AALBORG UNIVERSITY

# MASTER THESIS

# Towards Resilient and Circular Supply Chains

*A Systematic Process Framework for Assessing Practices and Overcoming Barriers through Gamification*

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# Preface

This thesis is written by a 4th Semester Master student from Aalborg University as the final project in the Master of Management Engineering with a specialization in Operation and Innovation Management at the Institute of Material and Production. The focus of this thesis is to use concepts and methods learned throughout the Master education in a context relevant for the studies and industries. The chosen topic of the thesis are circular supply chains, a continuously emerging concept for industries.

## Acknowledgements

"I would like to take this opportunity to express my gratitude to everyone who assisted me in completing this bachelor project.

Moreover, I would like to thank Verena Stingl, my supervisor who guided me through the process of writing this paper and provided valuable feedback and recommendations. It has been a great learning experience for me."

# Summary

## Objective of the Thesis:

Circular supply chains have recently gained more attention for creating more sustainable and resilient supply chains. However, this concept brings new uncertainties and complexity. Therefore, the objective of this thesis is to identify relevant practices and barriers for circular supply chains and to design a practical and feasible process framework for businesses that reduces the complexity of implementing circular practices into supply chains without harming the resilience.

## Methods:

A Design Science Research Approach is chosen for this thesis to gather relevant theoretical knowledge on circular supply chain practices and barriers through a literature review, while solving a specific and relevant business need through the iterative design of a practical solution. For the solution design interviews and workshops have been used to identify the problem and test the solution.

## Findings:

The thesis finds four key practices and seven key barriers for circular supply chains during the literature review of 65 articles. The key practices include closing-the-loop practices, collaboration, technology, and sustainable performance measurement while common barriers were lack of awareness, knowledge, skills, and financial resources. Moreover, the new complexity and risks that are created by implementing above-stated practices is seen as a common barrier in circular supply chain implementation. Additionally, the cause-effect relationships between these and supply chain resilience are mapped in the context of sustainable business performance. However, no clear positive or negative impact on supply chain resilience could be concluded. The solution design presents a systematic process framework to ideate and assess circular practices and to overcome specific barriers to these practices that might occur in potential scenarios. Gamified elements in this process are found to promise a higher innovation rate and increased collaboration for businesses when creating circular supply chains.

## Conclusion:

Concluding, the thesis gives an overview of circular supply chain practices and barriers as well as their influence on SC resilience. The complexity that is found in the practices and barriers highlights the need for the designed solution, which offers structure and tools to business that want to implement circular practices and create circular supply chains with their partners.



## Keywords:

Circular Supply Chain, Technology for Circularity, Circular Practices, Collaboration, Gamification

## Reading Guide

The thesis is divided into 7 chapters. The first chapter gives introduction to the thesis (Chapter 1), while the second chapter introduced the problem background and the thesis objective (Chapter 2). Chapter 3 offers a detailed the presentation of methods chosen for achieving the objective (Chapter 3), while Chapter 4 and 5 the apply these methods as problem analysis tools and solution design tools. Chapter 6 discusses the findings of the two chapters mentioned before and states theoretical and managerial implications as well as future research opportunities, while Chapter 7 concludes on the results of the thesis.

### List of Abbreviations

| **Abbreviation** | **Meaning** |
|---|---|
| CE | Circular Economy |
| SC | Supply Chain |
| SCM | Supply Chain Management |
| CSC | Circular Supply Chain |
| CSCM | Circular Supply Chain Management |
| I4.0 | Industry 4.0 |
| RL | Reverse Logistics |
| DSRM | Design Science Research Method |

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# Chapter 1. Introduction

The new emerging concept of Circular Supply Chains (CSC) is gaining more and more attention from both academia as well as industries to be able to achieve the ambitious sustainable development goals (Schroeder et al., 2019). These new types of Supply Chains (SC) evolved by integrating the Circular Economy (CE) concept into Supply Chain Management (SCM) and brings the opportunity to keep resources in a closed-loop system and minimize waste (Farooque et al., 2019; Geissdoerfer et al., 2018). To create this closed-loop system, the forward SC is extended with a reverse SC and integrating these processes into the operations while following the principles of CE (MahmoumGonbadi et al., 2021). Due to changing regulations, customer and supplier requests, and a general shift towards sustainability businesses need to start adapting these principles and eventually operate a CSC (De Angelis et al., 2018; Gaustad et al., 2018; Schroeder et al., 2019). Additionally, resource efficiency, a resilient SC, collaboration, and market strength need to be maintained and improved to stay competitive in today's business environment (Calicchio Berardi & Peregrino de Brito, 2021; Gaustad et al., 2018). How to achieve this by implementing CSC is uncertain for most businesses due to the high complexity of CSCs and the 'VUCA'[1] business environment. The missing information on how to implement what practices is one of the many barriers to prioritize objectives regarding CSC implementation. This creates a business need for a structured and systematic approach to implementing CSCs and considering risks, vulnerabilities and other influences on the resilience and business performance to be able to know the consequences for the SC after introducing circularity. While many articles in the literature are already mapping out the positive impacts if CE principles and CSCs on resilience and performance, only little describe a systematic process on how to implement these principles while admitting risks and a negative impact on resilience and performance (Dulia et al., 2021). This is due to the complex nature of CSC practices and enablers that help manage the SC.

Therefore, this thesis will analyze what practices, enablers, and barriers are relevant for CSC implementation and their consequences on SC resilience and sustainable business performance. Additionally, a potential solution to identifying circular practices and their implementation is sought for, focusing on simplifying the complex phenomenon for businesses. As a result of this objective, the Design Science Research Methodology (DSRM) was used by creating a systematic literature review on CSC practices and barriers as a knowledge base and a small case study to define the business need and test the feasibility of the solution design.

[1] https://hbr.org/2014/01/what-vuca-really-means-for-you (accessed 20-05-2023):
VUCA = volatility, uncertainty, complexity, ambiguity

# Chapter 2. Problem Background

The world overshoot day[2] in 2022 fell on the 208th day of the year, which means that on that day humanity has exceeded the number of ecological resources Earth can generate within that year. Over the last 30 years the Earth Overshoot Day arrived earlier and earlier, as shown in Figure 1, due to the increasing demand in ecological resources to the point where humanity would need about 1,75 Earths in 2022 to cover their ecological and carbon footprint (Earth Overshoot Day, 2022).

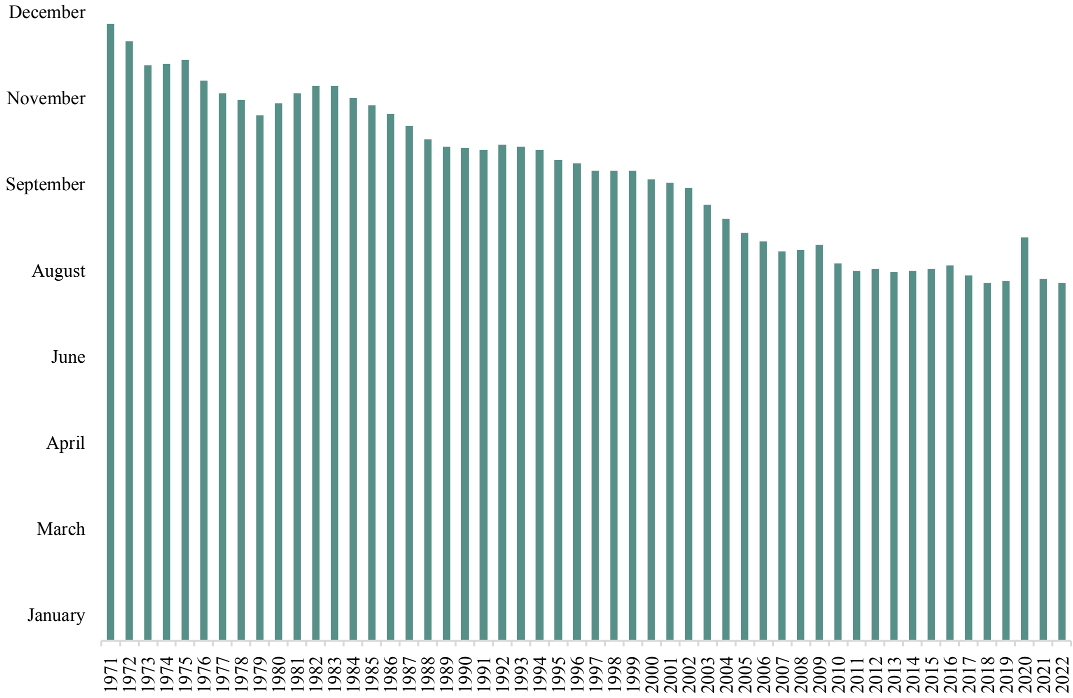


*Figure 1 - Earth Overshoot Days 1971-2022,* (Earth Overshoot Day, 2022)

The concept of the World Overshoot day raises awareness about the finite nature of our planet's resources and the urgent need for more sustainable practices. Academia and practitioners started acknowledging the impact of the linear consumption of resources on the environment and seek to create an economy where resources are not extracted, used, and discarded but kept in a closed loop system and thereby used more efficiently (Ellen MacArthur Foundation, 2022; Geissdoerfer et al., 2018). This concept called 'Circular Economy' (CE) aims at replacing the end-of-life concept on *"micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond)"*, (Kirchherr et al., 2017, p. 229). According to Geisendorf & Pietrulla (2018) common practices related to CE include the following:

[2] Overshoot Day is computed by dividing the planet's biocapacity (the amount of ecological resources Earth can generate that year), by humanity's Ecological Footprint (humanity's demand for that year), and multiplying by 365, the number of days in a year:
(Planet's Biocapacity / Humanity's Ecological Footprint) x 365 = Earth Overshoot Day

- Cradle to cradle
- Closed supply chains
- Regenerative design
- Blue economy
- Industrial ecology
- Reverse logistics
- Performance economy
- Natural capitalism
- Biomimicry

By implementing these practices into business models, circular business models can be created. These circular business models do not only focus on having a long-term perspective, sustainable value creation, and pro-active multi-stakeholder management, but also on the management of resource loops (Geissdoerfer et al., 2016, 2017) to align the interests of a *"broader set of stakeholders that is going beyond the monetary value for customers and shareholders of 'unsustainable' business models",* (Geissdoerfer et al., 2018). The objective of circular business models is to improve sustainability performance and create more sustainable business models (Bocken et al., 2013). Geisendorf & Pietrulla (2018) mention two core principles for CE thinking in businesses namely the 'R Framework' and having a system perspective. This can be enabled by innovating the business model and redesigning internal as well as external processes for value creation (Boons & Lüdeke-Freund, (2013). As a result, the redesign of SCs to support these new business models is an important building block to achieving a CE. In the context of production industries, CE can be enabled by changing production and consumption patterns to a circular system by repairing, reusing, refurbishing, and recycling resources (see Figure 2), thereby changing the SC structures and characteristics (De Angelis et al., 2018; Geissdoerfer et al., 2018).

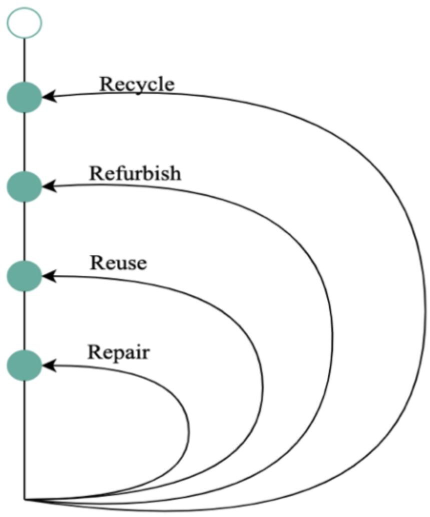


*Figure 2 - Closing the Loop (adopted from De Angelis et al. 2018)*

This is enabled by adding reverse logistics (RL) to the forward SC to close the loop and create a CSC (Kurt et al., 2019; Rentizelas et al., 2022). Here it needs to be differentiated between open-loop SC approaches, which mainly focus on creating a reverse flow of products by using a third party for coordination and operation of the reverse supply chain (Genovese et al., 2017) and closed-loop SC approaches, where both forward and RLs are centrally managed by one integrated network system (Rezapour et al., 2015). These two approaches are combined under the term CSC in this thesis. While continuously living up to the customers' demand, the second focus of CSC is to collect the end-of-life products from the consumer and maintain the resources by applying the R-principles (Govindan & Soleimani, 2017). In the current literature different extents of R-principles exist including those presented in Table 1.

| Author | R-Principles |
|---|---|
| (Kirchherr et al., 2017) | Reduce, Reuse, Recover, Recycle |
| (Gaustad et al., 2018) | Reuse, Remanufacture, Recycle |
| (Jawahir & Bradley, 2016) | Reduce, Reuse, Recycle, Redesign, Remanufacture, Recover |
| (Reike et al., 2019) | Refuse, Reduce, Resell, Reuse, Repair, Refurbish Remanufacture, Repurpose, Recycle, Recover, Re-mine |

*Table 1 - Examples of R-Principles*

Above-mentioned factors are important considerations for the area of SCM which was firstly mentioned by Oliver and Webber in 1982 (Christopher, 2016). Tan (2002) has performed a survey with senior supply and materials management professionals in the US and identified 25 practices of SCM which are presented below:

1. Determining customers' future needs
2. Reducing response time across the supply chain
3. On-time delivery directly to your firms points of use
4. On-time delivery directly to customers' point of use
5. Improving the integration of activities across your SC
6. Searching for new ways to integrate SCM activities
7. Creating a greater level of trust among SC members
8. Communicating your firm's future strategic needs
9. Establishing more frequent contact with SC members
10. Contacting the end users to get feedback
11. Increasing your firm's JIT capability
12. Communicating customers' future strategic needs
13. Use of formal information sharing agreements
14. Creating a compatible information system

15. Use of informal information sharing
16. Aiding suppliers to increase their JIT capability
17. Involving SC in your product/service/marketing plans
18. Identifying additional SC
19. Creating SCM teams to include different companies
20. Participating in the marketing efforts of customers
21. Participating in the sourcing decisions of suppliers
22. Extending SC beyond immediate suppliers/customers
23. Locating closer to your customers
24. Requiring suppliers to locate closer to your firm
25. Use of a third-party SCM specialist

