                    | Lewandowski, 2016 |
| Minimize waste            | Minimize waste                      |                                                                                                                                                    | Borza et al. 2018 |
|                           |                                     |                                                                                                                                                    | De Angelis et al. 2018 |
|                           |                                     |                                                                                                                                                    | Di Maio et al., 2017 |
|                           |                                     |                                                                                                                                                    | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Farooque et al. 2019 |
|                           |                                     |                                                                                                                                                    | Geissdoerfer et al. 2018 |
|                           |                                     |                                                                                                                                                    | Morseletto, 2019 |
|                           |                                     |                                                                                                                                                    | Potting et al. 2017 |
|                           |                                     |                                                                                                                                                    | Yang et al. 2018 |
| Make                     | Recovered material compared to      | virgin material used for production                                                                                                               | APICS, 2017 – GRI 301 |
|                           |                                     |                                                                                                                                                    | Farooque et al. 2019 |
|                           |                                     |                                                                                                                                                    | Genovese et al. 2019 |
|                           |                                     |                                                                                                                                                    | Jain et al. 2018 |
|                           | Minimize waste during production    |                                                                                                                                                    | Farooque et al. 2019 |
|                           |                                     |                                                                                                                                                    | Lacy et al. 2014 |
|                           | Lean thinking                       |                                                                                                                                                    | Lewandowski, 2016 |
| Use                      | Increase the number of products    | returned                                                                                                                                         | APICS, 2017 – GRI 301 |
|                           |                                     |                                                                                                                                                    | Bocken et al. 2016 |
|                           |                                     |                                                                                                                                                    | Di Maio et al., 2017 |
|                           |                                     |                                                                                                                                                    | Franklin-Johnson, 2016 |
|                           |                                     |                                                                                                                                                    | Lewandowski, 2016 |
| Recover                  | Collected material after use        | compared to recovered material                                                                                                                     | Lacy et al. 2014 |
|                           |                                     |                                                                                                                                                    | Azevedo et al. 2017 |
|                           |                                     |                                                                                                                                                    | Genovese et al. 2019 |
|                           |                                     |                                                                                                                                                    | Ghisselini 2017 |
|                           | Power of cascaded use               | Diversifying reuse across supply chains                                                                                                             | Ellen Mac Arthur Foundation, 2015b |
|                           |                                     |                                                                                                                                                    | Franklin-Johnson, 2016 |
|                           |                                     |                                                                                                                                                    | Parchomenko et al. 2019 |

(continued on next page)
production should only take place when there is demand (Franklin-Johnson et al., 2016). Raw materials, work-in-process and end products that are available without demand have used resources while their future consumption is still uncertain (Kalmykova et al., 2018). Demand can change, whereby these products become obsolete and the conversion of resources has not met the need for consumption (Ellen Mac Arthur Foundation, 2013a 2013). This performance objective implies that in a supply chain in a circular business model, Make-to-Order and Engineer-to-Order are preferred over Make-to-Stock (APICS, 2017; Lewandowski, 2016).

4.13. : Maximize the efficient use of supply chain assets

Several articles refer to the importance of a higher utilization of supply chain assets in a circular business model (Ellen Mac Arthur Foundation, 2013a; De Angelis et al., 2018; Geissdoerfer et al., 2018; Howard et al., 2019; Lewandowski, 2016; Morseletto, 2020; Potting et al., 2017). A more efficient use of supply chain assets (such as warehouses, trucks, machines) can support economic and environmental benefits. Potting et al (2017) describes the importance of increasing the efficiency of manufacturing or use of the product. This performance objective seems to relate to the Lean method as developed in the Toyota Production System. The Lean method aims to eliminate non-value adding activities, enhance quality and deliver value to end-users. It is recognized that the Lean method promotes an efficient use of materials, water and energy and thereby supports the realization of environmental performance goals (Environmental Protection Agency, 2018). Furthermore, there is an increased attention in circular business models for the use of sharing platforms to increase the utilization of available assets amongst supply chains (Geissdoerfer et al., 2018).

4.14. : Minimize waste

Waste refers to resources (materials, water, energy, land) that are disposed during or after resource extraction, production and use without being useful to the end-user. Several authors stress the opportunities for cost saving by waste reduction () and the importance of reduction of waste at every stage of the product life cycle (Morseletto, 2020; Yang et al., 2018). Waste occurs in every stage of the product life cycle: products are being produced, but not sold; products are being sold, but not returned; products are returned, but not recovered; and, finally, products are being recovered, but not used as input for production nor resold to end-users. Bocken et al (2016)
describe this performance objective as closing resource loops in which materials are reused as much as possible.