These 25 practices can be seen as the foundation for managing any SC and an enabler for implementing circular practices into a SC. Especially practices like 'requiring suppliers to locate closer to your firm', 'use of a third-party SCM specialist', or information sharing practices can be found as key practices in SCs in a CE. However, to manage a SC in a CE, additional practices, and a rethinking of the traditional SCM practices is required (Geissdoerfer et al., 2018). Based on this, multiple new subcategories of SCM are currently evolving such as 'sustainable supply chain management' (SSCM), or 'circular supply chain management' (CSCM), (Fobbe & Hilletofth, 2022). SSCM focuses mainly on sustainable value creation within and across traditional linear SCs while reducing resource input and waste output, whereas CSCM aims at integrating CE practices into SCs to create a zero-waste CE based on restorative and regenerative resource cycles (Farooque et al., 2019; Genovese et al., 2017). Figure 3 presents the chosen scope for this thesis regarding CSCM. Since CSCM can be seen as the link between CE and SCs the following two definitions (see Table 2) are relevant for creating a common understanding of this term throughout the thesis:

| CSCM Definition | Author |
|---|---|
| *"Circular supply chain management is the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users."* | Farooque et al., 2019, p. 884 |
| *Circular supply chain management is "the configuration and coordination of the organizational functions marketing, sales, R&D, production, logistics, IT, finance, and customer service within and across business units and organizations to close, slow, intensify, narrow, and dematerialize material and energy loops to minimize resource input into and waste and emission leakage out of the system, improve its operative effectiveness and efficiency and generate competitive advantages."* | Geissdoerfer et al., 2018, p. 715 |

*Table 2 - Definitions of CSCM*

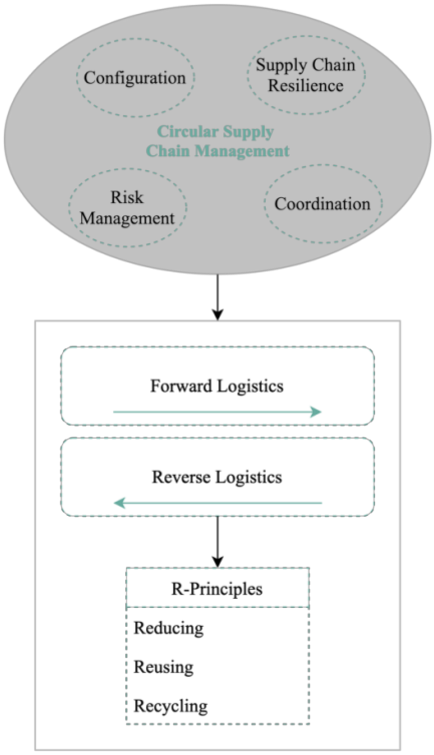


*Figure 3 – Chosen scope of CSCM*

This new perspective arguably brings new complexity and new risks as well as new opportunities to a SC and thereby impacts the resilience of it (Chhimwal et al., 2021).

Mauss et al. (2022) have mapped the potentials of CE approaches for SC resilience and proposed following opportunities based on a literature analysis:

- Enhanced collaboration leads to improvement in SC visibility, responsiveness, and flexibility,
- Information sharing and transparency increases SC responsiveness, flexibility and velocity, and supply security,
- Informed supplier selection processes increase the performance and enhance logistics capabilities,
- Closing of material loops increases security of supply and reduces dependencies on suppliers, therefore increases SC robustness,
- Coherent corporate culture according to CE practices and resiliency principles,
- Attention from top management needed for both CE and SC resilience can create synergies.

However, they highlight the increased complexity in the SC due to a more extensive network that comes with the collaboration-focused CE concepts. This increased complexity is one of the new risks and barriers inherited when adopting CE practices. Chhimwal et al. (2021) have mapped other CSC risks and how they differ from traditional SC risks. Based on a literature review they developed seven risk categories including 17 risk events. An overview of these can be found in Table 3.

| Risk Category | Risk Event |
|---|---|
| Economic Risk | Supply risk<br>Flawed incentive structures<br>High investment |
| Environmental Risk | Limited store of resources<br>Uneven geographical distribution of resources<br>Limited assimilative capacities of ecosystems |
| Social Risk | Excessive working time of the employees<br>Unfair wages<br>Work–life imbalance |
| Technological Risk | Threat of implementing newer/complex technology<br>Compatibility issues with existing systems |
| Waste Management Risk | Health-associated risk to the society<br>Penalties involving improper disposal of waste |
| Agile Vulnerability | Swift response to agile changes<br>Flexibility in production process |
| Risk of Cannibalization | Deregulated markets<br>Problematic ownership structures |

*Table 3 - CSC Risk Overview, adopted from Chhimwal et al., (2021)*

To understand the impact of these potentials and risks on SC resilience better, the 'supply chain resilience typological framework' developed by Kochan & Nowicki (2018) and shown in Figure 4 is described in the following section to create a common understanding of this area for this thesis. They have found inconsistent terminology around SC risks and SC resilience which increases the importance of creating a consensus (Kochan & Nowicki, 2018).

Based on various definitions they conclude SC resilience to be an ability or a capability that enables the SC to prepare for and recover fast from disruptions, disturbances, or other unexpected events (Christopher & Peck, 2004; Kochan & Nowicki, 2018; Tukamuhabwa et al., 2015). According to Kochan & Nowicki (2018) these disturbances or unexpected events can come from two different contexts, namely disruptions and risks. Disruptions are risks that realize and the higher the risks, the bigger is the vulnerability of the SC. With other words, *"as supply chain risks increase companies become more vulnerable to unforeseen disruptions",* (Kochan & Nowicki, 2018, p. 847). However, in most literature disruptions, risks, and vulnerabilities are not differentiated at this detail level or the terms are used interchangeably (such as in (Dulia et al., 2021; Simonetto et al., 2022). Therefore, going forward, vulnerabilities will be included in the context in which disturbances can happen and grouped together with risks and disruptions due to their dependencies. The next category that impacts SC resilience are capabilities which are categorized as interventions according to Kochan & Nowicki (2018) and can support the SC through recovery periods and avoid disruptions as well as mitigate risks. These capabilities have an impact on the business and can strengthen the competitive advantages as well as sustain business continuity due to a resilient SC. Examples for these capabilities can be found in various definitions of SC resilience such as readiness, responsiveness, and recovery (Tukamuhabwa et al., 2015). The ambition of every SC manager should be to match the vulnerabilities with capabilities and create a resilient SC that can predict, prevent, reduce, or even avoid disruptions (Kochan & Nowicki, 2018) to enable the above-mentioned advantages.

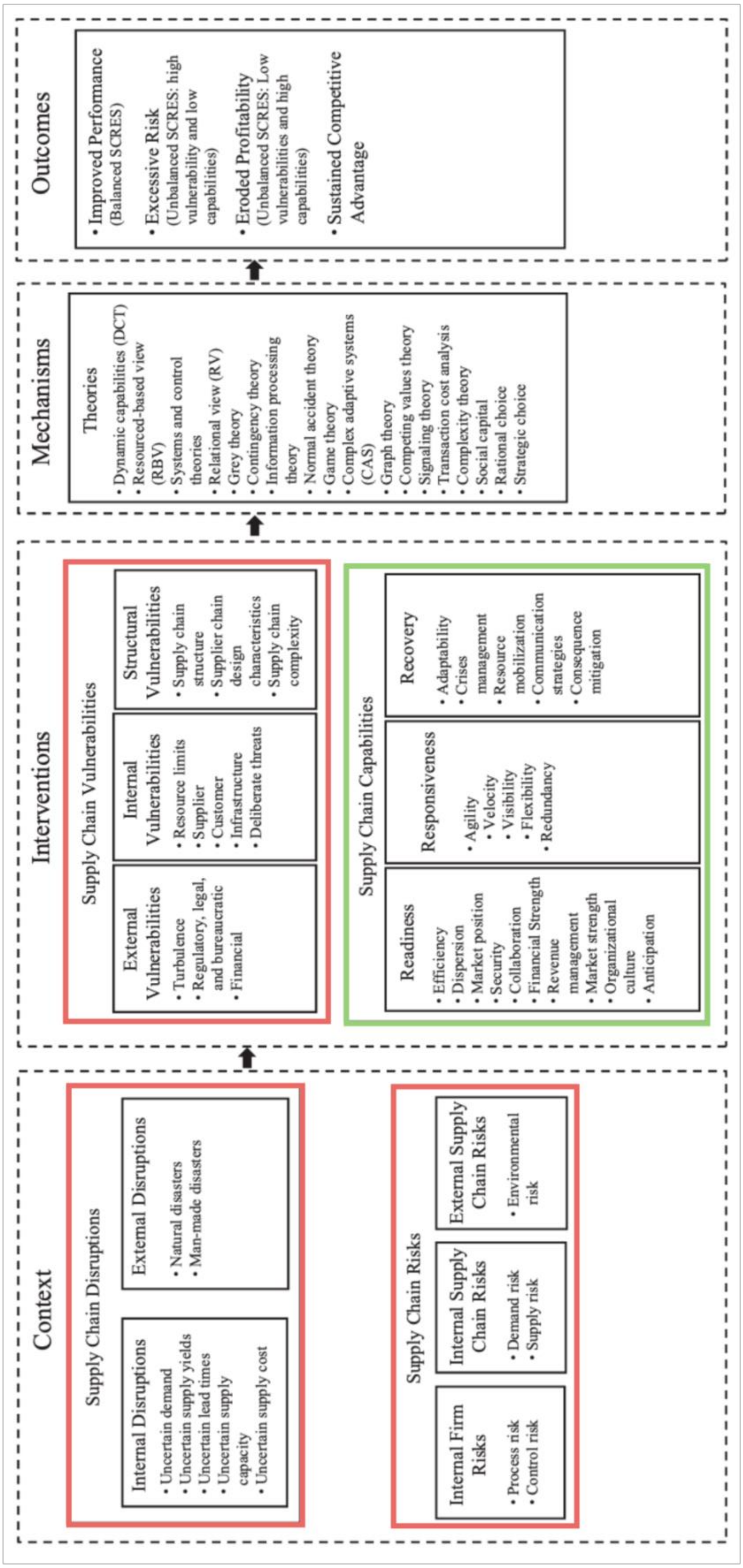


*Figure 4 - SC Resilience typological framework (Kochan & Nowicki, 2018)*

## 2.1. Problem Statement

The new concept of CSCs requires a firm to redesign their SC and creates a practical problem of operationalizing a more sustainable business. There is the business need of identifying and implementing circular practices without harming the resilience of the SC and negatively impacting the business performance. This requires a structured and systematic process that can support firms in prioritizing circularity and choosing the right practices to strengthen sustainable performance while being aware of and mitigating the consequences on the vulnerability of the SC. Therefore, the goal of this thesis is to develop an artifact that can systematically support businesses in chosen the right circularity practices and enablers to overcome barriers and risks for circularity in their SC. For this, a knowledge base of circular practices, enablers, barriers, and risks is needed to be able to design a practical solution for this business need. Consequently, the objective of this thesis can be defined as the following:

*"The objective of this thesis is to create a structured process for firms to evaluate which circularity practices can be implemented in their SC and to identify the consequences for the resilience of the SC by combining a theoretical knowledge base and a specific SC case by using DSRM."*

To structure the development of the knowledge base, a literature review is performed that investigates the following questions:

- *What are common practices and enablers specific for CSCs?*
- *What are barriers, including risks, vulnerabilities, and potential disruptions of implementation of CSCs?*
- *How do these circular practices and barriers influence the resilience of a CSC?*

# Chapter 3. Methodology

This chapter outlines the research approach for the thesis including how and why different methods were used to achieve the objective stated in the Chapter 2. The choice of methods was determined by the objective and the research questions which aim to identify how CSCs can be implemented into a business and what practices and barriers are relevant for this. This chapter firstly describes the general research approach which is Design Science, followed by the literature review design and the solution development methods, including how DSRM was used to develop a solution and how the data collection was performed.

## 3.1. Research Approach

The DSRM was chosen to reach the objective of this thesis, since it allows to find an innovative solution to a practical problem by applying theories of a knowledge base to a relevant business need (Hevner et al., 2004). Therefore, the thesis consists of multiple research methods where the first part is a structured literature review to create the knowledge base followed by an unstructured interview as well as a workshop with Fibertex Personal Care to justify, apply, and evaluate the theoretical knowledge to an empirical problem. Firstly, the secondary research in form of a structured literature review was performed according to Denyer & Tranfield (2009). The structured literature review aims at identifying practices of CE in the field of SCM and their effect on SC resilience to develop a conceptual framework on CSC resilience. This framework is then adopted and applied to a company that has the motivation to build a resilient CSC following the artifact development of the DSRM. For this part, two different data collection methods were used, namely unstructured interviews and workshops. The stated methods are described and discussed in detail in the following sections.

## 3.2. Literature Review

To analyze and answer the research questions stated in Chapter 2.1 a systematic literature review was performed. According to Denyer & Tranfield (2009) this approach enables selecting, analyzing, and evaluating most relevant articles to the research question. Due to its systematic manner, it allows the review to be reproducible by using the same keyword combination and inclusion and exclusion criteria (Petticrew and Roberts, 2008). The database SCOPUS[3] was used as a research source since it is one of the most widely used and largest databases with a wide coverage of peer reviewed journal articles (Scopus, n.d.). The following sections describe the detailed process of the systematic literature which is then summarized and visualized in Figure 5.

### 3.2.1. Source Identification

The objective of this SLR is to gain insights on CE practices and barriers related to the field of SCs and how they affect SC resilience. The scope of CE practices that are relevant for SCs is described in Chapter Chapter 2 and include CSCs and the R-principles. Therefore, only the following search

[3] https://www.elsevier.com/solutions/scopus/how-scopus-works/content?dgcid=RN_AGCM_Sourced_300005030

keywords for identifying papers dealing with such topics were applied to the SCOPUS database search engine:

*(Since not a lot of papers focus on CSC resilience it was not included as a criterion for the articles to get a wider set of CE practices in SCs)*

- *(TITLE-ABS-KEY (recycle OR remanufacture OR reuse OR refurbish) AND TITLE-ABS-KEY (supply AND chain AND practices) AND TITLE-ABS-KEY (supply AND chain AND management))*
- *(TITLE-ABS-KEY (circular AND supply AND chain AND practices) AND TITLE-ABS-KEY (circular AND supply AND chain AND management))*

Limiting the results of this set of keywords to English-language academic articles, and conference papers, a total of 484 articles were extracted for further screening.

- *(LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English"))*

### 3.2.2. Source Screening

The process of the article screening is visualized in Figure 5 according to the PRISMA flowchart. Due to the similarity in search keywords throughout the two database searches, duplicates needed to be removed after extracting the two separate datasets of articles. This resulted in 449 articles for further review. The next step was to set up inclusion and exclusion criteria based on the objective of the thesis and the defined questions that need to be answered by the knowledge base to focus on only relevant articles. The inclusion and exclusion criteria resulting from this are shown in Table 4 and used for screening the titles of the articles. This process led to articles being divided into three distinct categories; namely (1) relevant [122], (2) potentially relevant [42], (3) irrelevant [226], and (4) previously performed literature reviews [59]. Afterwards, a second screening was performed based on the abstracts, however, just including the relevant and potentially relevant articles. The inclusion and exclusion criteria were further defined as shown in Table 4 and based on the initial understanding of the different research scopes and focuses. This secondary screening resulted in 81 papers for detailed analysis. The full text reading was an iterative process where finally 75 articles were selected and analyzed for the SLR.

| | **Inclusion Criteria** | **Exclusion Criteria** |
|---|---|---|
| **Title of Article** | Title that indicates practices for specific CE concepts related to SCM in manufacturing industries | Titles that do not have SCM as focus or focus on chemical processes as well as food waste<br>*Excluded due to the different SC characteristics* |
| **Abstract of Article** | Same as for title and:<br>Papers presenting specific RL concepts,<br>Papers presenting tools for managing a CSC,<br>Papers presenting risks and barriers of implementation of CE or CSC,<br>Papers presenting enablers of CE and CSC | Same as for title and:<br>Focus on economic value of CE,<br>Focus on motivation behind CE,<br>Focus on special cases such as emerging markets with different technologies,<br>Process industries,<br>Performance measurement for implementing CE,<br>Reviews |

*Table 4 - Inclusion and Exclusion Criteria*

### 3.2.3. Data Analysis

Since the objective of the literature review was to identify common practices and barriers of implementing CSCs and how these impact SCR to create a knowledge base, only a content analysis and not a bibliographical analysis was performed. Firstly, the selected articles were summarized and analyzed according to the template shown in Appendix A. The focus of these synopses was to create an initial understanding of the perspective and main findings of the articles. For this, specific questions relevant to the research question were asked such as "What risks are mentioned" or "Do I agree with the findings?". Afterwards, the articles were coded according to practices and barriers of CSCs and their management and categorized according to the CIMO SC resilience typology framework (Kochan & Nowicki, 2018) presented in Chapter Chapter 2. Additionally, an open coding process was used to gather other relevant information on CSCs that did not fit into the selected coding framework to not miss any relevant information. These two steps enable a differentiated view on how the practices and barriers of CSC influence the resilience of a SC. The coding table can be found in Appendix B.

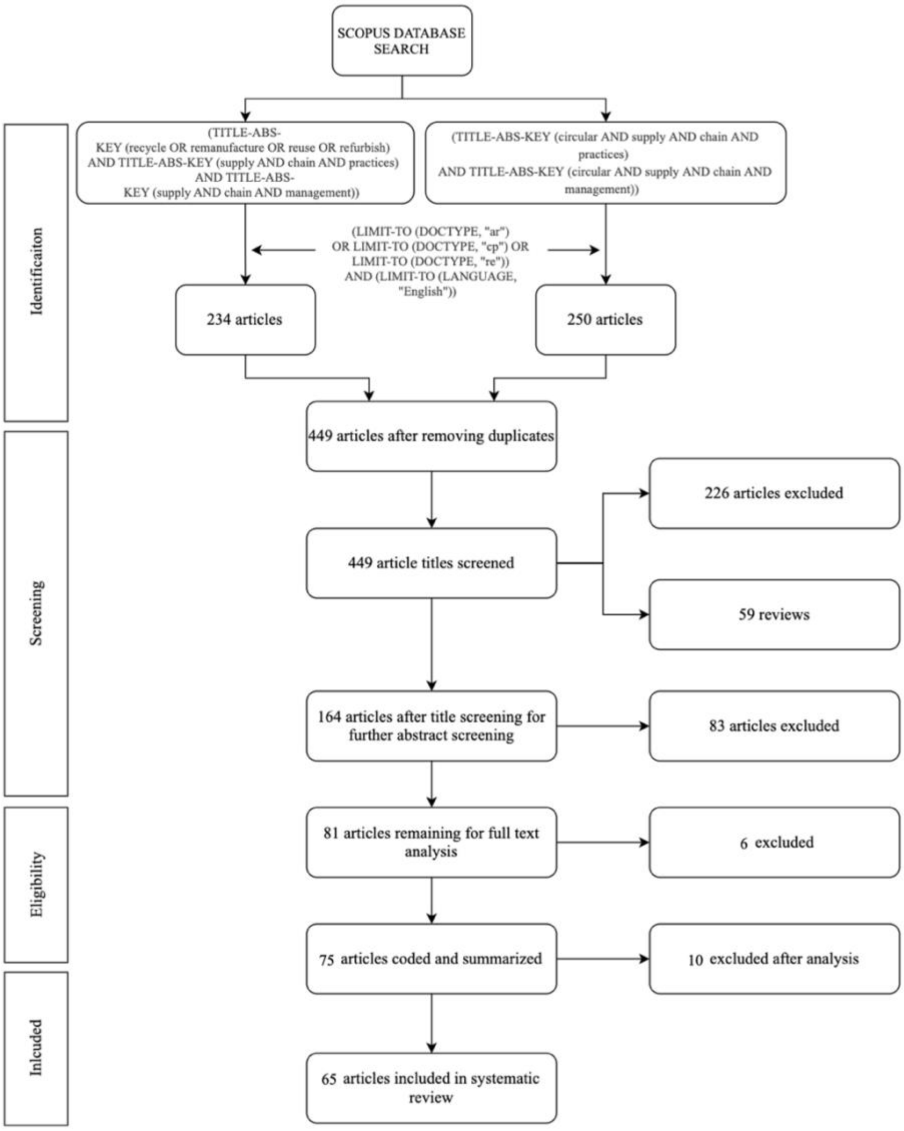


*Figure 5 - Prisma Flowchart*

## 3.3. Case Study

Using the theoretical findings of the literature review in form of the developed conceptual framework, the second part of this thesis aims at creating a resilient CSC for Fibertex Personal Care by using the design science research framework proposed by Hevner et al. (2004) (Figure 6). By applying the foundations of the knowledge base to a specific business need in the appropriate environment, DSRM aims at finding a practical solution by using the methods and tools described in Figure 6.

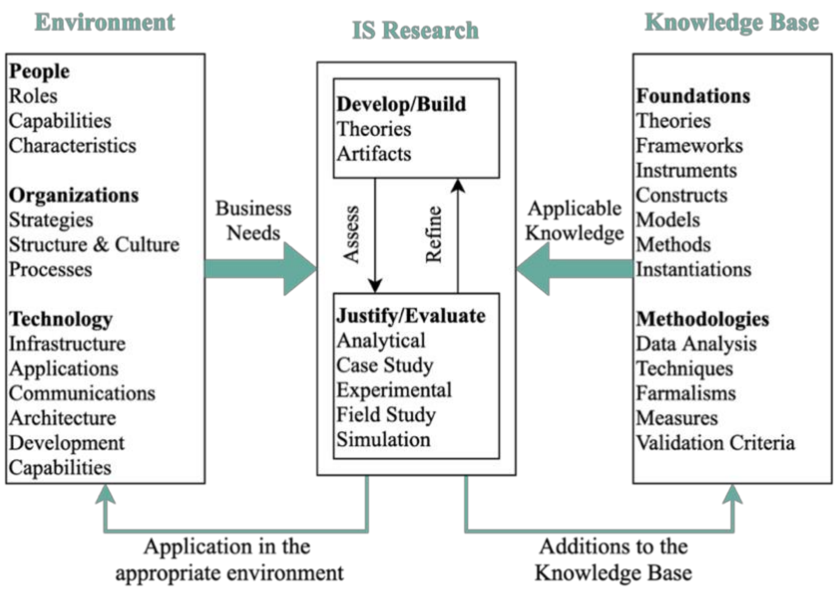


*Figure 6 - Design Science Research Framework, adopted from Hevner et al.* (2004)

DSRM was used throughout the thesis according to the DSRM Process Model by Hevner et al. (2004), shown in Figure 7. Firstly, the problem background (Chapter Chapter 2) scopes a specific problem, which is the complexity of the emerging concept of CSCs and how business can adopt the concept. This built the foundation for the objective of the study which was stated in the end of Chapter Chapter 2 and analyzed further in the Problem Analysis (Chapter Chapter 4). This was mainly done by performing a literature review (as described in section 3.2) that built the knowledge base for this research. Afterwards, a conceptual framework was built based on the knowledge base to support the solution to the objective. The explicit problem of structuring the process of creating a resilient CSC for Fibertex was then analyzed through applying the knowledge base to this problem in form of a small case study where the goal was to design an artifact that can support businesses in conducting a structured analysis on how to design and implement resilient CSCs. This is demonstrated and tested in a workshop setting with the SC director of Fibertex Personal Care who stated that becoming more sustainable is a critical business need and can be supported by circulating their raw material. The workshop is described in Chapter 5.2 as part of the solution design. Afterwards, the first iteration of the artefact is reflected on by using the workshop results and the existing knowledge base and potential improvements for the second iteration are discussed in Chapter Chapter 6. How the data during this process was collected is described in the following two sections.

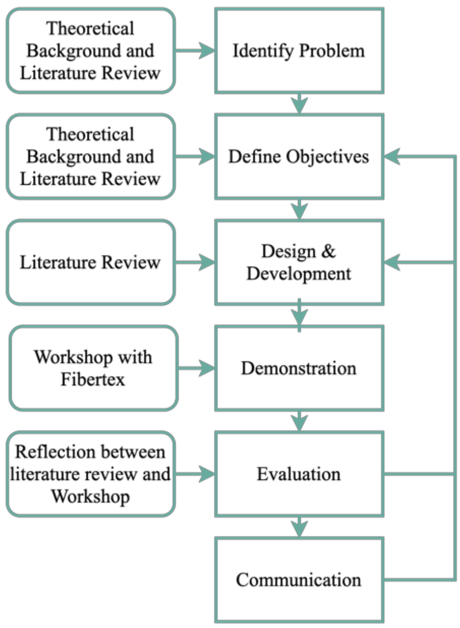


*Figure 7 - Application of DSRM Process Model* (Hevner et al., 2004)

## 3.3.1. Data Collection

The data that was necessary for identifying the business need and testing the solution was collected in different forms which are discussed below.

### *3.3.1.1. Identification of Business need*

To identify the specific business need related to CSC implementation and resilience an initial unstructured interview with the SC director of Fibertex Personal Care (referred to as Fibertex) was performed. This interview type was chosen since the company and the SC were unknown to provide a more holistic understanding of the interviewee's perspective and thoughts on CSC practices in the context of their SC. Unstructured interviews are characterized by not using an interview guide and using an informal language to gather information on unexpected themes and the perceived reality of the interviewee. However, a certain structure in asking questions was used, namely continuously asking why questions to understand the root-causes to not implementing circular practices yet. This enabled the interviewer to get a deeper understanding of the issues and challenges as well as their relationship with each other (Aarhus University, 2023).

### *3.3.1.2. Demonstration of First Iteration*

The demonstration of the designed artifact to achieve the objective of the study is an important part of the DSRM Process model, to evaluate if the artifact is solving the identified business need. This was performed through a workshop which is a popular form of qualitative data collection when brainstorming and out of the box thinking is required (Storvang et al., 2018). The workshop design proposed by Storvang et al. (2018), visualized in Figure 8 complements the use of the DSRM in this thesis by providing a structured approach to testing and evaluation of the developed framework. The focus of this workshop was therefore on the planning, facilitating, and analysis phase, since the diagnosis phase is irrelevant after performing the literature review and having the unstructured interview with the SC director, where the business need was diagnosed. During the workshop different roles are required, namely the researcher, the facilitator, and the participants (Storvang et al., 2018). In this case, the researcher and the facilitator were the same person, and the participant was the SC director of Fibertex Personal Care. How the workshop was planned, facilitated, and analyzed is described in Chapter 5.2 and 5.3.

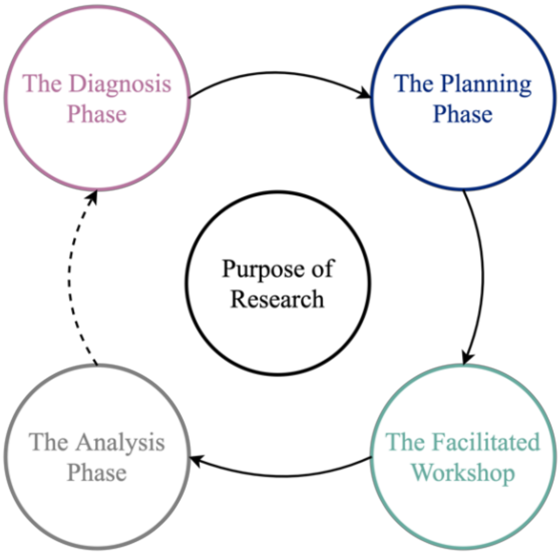


*Figure 8 - Workshop Framework, adopted from* (Storvang et al., 2018)

# Chapter 4. Problem Analysis

The following chapter creates the knowledge base which is required for achieving the objective of the thesis. By using a structured literature review approach, the problem of CSC implementation is analyzed based on the practices, enablers, barriers, and the impact on the resilience of a SC. Based on the findings, the Cynefin framework is used to categorize the current environment of CSC implementation for companies and highlights the relevancy of the thesis objective to reduce the complexity of CSC implementation for companies by developing a systematic process.

## 4.1. Literature Review Findings

The findings of this literature review are structured as follows: firstly, practices and methods that are commonly used in CSCs and CSCM are presented, followed by the most-mentioned barriers of CSC's. These barriers can both be risks or vulnerabilities towards the SC that are created by the practices but can also be an initial challenge such as costs for the implementation of these practices. Consequently, an initial understanding of advantages and problems of CSCs is created which is then set into context with the concept of resilience, following Kochan & Nowicki's (2018) framework of SC resilience typology.