4.15. : Maximise the availability of the product

The longer an end product is available for consumption, the less resources are used to produce a new product. By maximizing the availability of the end product, the use of resources is avoided (Lacy et al., 2014; Ellen Mac Arthur Foundation, 2013a; Bocken et al., 2016; Bressanelli et al., 2018; De Angelis et al., 2018; Di Maio et al., 2017; Franklin-Johnson et al., 2016; Howard et al., 2019; Jain et al., 2018; Parchomenko et al., 2019; Yang et al., 2018). Batista et al. (2018) refer to prolonged life cycles as a fundamental aspect of a supply chain in a circular business model. Furthermore, a longer life time is supported with standardization and compatibility of products and products that can be easily upgraded or adapted (Lacy et al., 2014; Bocken et al., 2016) and easily maintained and repaired (Bocken et al., 2016; Ellen Mac Arthur Foundation, 2015a). Finally, the support of a more intensive use of the product is a characteristic of a supply chain in a circular business model (Azevedo et al., 2017; Ellen Mac Arthur Foundation, 2015a; Franklin-Johnson et al., 2016; Geissdoerfer et al., 2018, Potting et al., 2017). More intensive use ensures that more end-users use in total fewer products, for example by sharing the use of the product. As a result, less new resources are required to produce and deliver products to end-users (Lacy et al., 2014; Azevedo et al., 2017; Batista et al., 2018; Ellen Mac Arthur Foundation, 2015a; Franklin-Johnson et al., 2016; Geissdoerfer et al., 2018; Jain et al., 20182018; Kalmykova et al., 2018; Lewandowski, 2016; Parchomenko et al., 2019; Potting et al., 2017).

4.16. : Maximise the number of recovery flows

This performance objective aims to maximize the number of times the product is recovered within the same supply chain or in distinctive supply chains (Azevedo et al., 2017; De Angelis et al., 2018; Ellen Mac Arthur Foundation, 2013a; Yang et al., 2018). After a product has been recovered multiple times, loss of its characteristics may occur. However, the product may still be very suitable for an application in another supply chain. This would mean that resources in the product remain to be available for consumption and that no virgin materials need to be mined. Ellen Mac Arthur Foundation (2013a) describes this performance objective as the power of cascaded use. Batista et al. (2018) describe returns from the same supply chain and from distinctive supply chains as a fundamental aspect of supply chains in a circular business model.

5. Discussion

The importance of supply chain management in the transition to a circular business model is widely recognized (Aminoff and Kettunen, 2016; Bocken et al., 2018; Geissdoerfer et al., 2018; Urbiniati et al., 2017). However, various concepts of supply chain management in a circular business model have not been sufficiently addressed (De Angelis et al., 2018; Batista et al., 2018; Bressanelli et al., 2018; Farooque et al., 2019; González-Sánchez et al., 2020 Lahane et al., 2020).

To describe a supply chain in a circular business model, the butterfly model of the Ellen Mac Arthur Foundation is widely used (Ellen Mac Arthur Foundation, 2013a). This model suggests that refurbish/remanufacture leads to a goods flow towards a product manufacturer, reuse results in a goods flow towards a service provider and recycling results in a goods flow to a parts manufacturer. Moreover, some models suggest that processes are defined by the direction of goods flows and its actors (Farooque et al., 2019). Describing a supply chain in a circular business model in this manner could lead to conceptual misunderstanding. To enable more insight in supply chains in a circular business model, this paper proposes a distinction between processes and actors. Processes are the set of key activities in the supply chain in a circular business model: Plan, Source, Make, Deliver, Use, Return, Recover and Enable. Actors in the supply chain in a circular business model are the organizations and private persons that are responsible for the performance of a certain process.

Supply chains in a circular business model take responsibility for the development of resources (materials, water, energy) and the health of our eco-system. Traditionally, supply chains are focused on balancing capabilities and requirements (APICS, 2017). In turn, the supply chain in a circular business model focuses on balancing the capabilities of our natural resources with the requirements following the demand from the supply chain.

In a circular business model, there will be successive series of use and reuse of products. As a result, actors in a circular business model will become more interdependent and the need increases to integrate activities and collaborate within the supply chain (Batista et al., 2018).