### 4.1.1. Sample Characteristics

The selected articles are found in about 40 different journals or conference records as shown in Figure 9. This shows the importance of the topic of CSCs across different subjects and industries. Especially journals focusing on sustainability, cleaner production, and operation systems published many articles about CSCs. Figure 10 presents the number of articles published per year highlights the increasing attention of academia on CSCs and CE. The number of articles published in 2022 has tripled from 2021 and shows the importance of identifying barriers and risks to CSCs for creating more resilient SCs.

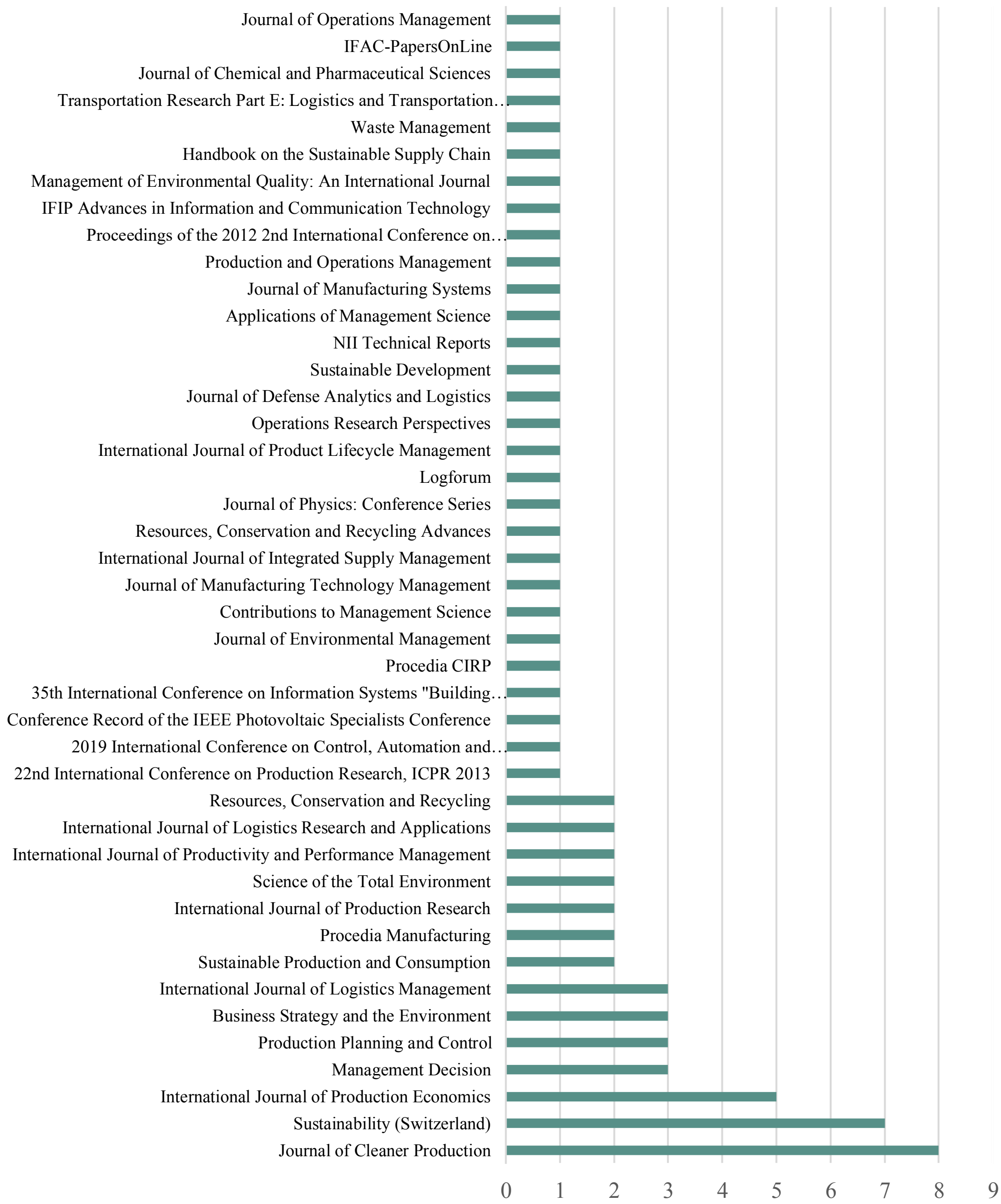


*Figure 9 - Number of articles published per journal*

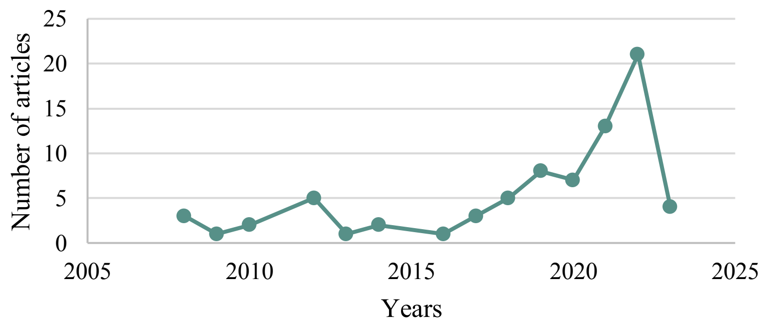


*Figure 10 - Number of articles published per year*

### 4.1.2. Enablers & Practices related to CSC

This section will introduce the findings of the literature regarding common practices, concepts, and methods related to CSCs and CSCM. These can be found in Table 5. For this purpose, practices, concepts, and methods are defined as something that helps to manage the SC in the scope of Figure 3.

#### *4.1.2.1. Closing the loop*

The most obvious practice and key element to CSCM is closing the loop of the material flow which means introducing product or resource recovery principles (R-Principles) into the SC and the operations (Geissdoerfer et al., 2018; MahmoumGonbadi et al., 2021; Masi et al., 2018) This process is very complex (Simonetto et al., 2022) and requires the forward logistics to be combined with RL processes. This non-linear structure is especially created by following the R-principles presented in Table 1. When closing the loop of a SC, end-of-life products, used components, or waste materials need to be returned to the supplier or a third party (Mutha et al., 2022). This has many implications for the relationship and collaboration of the stakeholders in a SC (Calicchio Berardi & Peregrino de Brito, 2021) as well as what technologies are required (Lu et al., 2022), how processes and products are designed (Agrawal et al., 2022) and how the performance of the CSC can be measured in the context of sustainability (Saroha et al., 2022). These mentioned points will be presented in the following paragraphs.

#### *4.1.2.2. Operational practices*

The reverse flow of goods and materials requires a rethinking of the operations of a manufacturing company including their logistics, internal and external processes, their facility design including the production layout as well as the product design (Agrawal et al., 2022; Ali et al., 2021; Calicchio Berardi & Peregrino de Brito, 2021; Hofmeester & Eyers, 2022). Calicchio Berardi & Peregrino de Brito (2021) mention that especially geographic distances to consumers and suppliers influence the complexity and feasibility of CSC and have an impact on logistical costs associated with the forward and reverse SC. The longer the physical distance between producer and consumer, the more costly and vulnerable will the product return be. Blackburn et al. (2004) identified that depending on the time sensitivity of the returned product, the value loss will be influenced by processing delays or quality loss during the remanufacturing process. Therefore, the practice of collecting resources is a critical one for the success of RLs and relevant for CSC. This practice requires another new process in CSC, namely the tracking and tracing of products or components to know when and where a product reaches its end-of-life or needs repair, to improve operational performance due to a more structured RLs process (Lu et al., 2022). This enables controlling the different product life cycle phases for better forecasting of demand and supply in the SC (Tseng et al., 2022). After collecting the products that have reached their end-of-life internal new processes are required compared to a traditional SC. These include the inspection of the returned products to investigate which components can be reused, remanufactured, or recycled (Agarwal et al., 2023). While the inspection process is very time and labor intense, the remanufacturing process requires a dynamic manufacturing set up that can adapt to different components, manufacturing steps, product types, and product volumes fast (Bag et al., 2019; Kazancoglu et al., 2021). Mutha et al., (2022) suggests outsourcing these processes to a third party that takes care of the inspection and remanufacturing of the products. A practice related to the remanufacturing and reassembly of products in a CSC is the product design as mentioned above. The objective of the product design for CSCs is for the products to have a longer life cycle and additionally are easy to take apart for recovery at their end-of-life (Stindt, 2017). A specific practice for extending the product life cycle and simplifying the product recovery process such as remanufacturing or repairing is additive manufacturing as it for example enables spare part production for discontinued products or through automation of the repairing or remanufacturing process (Hettiarachchi et al., 2022; Simonetto et al., 2022).

#### *4.1.2.3. Collaboration*

Collaboration is a frequently mentioned enabler and practice of CSCM and has been identified as *"a key element in the evolution of a CE ",* (Calicchio Berardi & Peregrino de Brito, 2021, p. 1). This collaboration spreads across all stakeholders of the CSC such as suppliers, customers, other SC members and employees of the organization (Lahane & Kant, 2021). Due to the increased number of participants in the CSC, additional coordination and communication in this supply network is required. An example of the increased importance of collaboration is given by Mutha et al. (2022). Since components are bought only once from a supplier but used for multiple lifecycles due to the remanufacturing and repairing characteristics of a CSC, a close collaboration between supplier and manufacturers is important for a healthy relationship. A holistic and well-designed SC network, including RLs does not only strengthen relationships but positively influences the operational activities, mentioned in the section above, as well as the performance of the SC, as described in section 4.1.2.5 (Lahane & Kant, 2021). Such a strategic network can support collaboration across the SC in different forms as stated by González-Sánchez et al. (2020), namely inter-organizational links through strategic alliances or long-term buyer-supplier partnerships. These links can be created in only one industry or even across multiple sectors which adds more opportunities but also more complexity (Kalmykova et al., 2018). However, it is essential for healthy CSCM to have collaboration between the manufacturing sector, RLs sector, and the waste management sector (Agarwal et al., 2023). Moreover, collaboration supports an important practice of CSC, which is green purchasing. Supplier collaboration for green purchasing as a CSCM practice increases the environmental performance of the CSC (Susanty et al., 2020). Similarly, Zhu et al. (2010) state that collaboration with suppliers and customers is emphasizing environmental concerns and eventually leads to environmental and productivity gains. They call this practice 'environmental-oriented supply chain cooperation' (ESCC) and consider it as a key management approach in CSCM.

Concluding, Academia agrees that CSCs cannot be built alone and require collaboration and unified goals and objectives from *"all players in the value chain, from suppliers, logistics providers, waste management companies, to customers, amongst others",* (Mauss et al., 2022, p. 3). However, Academia also agrees that due to the complex characteristics of these networks and interactions, innovative collaboration, cooperation, and coordination practices are required, supported by technology (Agrawal et al., 2022; Lu et al., 2022; Simonetto et al., 2022).

#### *4.1.2.4. Technology*

The above-mentioned closing-the-loop and collaboration practices require *"adequate infrastructure and technology to make the procedure economically feasible"*, (Tseng et al., 2022, p. 2093). Throughout the entire product lifecycle tracking of the components must be able to forecast demand and supply of new and remanufactured products or parts and thereby increase the visibility and transparency of the SC (Lu et al., 2022; Saroha et al., 2022). This tracking requires complex IT-system solutions (Lahane & Kant, 2021) such as artificial intelligence, machine learning, blockchain technology, or internet-of-things technology which can analyze and manage all collected data about the lifecycle stage of the component (Mutha et al., 2022). Specific technologies for this real-time data collection are mentioned by Lu et al. (2022) and include for example barcodes, radio frequency identification and wireless sensor networks. Mutha et al. (2022) point out that the supply of collected components and products impacts manufacturing plans and needs to be coordinated with the demand of remanufactured and new products. The big data that is created through the above-mentioned technologies can help with creating demand plans and keeping them updated to satisfy the customers' requests (Kazancoglu et al., 2021; Lu et al., 2022; Simonetto et al., 2022). Moreover, in their literature review Simonetto et al. (2022) find further multiple advanced and digital manufacturing technologies next to big data that can help to unluck the circularity of resources and components in SCs, such as cloud computing, cyber-physical systems, additive manufacturing, blockchains, artificial intelligence, augmented reality, and virtual reality, as well as collaborative robots. However, these technologies do not only support operational practices but are also an enabler for collaboration between SC stakeholders and members (Agrawal et al., 2022). To summarize, Dulia et al. (2021) emphasize that integrating *"system thinking with technological improvements and conventions at all stages of the supply chain [...] increase[s] the circularity of resources",* (Dulia et al., 2021, p. 10). Therefore, it can be concluded that technological investments and digital maturity are relevant for CSCM.

#### *4.1.2.5. Performance Measurement*

The third area that significantly changes from a traditional SC to a CSC is the performance measurement of the SC (Saroha et al., 2022; Zhu et al., 2010). CSC have the unique goals of creating *"restorative and regenerative cycles [...] based on circular thinking; [... and] a zero-waste economy that is inherent in the CE philosophy"*, (Farooque et al., 2019, p. 5). For companies, this means that they cannot only measure performance on economic factors only but need to involve additional indicators. Elkington (1994) introduced the so-called 'Triple Bottom Line' as a guideline for business to create and measure sustainable value. The triple bottom line includes not only economic indicators but also ecologic and social aspects which are mentioned as relevant for CSCM by Saroha et al. (2022). Creating performance indicators on the 3P's (People, Planet, and Profit) is therefore another practice of CSCM and requires high commitment from the top management (Saroha et al., 2022).

| Category | Practice | Source |
|---|---|---|
| Operational Practices (43) | Closing the loop: Collecting Resources, Returning end-of-life products, used components, or waste materials to the supplier or a third party | Simonetto et al. (2022) Agrawal et al. (2022); Ali et al. (2021); Bag et al. (2019); Blackburn et al. (2004); Calicchio Berardi & Peregrino de Brito (2021); Hofmeester & Eyers (2022); Kazancoglu et al. (2021); Lu et al. (2022); Mutha et al. (2022); Stindt (2017); Tseng et al. (2022) |
| | Tracking and tracing on item or product level | |
| | Inspection of returned item | |
| | Remanufacturing, repairing, recycling, reassembling | |
| | Additive manufacturing | |
| | Designing products for longer life cycles and easy recovery | |
| | Strategic positioning of production sites and distribution as well as collection centers | |
| Collaboration (27) | Strategic alliances & cross-industry collaboration | Calicchio Berardi & Peregrino de Brito (2021); González-Sánchez et al. (2020); Lahane & Kant (2021); Mutha et al. (2022) |
| | Supplier-buyer partnerships | |
| | Knowledge-sharing | |
| Technology (35) | To support new operational practices (such as item tracking, creating transparency for product returns, digitalizing production processes) and collaboration through coordination technologies and data sharing | Lu et al. (2022); Lahane & Kant (2021); Kazancoglu et al. (2021); Dulia et al. (2021); Agrawal et al. (2022); Simonetto et al. (2022); Calicchio Berardi & Peregrino de Brito (2021) |
| Performance Measurement (17) | Performance indicators for triple bottom line | Saroha et al. (2022) |

*Table 5 - Overview of practices special for CSCs*

### 4.1.3. Barriers & Challenges related to CSCs

Even though CSC are gaining popularity and businesses are recognizing their benefits, there are multiple barriers and challenges in (Dulia et al., 2021; Lahane & Kant, 2021; Zhu et al., 2010). These barriers[4], how they relate to the practices described above, and their implications for the business regarding creating resilient CSCs are presented now. A summary of all barriers can be found in Table 6.

#### *4.1.3.1. BMI*

Creating CSC and following the principles of CE requires a rethinking of the business model of a company and can consequently lead to business model innovation (Geissdoerfer et al., 2018; Kazancoglu et al., 2021). All business processes such as product design, production, distribution, R&D, marketing, and finance as well as the internal and external infrastructure are impacted by the new business model (Kazancoglu et al., 2021). Dulia et al. (2021) state that there is a *"lack of successful business models and frameworks to implement ",* (Dulia et al., 2021, p. 11) which increases the uncertainties and risks for companies to innovate their business model and move towards CSCs

[4] Barriers involve risks, uncertainties and challenges as most literature calls most barriers risks (Dulia et al., 2021; Kazancoglu et al., 2021)

(Geissdoerfer et al., 2018). Especially the implementation of new processes and resources (described in Table 5) that are required to deliver the new, more sustainable value proposition are challenging.

#### *4.1.3.2. Closing the loop barriers*

As described above, the practice of closing the loop involves the return or collection of end-of-life products, components or resources from the consumer as well as managing the waste of these returns and planning the remanufacturing, repairing, or recycling. A barrier related to implementing this process is a lack of transparency in the traditional SCs, which means that there is limited visibility on where a component is and in what lifecycle stage it is (Lu et al., 2022). Similarly, *"the visibility of the process [CSC] is much less transparent"*, (Ali et al., 2021, p. 98) compared to the one of traditional SCs. Consequently, the number of returns is unknown, and the product recovery process not fully controlled (Carrasco-Gallego et al., 2012). This stochastic nature of product returns is mentioned by multiple authors as a barrier and challenge in CSCM as follows. Agarwal et al. (2023) argue that this is caused by the poor forecast accuracy of supply and demand and leads to inefficient use of existing resources such as manufacturing capacity. Additionally, it is stated that the critical objective of matching the demand and return flow is impaired by the uncertainty in product returns. Turki & Rezg (2018) support that statement by arguing that the *"returned-used products are derived from sales rather than market demand"*, (Turki & Rezg, 2018, p. 2). Another unknown variable regarding the return of products is the quality of the components, and the degree of repair, or remanufacturing that is needed (Agarwal et al., 2023) which leads to unused or overused production capacity and requires certain dynamic capabilities to cope with the uncertainty of returns (Bag et al., 2019). Moreover, when a product is returned, not all components can be reused, which creates the need for waste management. However, Mastos et al. (2021) argue that the waste management in CSCs is challenging due to a lack of ecosystem where industrial waste is collected and sold.

#### *4.1.3.3. Sustainable Performance barriers*

Since CSCs consider not only economic performance but also environmental and social performance aspects, the context of the SC gains complexity due to the dynamic characteristics of sustainability (Mastos et al., 2021). Especially the rapid changes in regulations regarding the impact of business on the environment create the risk of disruptions (Salmenperä et al., 2021).

#### *4.1.3.4. Collaboration barriers*

Collaboration is one of the core principles of CE and CSCs since the extended network offers new opportunities for waste management and reuse of materials. However, the higher the number of stakeholders in this network, the more complexity is created and advanced coordination techniques and technologies are required to manage the collaboration (Calicchio Berardi & Peregrino de Brito, 2021; Mastos et al., 2021). Mastos et al. (2021) argue that it additionally increases uncertainty in the SC due to this more dynamic and complex stakeholder network while Dulia et al. (2021) emphasizes the importance and difficulty of synchronizing the activities in the SC across all members. While Agrawal et al. (2022) argue that the high level of collaboration can lead to *"shared responsibility system across the supply chain for better recovery and fewer disruptions "*, (Agrawal et al., 2022, p. 2), Chhimwal et al. (2021) found that especially the involvement of third parties for collecting, remanufacturing, or recycling purposes involves a variety of risks, such as harming competitiveness due to knowledge sharing of product design or technology privacy and other intellectual property (Kazancoglu et al., 2021; Mutha et al., 2022). Additionally, involving a third-party remanufacturer to reuse components might harm the relationship with the supplier of the material or components since smaller volumes are bought (Mutha et al., 2022). Concluding it can be said that collaboration enables many CSCM practices such as remanufacturing but adds new challenges such as data-security and intellectual property loss. For collaboration to work in a CSC trust and coordination capabilities are needed.

#### *4.1.3.5. Technology barriers*

While academia agrees on technology and Industry 4.0 (I4.0) being an important enabler of CE and CSCs (Kazancoglu et al., 2021; Lu et al., 2022; Mastos et al., 2021) it adds new complexity, costs, and risks to a SC and its stakeholders (Dulia et al., 2021). Especially the data and cyber security aspect is highlighted in the latest studies since collaboration across the SC requires data sharing (Tseng et al., 2022). Moreover, Dulia et al. (2021) highlight that SCs often spread over multiple geographic areas with different maturity levels. This leads to different uses of more, or less advanced technologies in different countries which limits data sharing and implementation of advanced tracking systems. This is related to different levels of knowledge and expertise around information technology (IT). Many companies still face obstacles when applying these technologies or developing innovative devices to operate the CSC (Tseng et al., 2022). Furthermore, Dulia et al. (2021) found that the *"lack of accurate information regarding the tracing of materials through reprocessing is another issue limiting CSC adoption",* (Dulia et al., 2021, p. 11) which is related to the reliability of data and the IT systems as well as to the design of the RL routes. Since innovative technology is an enabler for CSCs, overcoming these barriers and mitigating the risks is essential to a successful adaption of CSCs. However, *"uncertainty and risks will increase as inefficient use of innovative technology and information systems may increase the system's complexity",* (Lu et al., 2022, p. 9) implying that the right technological skills are needed to reduce complexity of CSCs as stated in paragraph 4.1.3.7.

#### *4.1.3.6. Lack of Awareness*

A main barrier for implementing and managing CSC is a lack of awareness in both the internal and external business environment of an organization. A specific reason why the internal awareness is low is a lack of top management commitment to support this unified objective of creating a CSC (Ali et al., 2021; Sonar et al., 2022) due to a lack of prioritization relative to other, more short-term, urgent projects (Chan & Kai Chan, 2008). The lack of external awareness can also be rooted in suppliers, governments, and consumers or customers (Agarwal et al., 2023; Fobbe & Hilletofth, 2022; Kazancoglu et al., 2021). This lack of awareness can lead to misconceptions such as a perceived lower quality of remanufactured products (Turki & Rezg, 2018) and a lack of regulations from the government for both production and consumption aspects of sustainability supporting CSC (Tseng et al., 2022). This increases the difficulty of pressurizing suppliers of materials to become more sustainable and is therefore creating a barrier to CSCs (Fobbe & Hilletofth, 2022). Masi et al. (2018) have conducted a survey with 77 respondents working in various positions from different industries across the world and found that 65.33% of the respondents are aware of the concepts of CE while 34,67% are unaware. This supports the identified hypothesis that the lack of awareness is a barrier to CSCs.

#### *4.1.3.7. Lack of Knowledge and Skills*

Another barrier that makes CSCM more difficult is a lack of knowledge and skills which can be either caused by a lack of awareness, missing top management commitment or missing training for employees (Agrawal et al., 2022; Ali et al., 2021; Fobbe & Hilletofth, 2022). Especially the 'closing the loop'-practices such as the inspection, repairing, remanufacturing, and reassembling of used products need higher labor intensity as well as a more skilled and experienced workforce (Agarwal et al., 2023; Bag et al., 2019; Kazancoglu et al., 2021). Moreover, the increased collaboration requires new coordination skills to effectively interact with suppliers and customers. However, there is a lack of focus on training and development of these 'soft skills' (Agrawal et al., 2022; Hofmeester & Eyers, 2022). More feasible skills that are necessary for CSCs are technical skills to handle the complexity of the technology required for creating transparency and visibility across the SC. Handling big data demands specialized expertise and knowledge which is not yet fully developed in companies and can therefore be a barrier to CSCs (Ali et al., 2021; Hofmeester & Eyers, 2022). Lastly, Dulia et al. (2021) mention, that there is no method yet to assess the risks of CSCs due to their novelty. Consequently, this lack of knowledge and experience results in companies either sticking to their traditional SC, or in failure of CSCs (Tseng et al., 2022).

#### *4.1.3.8. Financial barriers*

Lastly, an often-mentioned barrier to CSCs are financial challenges. These can be related to different aspects of CSCM and are presented now. Firstly, the profitability of CSC implementation is unknown, as it involves for example high technological investments and costly manufacturing equipment as well as additional labor to be able to develop and operate an efficient take-back system (Ali et al., 2021; Dulia et al., 2021; González-Sánchez et al., 2020; Tseng et al., 2022). A lack financial resources can therefore be the first barrier to CSC (Chan & Kai Chan, 2008), however, even companies with available resources see a risk in the high investments *since "the benefits from investment in technology are not clearly defined, and operational efficiency is uncertain",* (Tseng et al., 2022, p. 2094) and a potential lack of economic benefits in the short run as stated by Agrawal et al. (2022). Secondly, Kazancoglu et al. (2021) and Agrawal et al. (2022) found that purchasing green materials or components is a barrier in CSCs due to the *"high costs of environmental-friendly products and the long return time on investments"*, (Kazancoglu et al., 2021, p. 4). Concluding Dulia et al. (2021) found that usually, *"the payback period regarding CSC projects is 5–10 years, which can be too long for most people who are generally risk-averse "*, (Dulia et al., 2021, p. 10) which is one of the main barriers for CSC implementation.

| Practice / Category | Barrier | Source |
|---|---|---|
| Closing the loop barriers | Potentially requires Business Model Innovation | Geissdoerfer et al. (2018); Kazancoglu et al. (2021) |
| | Lack of visibility and transparency | Lu et al., (2022); Ali et al. (2021) |
| | Lack of control due to many unknown variables (product return number and quality) | Carrasco-Gallego et al. (2012) |
| | Stochastic nature of product returns leads to poor forecasting of supply and demand and inefficient use of resources | Agarwal et al. (2023) |
| | Supply is derived from returns not from market demand | Turki & Rezg (2018) |
| | Uncertain required manufacturing capacity since quality of returned products is unknown | Agarwal et al. (2023) |
| | Lack of waste management solutions | Mastos et al. (2021) |
| Sustainable performance (measurement) barriers | Dynamic characteristics of sustainability create complexity and vulnerabilities | Mastos et al. (2021) |
| Collaboration barriers | Increased number of stakeholders creates complexity and requires innovative coordination techniques for synchronization | Calicchio Berardi & Peregrino de Brito (2021); Mastos et al. (2021); Dulia et al. (2021) |
| | Third party involvement can risk intellectual property and requires knowledge sharing, might lead to loss of competitiveness | Kazancoglu et al. (2021); Mutha et al. (2022) |
| | Loyalty towards supplier is questioned | Mutha et al. (2022) |
| Technology barriers | Data and Cybersecurity risks due to data sharing | Tseng et al. (2022) |
| | Different digital maturity levels in companies of different geographic regions → limits data sharing and tracking of components | Dulia et al. (2021) |
| | Lack of data and unreliable systems | Dulia et al. (2021) |
| | Inefficient use of technologies creates new risks and uncertainties | Lu et al. (2022) |
| Lack of Awareness (Barrier to multiple practices) | Lack of prioritization relative to other issues | Chan & Kai Chan (2008) |
| | Lack of top management commitment | Ali et al. (2021); Sonar et al. (2022) |
| | Lack of external awareness (customers, suppliers, government, other stakeholders) → can lead to misconceptions and conflicts | Agarwal et al. (2023); Fobbe & Hilletofth (2022); Kazancoglu et al. (2021); Turki & Rezg, (2018) |
| | Lack of regulations | Tseng et al. (2022) |
| | About 35% unaware of CE | Masi et al. (2018) |
| Lack of Knowledge and Skills (Barrier to multiple practices) | "Closing the loop practices" need specific skills and experienced workforce | Agarwal et al. (2023); Bag et al. (2019); Kazancoglu et al. (2021) |
| | Collaboration requires specific coordination skills | Agrawal et al. (2022); Hofmeester & Eyers (2022) |

| | | |
|---|---|---|
| | Lack of technical skills to deal with complexity of I4.0 technology | Ali et al. (2021); Hofmeester & Eyers (2022) |
| | Lack of knowledge on risks management in CSCs | Dulia et al. (2021) |
| **Financial barriers** | Uncertain ROI<br>High investment in technology<br>High investment in equipment<br>Investment in training<br>Investment in green purchasing | Ali et al. (2021); Dulia et al. (2021); González-Sánchez et al. (2020); Tseng et al. (2022); Chan & Kai Chan (2008); Kazancoglu et al. (2021); Agrawal et al. (2022) |

*Table 6 - Overview of barriers special for CSCs*

## 4.2. Conceptual Framework

This section analyzes the impact of above-described practices and their barriers on SC resilience and consequently the business performance in the context of a company's business model and its governance. In Figure 11 on overview of the relationships is shown and the specific focus areas specified with the letters "A-D" which are described in the following sections. This framework has the limitation of not showing the positive impact that some of the practices have on the barriers and opposite.