In literature, a supply chain that includes a return flow of goods is often referred to as a circular supply chain (Batista et al., 2018; Farooque et al., 2019; Genovese et al., 2017). This is probably because activities such as, reuse, remanufacturing, refurbishing, upcycling, recycling and downcycling are at the center of attention of the circular economy (Ellen Mac Arthur Foundation, 2013a; Potting et al., 2017). These activities have in common that they lead to a return flow of goods. However, a historical overview of the development of supply chain management indicates that a return flow of goods is not a unique characteristic of a circular supply chain. A return flow has already been a subject of research since the rise of e-commerce at the turn of this century (Lambert et al., 2005). A return flow is primarily a characteristic of an open-loop supply chain (return flow in another sector) and a closed-loop supply chain (return flow in the same sector) (Batista et al., 2018; Farooque et al., 20192019; Genovese et al., 2017; Guide et al., 2009). The circular supply chain appears to have other unique characteristics. The unique characteristic of a circular supply chain is that it closes the loop with the environment. A circular supply chain takes into account the resources (materials, water, energy, land) it derives from the Earth’s ecosystem, uses and maintains resources in the most efficient way while maximizing the availability of these resources for consumption.

Traditionally, the supply chain focuses on the forward flow of goods and consists of the processes Plan, Source, Make, Deliver and Enable. In addition to these processes, the closed-loop supply chain and open-loop supply chain also consider the reverse flow of goods from end-users and therefore include the process of Return. In addition to these processes, the circular supply chain closes the loop with the environment by including the processes Use and Recover.

Based on the previous sections, key characteristics of a circular supply chain are:

- focus on resource efficiency by reducing, maintaining and recovering resources (materials, water, energy)
- strives for economic, environmental and social benefits
- in addition to the processes of Plan, Source, Make, Deliver, Return and Enable, it also contains the processes Use and Recover
- since a circular supply chain contains the process Use, a circular supply chain is no longer formed solely by organizations but also by end-users

These key characteristics lead to the following definition of circular supply chain management:

Circular supply chain management is the design and control of a network of organizations and end-users that strives for economic, environmental and social benefits by reducing, maintaining and recovering resources.

The overall performance objective of circular economy focuses on resource depletion as a means to achieve environmental benefits
Alsominimizing carbon footprint, toxicity and pollution (APICS, 2017 – of environmental benefits. Not only minimizing resource depletion, but also minimizing carbon footprint, toxicity and pollution (APICS, 2017 – to environmental benefits. Not only minimizing resource depletion, but also minimizing carbon footprint, toxicity and pollution (APICS, 2017 – 305; Azvedo et al., 2017; Di Maio et al., 2017; Ellen Mac Arthur Foundation, 2013a; Genovese et al., 2017; Ghisellini et al., 2016; Koh et al., 2017; Vogtlander et al., 2001). It is plausible that activities of a circular business model lead to less resource depletion. However, when these activities also lead to an increase of the carbon footprint, still the desired effects are not accomplished.

This paper identifies the performance objective to maximize the availability of the end product for the end-user. Strategies of 3Rs (reduction, reuse, recycle) (Ghisellini et al., 2016) and 9Rs (refuse, rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, recover) (Kirchherr et al., 2017; Kravchenko et al., 2019 Potting et al., 2017; Saidani et al., 2019) are widely used. In these strategies there is scarce attention for the performance objective to maximize the availability of the end product for the end-user. In the 9Rs framework, this performance objective is partly captured with the action of ‘repair’ and together with maintenance these actions should extend the lifetime of a product. However, a longer lifetime should mean that the product is designed so that no repair and maintenance have to occur. Therefore, we suggest that the 9Rs framework should be supplemented with ‘longer lifetime without repair or maintenance’. A light bulb in a fire station in Livermore California serves as a shining example.

The literature review also indicated that scarcity of resources may lead to supply risks and volatile prices. This may rise the need to arrange a return flow from end-users that secures the availability of these materials. Moreover, reducing the dependency on natural resources may lead to less sensitivity to price volatilities. This paper acknowledges that the mitigation of supply risk and price volatility risk might be an important driver of circular business models.

Currently supply chain management literature is focused on the supply chain as a cooperation of organizations (Croom et al., 2000). As the supply chain in a circular business model contains the process Use there is also cooperation with the end-user. The end-user can be an organization as well as a private person. Therefore, management of a supply chain in a circular business model is focused on organizations and private persons. Private persons have different power and interests compared to organizations. Decision making and information exchange with private persons is different from that of organizations.

By including the end-user and activities that aim to prolong the lifetime of the product, new interesting challenges will arise in the field of supply chain management. Furthermore, end-users are also suppliers in a circular business model. Their products are – after end-of-life – a source of new products. Buy back and take back programs promote that end-users return their products after end-of-life. These programs will become more important in a circular business model.

6. Conclusion

To date, the processes and performance objectives of a supply chain that supports a transition towards a circular business model have not been adequately described. This has led to the following research questions:

RQ1: What processes conceptualize a supply chain in a circular business model?
RQ2: What performance objectives characterize a supply chain in a circular business model?