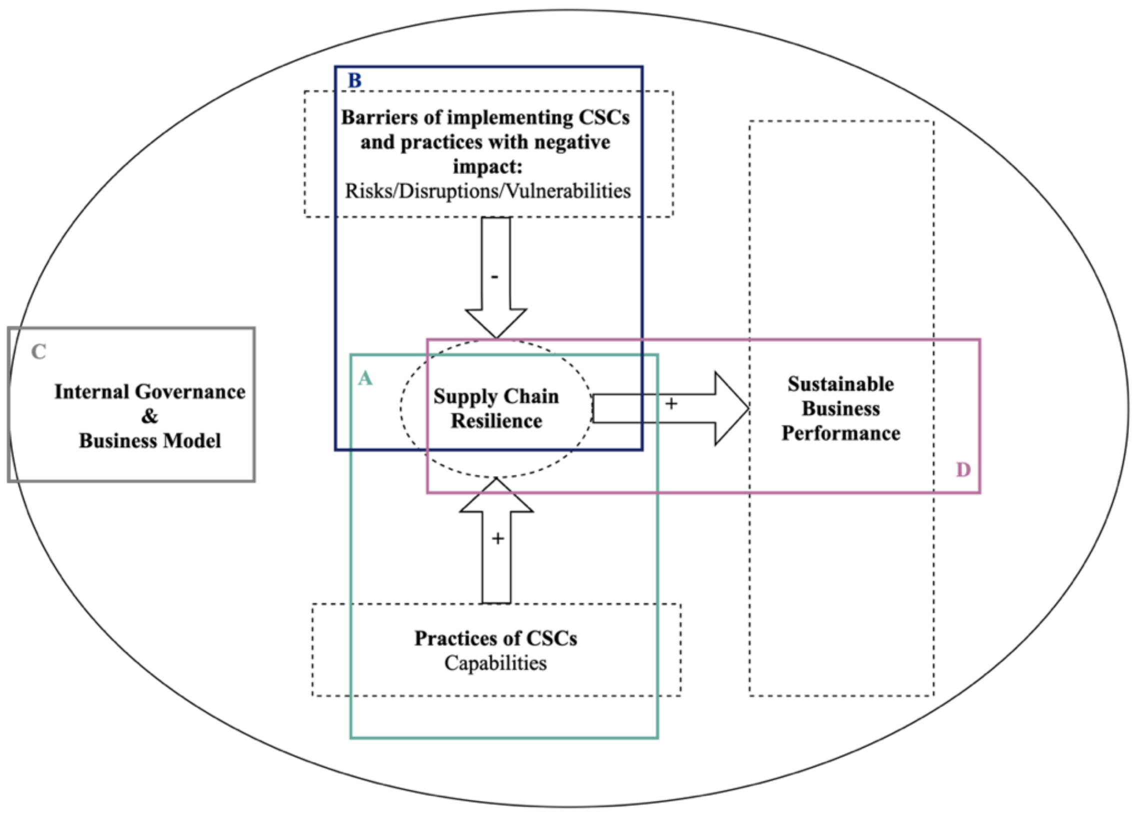


*Figure 11 - Overview of conceptual framework*

### 4.2.1. A – CSC Practices and their positive influences on SC capabilities

Figure 12 presents an overview of how the identified CSC practices influence the capabilities of a resilient SC. Starting with the key practices of CSCs such as closing the loop and reducing waste (shown in green boxes) as well as collaboration (shown in orange boxes), and technology (shown in blue boxes) that support these are presented in the rectangle boxes while the SC resilience capabilities from Kochan & Nowicki (2018) (see Figure 4) are shown in the light green boxes with rounded corners.

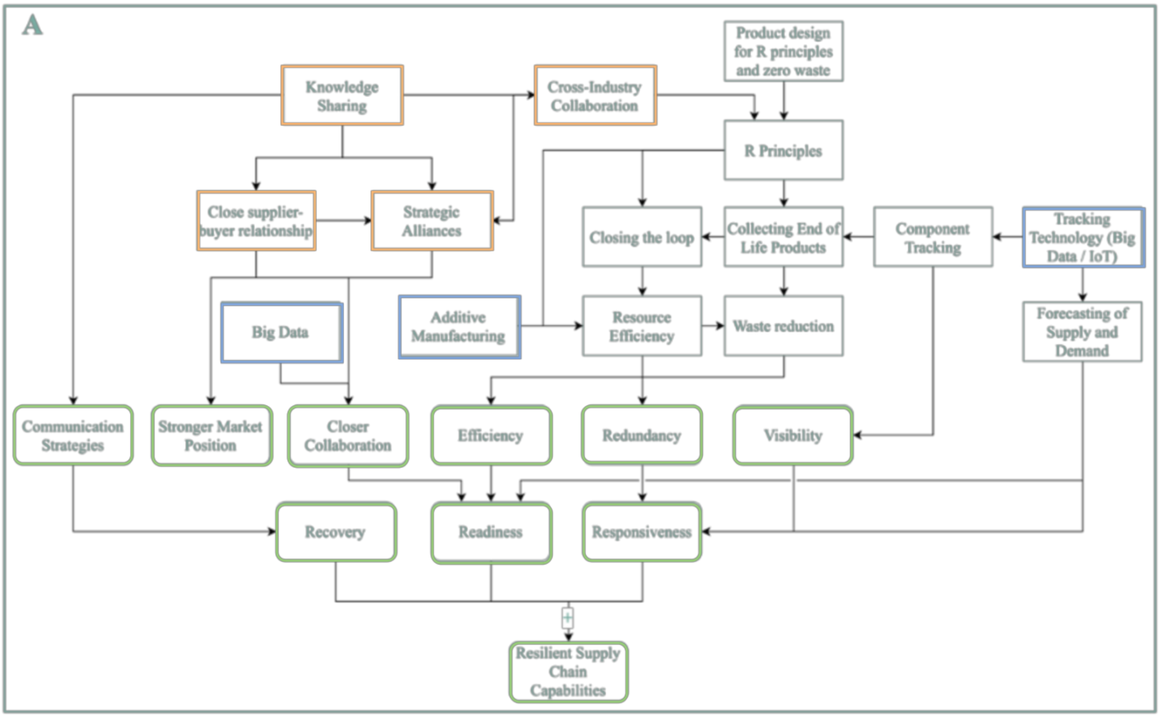


*Figure 12 - Cause and Effect Overview of CSC Practices and SC Resilience Capabilities*

### 4.2.2. B – CSC Barriers and their negative influence on SC resilience

The barriers that are identified above are now set into relation with each other and with the risks, vulnerabilities, and disruptions of a SC (shown in red boxes) as defined by Kochan & Nowicki (2018). These cause-effect relationships are presented in Figure 13.

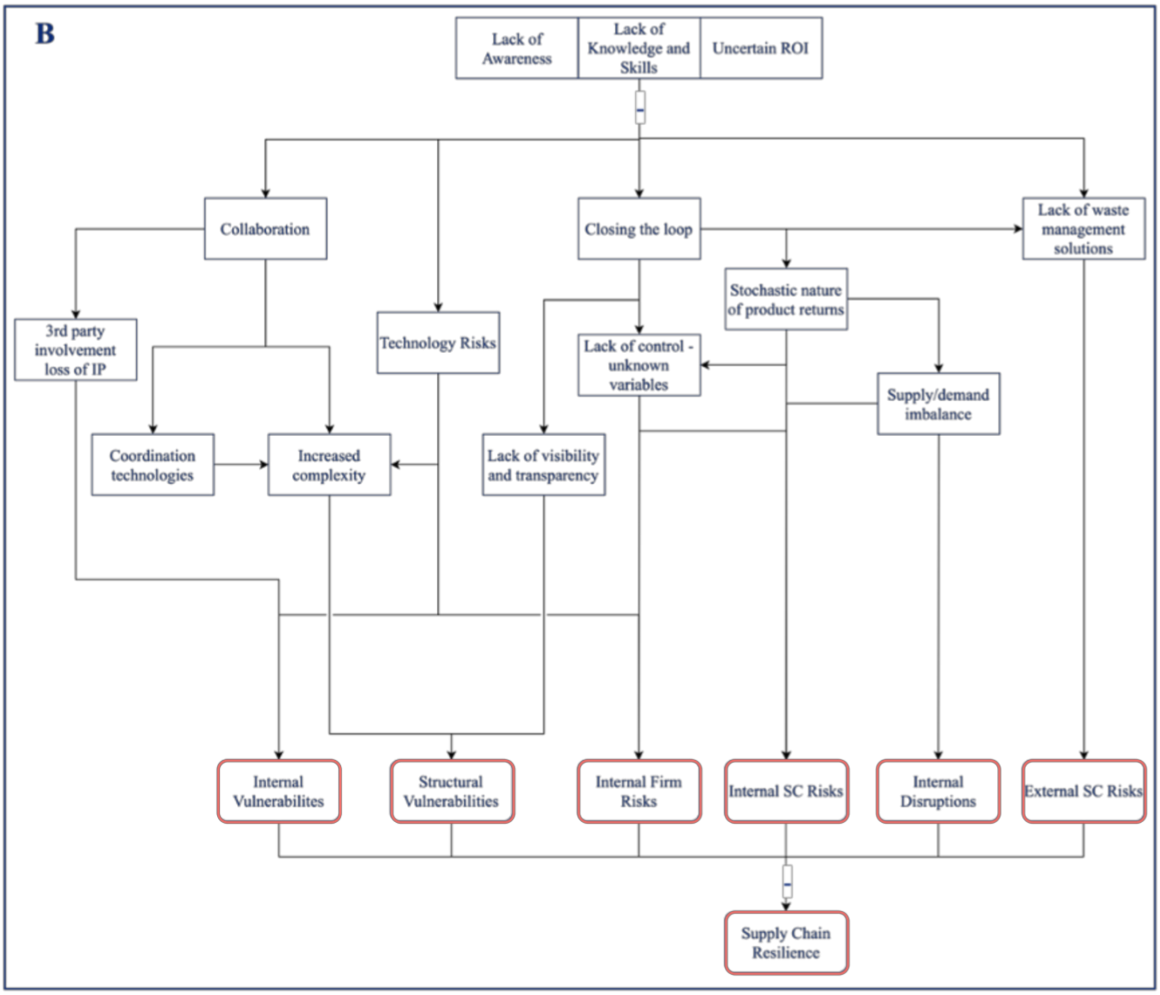


*Figure 13 - Cause and Effect Overview of CSC Barriers and SC Resilience Risks, Vulnerabilities, and Disruptions*

### 4.2.3. C – Company Governance and its impact on CSC implementation

Figure 14 visualizes which aspects of SC resilience are influenced by the implementation of new business models and governance processes which are required for operating CSCs as mentioned in the literature review.

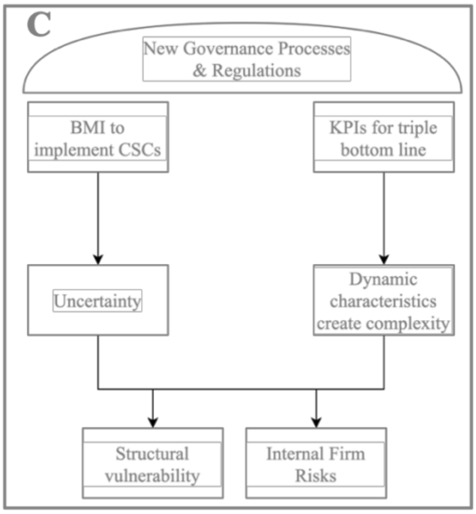


*Figure 14 - Cause and Effect Overview of New Governance Processes and SC Resilience*

### 4.2.4. D – Relationship between resilience, performance, and sustainability

The triangle shown in Figure 15 visualizes how both resilience and sustainability in the business positively influences the performance, while a sustainable business increases resilience and resilience can support a sustainable business.

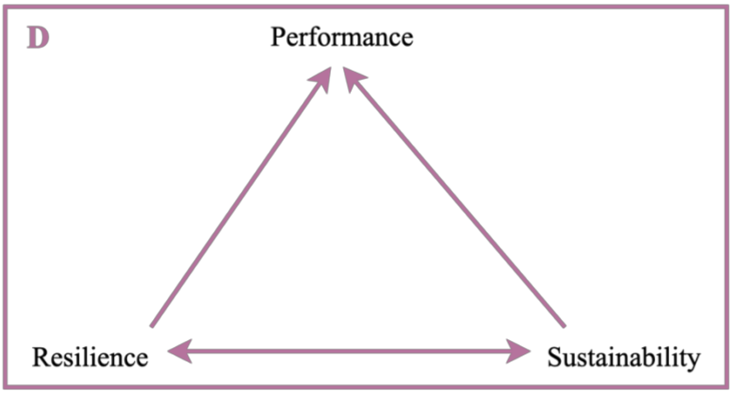


*Figure 15 - Resilience - Sustainability - Performance Triangle*

## 4.3. Complexity of CSCM

Based on the theoretical background mapped out in this chapter it can be argued that implementation of CSCs categorizes as an unordered phenomenon due to a lack of best practices, and no visible or perceivable cause-effect relationships. This is also supported by the slow adaption of CE concepts in the industry as described in Chapter 2. Many companies wait for the early adopters to make a first move and learn from their failures or successes. Consequently, it can be argued that the high complexity is the main barrier for companies to implement circular practices. Therefore, a structured process is required to break down the complexity and move towards a complicated or simple business environment (Snowden & Boone, 2007). According to the Cynefin framework (see Figure 16) analyzing and acting is possible in this environment, due to available information, and a clear structure for implementation without fearing disruptions. This complexity assessment supports and highlights the importance of the objective of the thesis which is to reduce the complexity of circularity practice implementation by creating a structured and systematic process for identifying and evaluation potential practices.

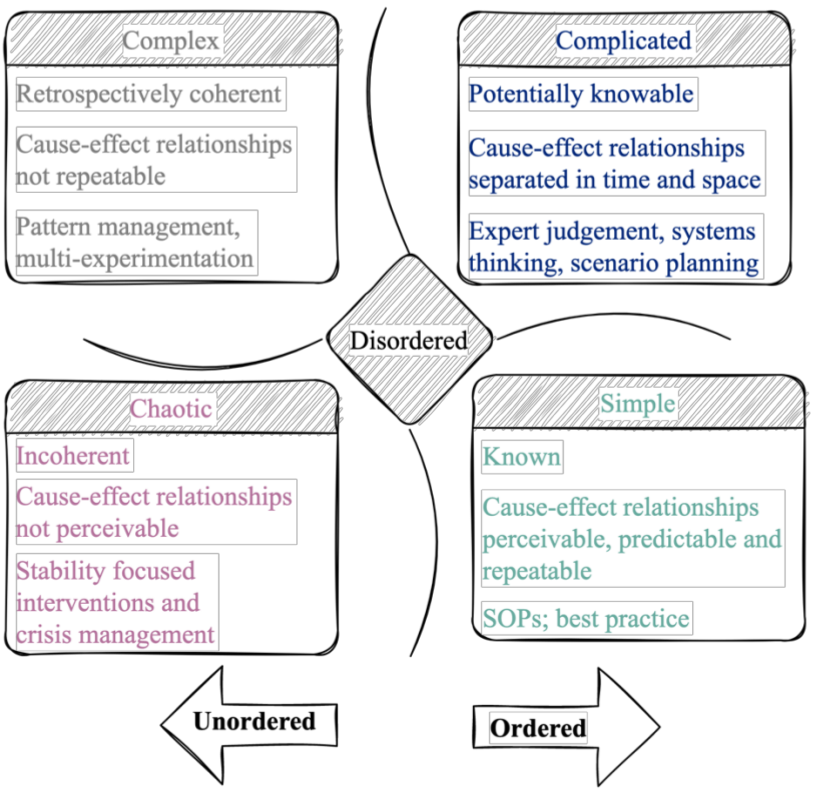


*Figure 16 - Cynefin Framework (Snowden & Boone, 2007)*

# Chapter 5. Solution Design

This chapter describes the solution artifact that is designed to achieve the objective of this thesis, which is to create a structured process for firms to evaluate which circularity practices can be implemented in their SC and to identify the consequences for the resilience of the SC. After analyzing the literature and creating a knowledge base, an empirical problem is identified and used to evaluate the conceptual framework for companies to implement CSCs. Accordingly, this chapter describes the process of designing the solution, supported by DSRM and presents the first and second iteration of the solution.

## 5.1. Model Design

When designing a tool or a model for companies to analyze how to implement circularity into their SC it is important to define the requirements for the model according to the key objective of it (Hevner et al., 2004). However, the literature review showed a variety of different practices and enablers that can be used complementary but also interchangeably, depending on the context of the SC. The model design needs to take that into account by designing an open process where the environment of the SC decides the practices that need to be implemented and not the model itself. Moreover, some practices can be implemented relatively easily once the financial resources are available (e.g., training of employees in forms of workshops/rethinking product design), while other practices are more complex to implement and need more innovative approaches (e.g., strategic RLs network/ I4.0 technology). This highlights the above-mentioned point that there is no one right solution for all companies and practices but the process needs to enable ideation that leads to finding the right practices for the company. However, the identified key practices and barriers as well as the cause-effect relationships can still be used as guidelines for this solution framework. Since the literature review from Chapter Chapter 4 showed that there is no existence of a theoretical or practical solution for the identified problem, the needs and requirements for the model related to the objective of the thesis are explored now and based on the knowledge base created in Chapter Chapter 4. Consequently, it can be argued that the first iteration of the model and its requirements is only theoretical and needs application to a practical problem to create a more relevant and tangible solution for companies.

### 5.1.1. Requirements

The model requirements are scoped towards fulfilling the objective of the thesis and solving the needs of businesses and are used to evaluate the first iteration of the artifact. These requirements are based on the initial theoretical understanding of the problem, resulting from the knowledge base. The knowledge base showed that there are certain enablers and drivers for CSC implementation such as collaboration or technology, but different barriers related to these. This resulted in a complex phenomenon for companies to decide on what enablers and practices are fitting for their SC environment. Additionally, the lack of knowledge and awareness, as well as no unified objective for circularity implementation are often-mentioned barriers. Therefore, the solution should not only include the analysis process for new practices and their barriers, but also a learning aspect regarding CSCs and the required practices, since it was found during the literature review that the right employee skills can help reduce the complexity of implementing and managing CSCs. Due to the complexity and the uncertain needs in businesses to balance the learning, the ideation, and the analysis aspect, the first iteration will be a pilot test focusing especially on the feasibility of the solution. However, the main requirement and evaluation criterion will be the fulfillment of the objective of the thesis, namely, to make the implementation of circular practices less complex for companies and move towards the complicated environment (see Figure 16) according to Snowden & Boone (2007). Based on this the following specific requirements are used:

- Reduce complexity of circular practice implementation
    - Create a systematic and structured process
    - Show cause-effect relationships
- Solution needs to be feasible
    - Feasible analysis of current SC
    - Feasible ideation for new practices
    - Feasible creation of scenarios to test and critically analyze practices according to risks, disruptions, and vulnerabilities

### 5.1.2. Solution Framework

To fulfill these requirements the solution consists of two building blocks, based on the knowledge base presented in Chapter Chapter 4 and the model design requirements set up in section 5.1.1. The first block is a framework, presented in Figure 18, consisting of four phases which describe the process and tools of identifying practices and barriers and evaluating how these enable circularity and impact resilience. This process is discussed below and aims at breaking the complex phenomena down into more structured steps. Secondly, the preferred setting of how the model is applied in a real-life scenario is presented.

#### Understanding Phase

The SC where circularity needs to be introduced is analyzed in this phase. The goal is to gather information about the SC and to understand the key stages, key stakeholders, as well as main risks and vulnerabilities of the SC. To identify the key stages of a SC, it can be helpful to use tools such as value stream mapping (VSM), supply chain mapping (SCM), or activity-based costing (ABC). The differentiated perspectives of these tools enable a full picture of the SC, the value creation and related activities and costs. When identifying key stakeholders, Hermans & Thissen (2009) propose multiple actor analysis methods that can be used for selecting and analyzing the key stakeholders. These methods have been adapted for the purpose of identifying SC actors. Lastly, information on known risks and vulnerabilities of the SC should be collected. For this different risk identification analytical and creative methods can be used such as a system influence map, a fishbone diagram, brainstorming (Bharathy & McShane, 2014), scenario-based planning (Van der Heijden, 2011), or pre-mortem (Klein, 2007). Combining multiple methods will give a more diverse risk event overview (Bharathy & McShane, 2014).

### Exploration Phase

When moving to the exploring phase it is important to challenge the current SC configuration and think out of the box since a lack of awareness and lack of knowledge has been identified as a main barrier in the literature review. To overcome this, learning, creativity, and ideation is needed. In this phase, the goal is to identify certain circular practices based on the R-Principles to slow down or close the resource loop. To structure the process better, it is helpful to focus on just one product line at a time since different products might have different potentials in terms of reducing, reusing, or recycling. Additionally, mapping the right partners and technologies for this process is an important enabler of operating a CSC as identified in the literature review. Lastly, the knowledge base suggests BMI to find the right business model and operating model to achieve sustainable performance in a CSC. Table 5, in which the most common practices and enablers are mentioned, can support this phase by giving inspiration and best-practice examples of circular practices. To make it more accessible to the participants, the table is converted to a list of discussion items as shown below:

- How can we close the loop of one of our raw materials/ resources/ components/ products?
- How can we collect these raw materials/ resources/ components/ products after use?
- How can we identify if R-principles should be used or how to manage the waste?
- How can we ensure visibility of the raw materials/ resources/ components/ products?
- What internal changes can we make to optimize the above?
    - Product design?
    - Production layout and capabilities?
- Who do we need to involve for enabling the above?
    - How do we involve them?
    - When do we involve them?
- What technology can help us?
    - Can we use existing data to track and collaborate?
    - Do we need to invest in new technology?
- How can we create an incentive to implement CSC?
    - Do we have the right performance measurements in place?
    - What are better performance measurements?

To reduce uncertainties during this, potential experimentation scenarios based on scenario-thinking should be developed in the exploration stage. The practices that were identified during the exploration phase can then be tested in the scenarios in the next phase to identify potential risks or barriers.

### Critical Analysis Phase

The objective of this phase is to challenge the feasibility of the explored practices and map potential risks and vulnerabilities or other barriers. This process is supported by using the different scenarios and the practices from the exploration phase. Additionally, the barriers and risks identified in Table 6 can support this process through awareness creation regarding certain risks. Not only critical thinking is necessary here but also critical questioning such as using the 'Root Cause Analysis' method (Doggett

2005). For this, Table 6 and the different scenarios can be used as a starting point for finding an issue while applying the why-why questioning to that issue is going to help finding the underlying cause for the barrier.

During this phase the focus should be on internal barriers that are in the circle of control and in the circle of influence as shown in Figure 17 to enable internal solutions to the barriers.

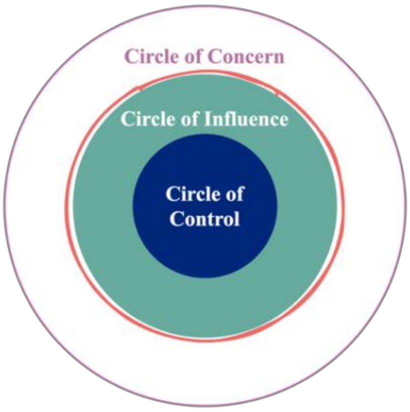


*Figure 17 - Circle of Concern, adapted from* (Covey, 2013)

### Evaluation Phase

The goal of the last phase of the framework, the evaluation phase, is to identify the interdependencies between the identified practices and barriers to create cause-effect relationships based on Figure 12, Figure 13, and Figure 14. Based on this the impact on SC resilience can be identified and risk management tools can be applied to mitigate the potential vulnerabilities and risks in the CSC. In Chapter Chapter 4 it was identified that certain practices for CSC implementation such as collaboration can also be a barrier since it adds complexity. Additionally, an enabler for this practice is technology, since it can provide coordination tools that are required to manage the network complexity. However, using these technologies creates new risks and a different kind of complexity to the SC. Therefore, mapping the cause-effect relationships for the identified practices and barriers highlights the importance for companies to find the balance between using a practice to enable another practice and not creating unnecessary new complexity and risks. This balance heavily depends on the SC characteristics such as maturity level of suppliers and customers as well as the number of SC actors which were identified in the 'Understanding Phase'. Another aspect of the evaluation phase is to consider resilience trade-offs and consequently business performance trade-offs when increasing sustainable performance (focusing on people and planet aspects) as shown in Figure 15.

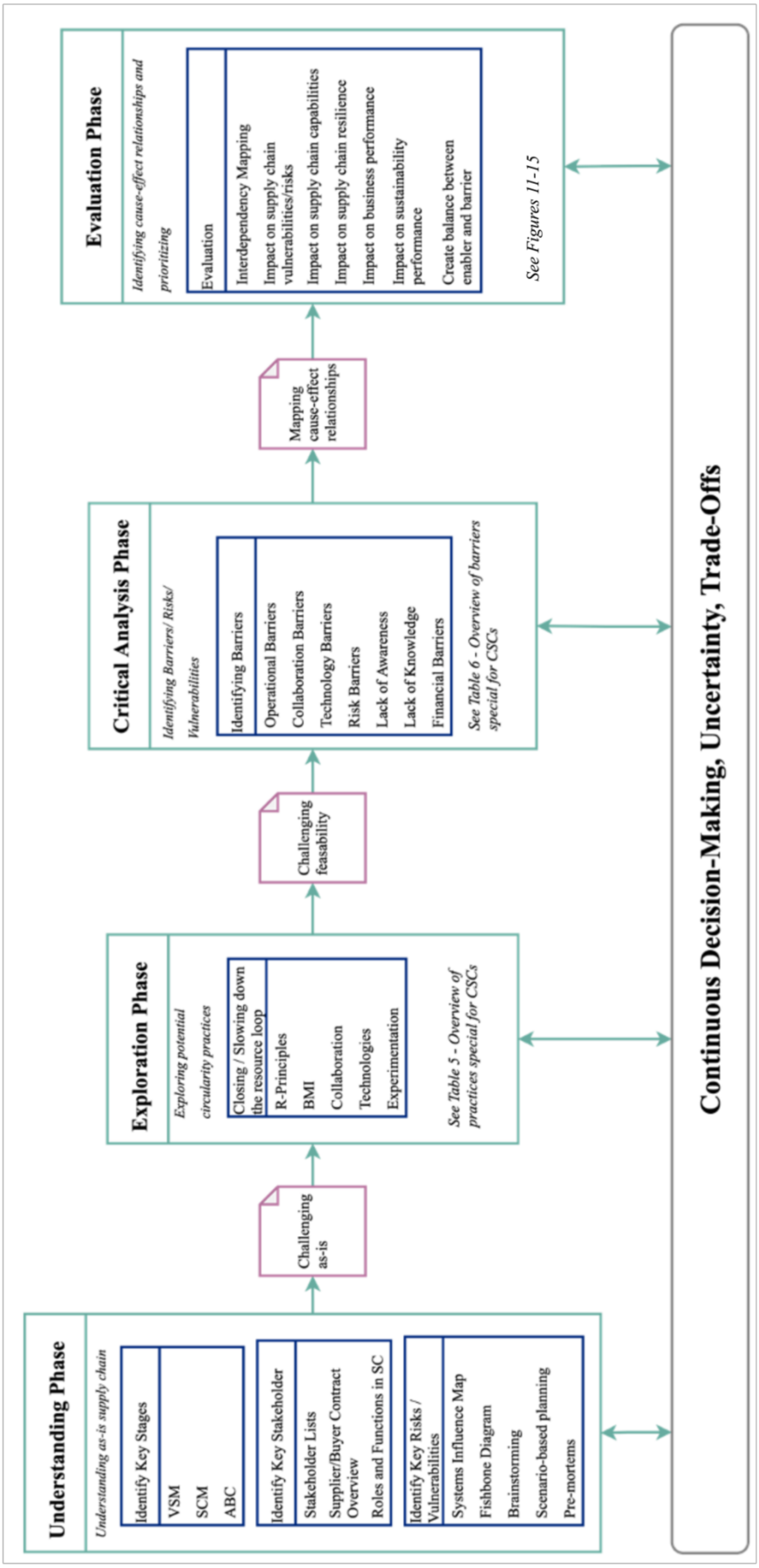


*Figure 18 – First Iteration of CSC Implementation Process Framework*

## 5.2. Demonstration

After building a knowledge base and identifying a business need, a framework that aims at utilizing the knowledge to solve the problem was designed, shown in Figure 18. This is now demonstrated and applied to the company where the business need originates from. To test the fit of the framework to the business need, it is applied to Fibertex, a company producing non-woven for hygiene products such as diapers and fem-care products. Fibertex Personal Care is part of the Schouw & Co. Group and is one of the world's biggest producers of non-woven materials (Fibertex Personal Care, 2023). The company has a product range of 25-30 different products and about ten different suppliers for their raw material, which is plastic granulate. Additionally, they have partners for waste management and coloring of the plastic granulates. The SCM team consists of two FTEs, one being the SC director and one responsible employee for sourcing of the materials (see Appendix C). The workshop to demonstrate and test the artifact was conducted according to the framework presented in Figure 8 in Chapter 3.3.1.2. Moreover, a PowerPoint presentation as a guide for the workshop was created based on the solution framework, which can be found in Appendix D.