Based on a systematic review of the literature, these questions have been addressed. This paper has conceptualized a supply chain in a circular business model based on the processes Plan, Source, Make, Deliver, Use, Return, Recover and Enable. The supply chain in a circular business model consists of two additional processes compared to a supply chain in a linear business model: Use and Recover. The process Use focuses on maximizing the availability of the product for the end-user in the supply chain. The process Use is subdivided into the subprocesses Use, Maintenance and Repair. The process Recover consists of the subprocesses Reuse, Remanufacturing, Refurbishing, Upcycling, Recycling and Downcycling. Furthermore, the process Plan needs to be supplemented with the subprocesses Plan Use and Plan Recover. The process Deliver needs to be supplemented with the subprocess Deliver MRO (maintenance, repair, overhaul) Product. The process Return needs to be supplemented with the subprocesses Source Return End-of-Use Products and Deliver Return End-of-Use Products.

Furthermore, a number of processes which are already part of the supply chain in a linear business model should shift their focus to enable a transition towards a circular business model. A shift of focus concerns the planning activities where availability of resources (materials, water, energy) is matched with the requirements of the supply chain. Planning activities should identify the impact of the availability of resources on the supply chain as well as the impact of the supply chain on the availability of resources. Sourcing should focus on materials that minimize waste and enable return, disassembly and recovery of materials after end-of-use. Finally, a supply chain in a circular business model has more focus on resource efficient production, sustainable packaging and collection and disposal of waste. Buy-back, take back programs and communication with organizations and private persons are new elements of management of supply chain in a circular business model.

To date, the performance objectives that characterize a circular supply chain have not been sufficiently addressed. This paper has identified performance objectives on three levels: the overall performance objective of the circular economy, performance objectives aimed at economic, environmental and social benefits for the supply chain and performance objectives that characterize a supply chain in a circular business model.

7. Suggestions for further research

The supply chain in a circular business model focuses on balancing the capabilities of our natural resources with the requirements following the demand from the supply chain. This topic seems to provide an interesting opportunity for further research. In particular research could focus on: which activities are needed to gain insight in the balance between the capabilities of natural resources and the requirements of the supply chain, which actions could result from this insight, what should be the goal of these actions, how can the progress towards this goal be determined, which technologies and skills are required for these activities.

To enable collaboration, key actors within a circular business model will need to gather and share information which requires specific cross-organizational workflows. A promising opportunity for further research could be to develop these cross-organizational workflows. Via supply chain coordination contracts the risks and benefits of a collaboration are being shared amongst the supply chain actors (Govindan et al., 2013). Development of supply chain coordination contracts that optimize circular business models could be a promising opportunity for further research.

Performance objectives in literature on circular business models focus on economic, environmental and social benefits (Carter and Rogers, 2008). However, mostly two out of the three benefits are described: economic and environmental benefits. Literature that refers to social benefits, such as employment or safety, is rather scarce. This provides a promising opportunity for further research, in particular to investigate how economic, environmental and social benefits are interrelated, which trade-offs exist between these performance objectives and whether these performances can be optimized in parallel.
To enable performance reporting, control and improvement, performance objectives should be supported with appropriate performance measurements. The development of a performance measurement system for supply chains in a circular business model could be a promising opportunity for further research.

Buy back and take back programs will have a large impact on the performance of a supply chain in a circular business model. Buy back and take back programs aim to stimulate returns from end-users. However, these programs will also require reverse logistics and assembly processes. This will lead to more use of energy, water, production and distribution and thereby, to more costs and more environmental impact. Moreover, the quantity and quality of returns is still uncertain (Govindan and Hasagagic, 2018; Jain et al., 2018). Buy-back and take back programs could possibly contribute to more certainty in quantity and quality of returns. In particular, the impact of buy back and take back programs on economic and environment performance could provide an interesting topic for further research.

The technology that should support the supply chain in a circular business model is still open for discussion. In a circular business model, the need increases to share information at the beginning of the product’s lifecycle (such as design and production), middle of the product’s lifecycle (such as distribution, use, maintenance) and end of the product’s lifecycle (such as recovery of valuable materials). Moreover, this information needs to be exchanged between more actors, organizations and private persons alike. Information exchange could promote a longer product life cycle and faster recovery. Therefore, a promising opportunity for further research could be to develop ways to exchange this information within the supply chain.

The focus of this paper is on incubants and their transition towards circular business models. Start-ups operate in a different context and experience specific bottlenecks in their development. The application of the processes and performance objectives of supply chains in a circular business model for start-ups may therefore provide an interesting opportunity for further research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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