**Planning Phase:** One could argue that the content planning of the workshop is covered by the design of the artifact since it provides the facilitator with a guideline and tools to use to achieve the objective of each of the phases in the framework. However, there is practical planning required to facilitate a workshop which is described now. Firstly, the list of participants is created which in this case only includes the SC director due to lack of resources in the team and a perceived opinion of the SC director that he will have most relevant knowledge for this workshop (see Appendix C). Secondly, a time plan is created to fit the participants available working hours. In this case, two hours including a tour through the production facilities are planned, however, the preferred timeframe for this is an entire day with multiple participants to cover all phases of the framework in depth and leave room for discussion and breaks. Lastly, the prepared presentation template based on the framework including the time plan is shared with the participant beforehand to allow him to prepare. During the planning phase it is important to align with the top management of the company to generate a high commitment from their side and available resources since a lack of this commitment was identified as a barrier in Chapter 4 (Ali et al., 2021).

**Facilitating Phase:** The workshop was facilitated according to the phases of the framework in Figure 18. The main findings are presented in Table 7. During the workshop it became obvious that the participant had difficulties with thinking outside of the company's borders such as collaboration across the entire industry and additionally continuously highlighted their current practices as better than industry standard and sufficient. This created a challenge for moving out of the exploration and critical analysis phase towards evaluating potential concepts. How this can be improved in the framework will be discussed in the next section. Since the findings specifically for the company are not directly relevant for the improvement of the solution, the next phase, namely the analysis phase will be replaced by the evaluation phase of the DSRM. The evaluation phase of the DSRM is focusing on if the requirements and the objective of the artifact is achieved.

| Phase | Findings |
| --- | --- |
| **Understanding Phase** | - Relatively little complexity in SC (10 suppliers, one raw material source, 25-30 different products)<br>- Multiple suppliers for resilience<br>- 2 Partners in SC<br>- Main risks: product innovation and plastic regulations<br>- Internal circularity<br>- High hygiene and quality standards in industry |
| **Exploration Phase** | - Focus on R-principle "Reducing"<br>o Idea on reducing material needed for producing the non-woven |
| **Critical Analysis Phase** | - Would require customers to change production equipment |
| **Evaluation Phase** | - Lobbying is required to implement the new idea, collaboration and brainstorming with customers how to overcome the challenge<br>- Experimentation of how to produce with less material can reduce costs |

*Table 7 - Workshop Findings*

## 5.3. Evaluation

This section evaluates the demonstration findings of both the developed process solution framework and the workshop setting in the context of the business need and aims at identifying successful factors and improvements for the first iteration of the framework and demonstration process. The objective of this evaluation process is to propose a second iteration of the framework and an improved workshop structure to effectively solve the business need by use of the existing knowledge gathered in Chapter Chapter 4 and the findings of the demonstration workshop of the first iteration. To structure this evaluation better, firstly the requirements from section 5.1.1 are reflected on. Afterwards, the workshop setting is reflected on, highlighting both positive and negative aspects, followed by an evaluation of the framework phases and their effectiveness and completeness.

### 5.3.1. Requirement Reflection

The first iteration was set up as a pilot test where the focus was on creating a process for reducing the complexity of circular practice implementation. Since one workshop with one company cannot achieve the latter, this evaluation criterion is out of scope for the first iteration and will be discussed in Chapter Chapter 6. Therefore, the focus was on testing the feasibility of the process and the setting. More specifically, the goal was to identify if the current process can analyze the as-is SC, support ideation for new circularity practices and eventually create scenarios where these practices can be tested and evaluated in. During the workshop it was found by both the participant and the facilitator that the biggest challenge was to ideate for new ideas since the provided tools were not sufficient. Therefore, the overall conclusion on the requirement evaluation is that the feasibility is not given yet, due to a lack of ideation tools and creative out-of-the-box thinking. In section 5.4 methods to enhance the creativity for a more successful ideation phase are presented and discussed. Before, the following sections below will evaluate the individual parts of the solution framework.

### 5.3.2. Workshop setting

Reflecting on the planning phase of the workshop, putting time aside for a tour through the production facilities was very valuable and created a more holistic understanding of the volume and type of product that is produced in the company. Additionally, it showed that sending a plan about the workshop in advance enabled deeper conversations and a higher focus on details and facts. Additionally, facilitating the workshop physically reduced miscommunication and created a better understanding of the facilitator and the participant. An important part of the planning phase is deciding on the participants. For the first iteration of the. Framework, only the SC director participated. Reflecting on that decision, expanding the list of participants internally as well as external would have been valuable. During the workshop, the participant mentioned that the sourcing, sales, and R&D team is working with external partners such as customers and suppliers. Including representatives of these parties supports the initial understanding of collaboration being an enabler for implementing CSC practices (Calicchio Berardi & Peregrino de Brito, 2021; Zhu et al., 2010). It also reduces the risk of creating new vulnerabilities since the parties can align on their concerns and commonly decide on mitigation techniques. As Mauss et al. (2022) stated, all players in the value chain will have to work together to create and achieve unified objectives towards CSCs. Additionally, the awareness about the topic is raised by involving a wide group of people from different backgrounds which can overcome the barrier of lacking awareness. Another improvement for the 2nd iteration is an expansion of the available timeslot. Breaking the phases down to two or three sessions will give the participants time to reflect on thoughts and enable more critical thinking towards certain practices. Additionally, the top management commitment can enable a prioritization of the outcomes of the workshop which then need to be followed up on for implementation.

During the facilitation phase, the framework helped to structure the process into different sessions and mindsets. Additionally using visualizations such as the overview of practices and how they influence SC resilience not only created a common ground for discussion but also enabled the participant to think outside of his current area of expertise and experiences. However, shifting the focus during the discussions from as-is towards to-be SC configuration turned out to be a challenge. This could be caused by only having one participant but also by asking the wrong questions. Therefore, focusing more on phase two and three of the framework and continuously asking why questions can create more in-depth discussions and raise awareness towards uncertainties and challenges. Another solution for focusing more on new practices could be to use more creativity tools such as ‘Thinking Heads’ or the ‘gamification’ method, which will be further discussed as tools in the exploration phase reflection. A summary of the key highlights and improvements is shown in Table 8.

| Workshop Phase | Positive Highlights of 1st Iteration | Improvements for 2nd Iteration |
|---|---|---|
| Planning Phase | - Planning a production facility tour<br>- Sending workshop plan in advance to align on expectations<br>- Physical setting | - Expand invite of participants:<br>o Include SC partners<br>o Include R&D<br>o Include Sourcing Responsible<br>o Include Sales<br>- Expand available time slot<br>o Consider multiple days for the different phases |
| Facilitation Phase | - Structured process | - Focus on to-be not as-is |

| | | |
|---|---|---|
| | - Use of tables and tools from framework to visualize and inspire out of the box thinking | - Use why-why questioning method to avoid superficial answers and create awareness for underlaying issues<br>- Use creativity methods such as Thinking Hats, or Gamification |

*Table 8 - Workshop Evaluation*

### 5.3.3. Solution Framework

Based on the outcome of the first iteration demonstration, some improvements are identified and described in this section as well as summarized in Table 9. The improvements are structured by the different phases and finalized with general improvements for the framework.

**Understanding Phase:** Even though this phase gave the participant a lot of security due to his expertise in the area, the value creation in this phase was limited since no alignment between participants was needed and no discussion about different SC risks from different perspectives developed. However, when having multiple participants from different stages of the SC with different focus areas, it can be valuable to dive into some critical areas where misalignment is present or perspectives on vulnerabilities and capabilities differ. Nevertheless, a general take-away from the first iteration is to emphasize the current state of the SC less since it can create a less open mindset towards new changes. Therefore, an improvement for the second iteration is to understand the SC in the context of circularity opportunities.

**Exploration Phase:** As mentioned above, in the exploration phase, a lack of creativity was recognized. Therefore, this phase should include more tools for scenario creation and out of the box thinking. This can be supported by multiple different ideation methods that leverage the knowledge base to trigger creative thinking. An emerging concept for this is the gamification of business issues (Hamari et al., 2014). Gamification is defined as "a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes", (Hamari et al., 2014, p. 3026) and is mainly used in the context of education and learning and intra-organizational systems. However, Hamari et al. (2014) found that it has also been used in the context of sustainable consumption as well as ideation and innovation, which makes the concept applicable to this thesis. While gamification always tries to *"translate the engaging aspects of games into other domains of life to create positive experiences and drive desired behaviors"*, (Deterding, 2019, p. 131), there are different levels to which it should be used in certain situations. Madsen & Rasmussen (2021) have developed a matrix that presents different parameters which can be used to decide the extent of gamifying for a workshop conducted during innovation or development processes (see Figure 19). The first deciding parameter is the purpose and outcome of the workshop. It can be either as-is focused, where just a mapping of the process is required, or to-be focused where radical innovation is sought. The latter is the case for the exploration phase since out-of-the-box thinking is required. Secondly, the framing and the context decides the amount of facilitation that is required for the gameplay. Since the purpose of the exploration phase is innovation, it is assumed that *"some level of facilitation is required to achieve a co-creative space for creativity between participants holding multiple professions to achieve the desired interdisciplinary outcome ",* (Madsen & Rasmussen, 2021, p. 8). Lastly, the level of game fidelity is dependent on the desired outcome and the level of facilitation. While the first extreme is a serious game with a tight set of rules, the other extreme is using gamified exercises *to "[break] down barriers between participants and [encourage] creativity and dialogue",* (Madsen & Rasmussen, 2021, p. 10) which is required for successful innovation. This tool is now used to map out the gamification of exploring new circular practices in SCs to enhance creativity during this ideation.

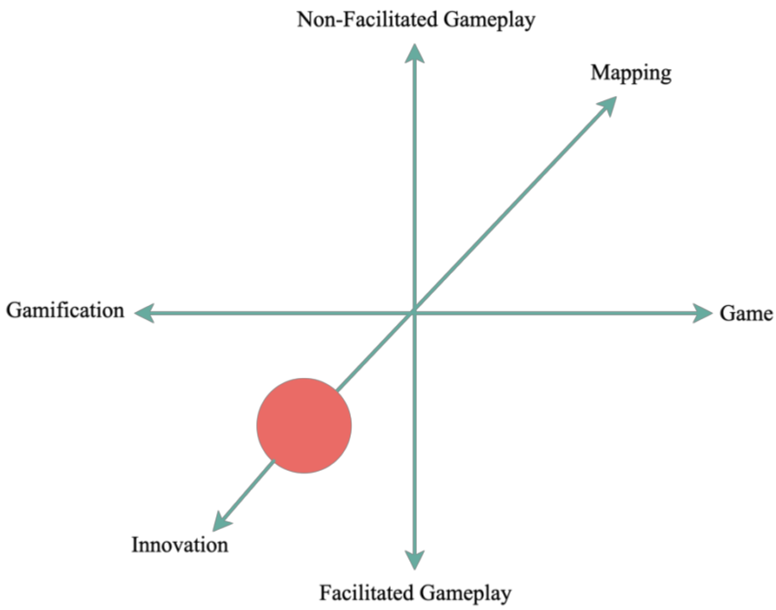


*Figure 19 - Gamification Matrix (Madsen & Rasmussen, 2021)*

As already mentioned, gamification will be used to enhance creativity and improve the ideation process. This aligns with the innovation purpose in Madsen & Rasmussen's matrix. However, in some cases more incremental changes to the as-is SC are required as stated in the literature review as BMI as a radical change brings many uncertainties. The red dot in Figure 19 indicates the level of innovation that is most likely to be required during the exploration phase. Consequently, no strict game rules should exist, but the workshop should consist of gamified exercises, supported by a facilitator. The incentive of winning a game can spark the missing creativity and support the exploration phase. When designing the game, the tables and models created in Chapter Chapter 4 should be used as core design principles, while leadership boards and a point ranking system can be used as supplementary game elements. The concept of collaboration in games should be used to support the collaboration in the workshop and going forward in the SC, as this is an important enabler for CSCs.

Concluding, the reflection on the exploration phase shows that gamification has a big potential to increase the creativity and ideation outcome during this phase. It allows the players to position themselves in the situation of a future SC which enhances generation of CSC practices. Additionally, it provides an engaging and interactive experience where innovation is promoted, and collaboration supported. Besides that, it is important to emphasize that there are no wrong ideas during the exploration phase, and no challenges should be mentioned yet. A clear differentiation between the first phase, this phase, and the third phase is required to enable free thinking in this phase.

**Critical Analysis Phase:** The content and goal of this phase was clear during the first iteration. However, when there are more participants, it might be a challenge to not be too critical during this phase since every actor of the SC will have their own interests in mind. Therefore, a positive mindset and more collaboration and communication techniques are required to align the interests. The created team feeling from the first two phases is crucial for this phase to succeed. Furthermore, the gamification approach from the exploration phase can be used in the critical analysis phase as well. The created scenarios can be used as game cards in which the different practices are tested. Here it is important to emphasize collaboration between the teams to solve the problem and overcome the challenge that the scenario presents.

**Evaluation Phase:** This phase was the most challenging during the workshop since only one new practice was identified, and the biggest barrier to this is the new production technology required from the customers. Additionally, due to the limited time and expertise diversity only a superficial evaluation could be performed. Most of the improvements to avoid this are already presented in the workshop setting reflection. However, adding another iteration of the exploration and critical analysis phases might help to create more options to discuss and compare. These general improvements of the framework are discussed and visualized in the next section.

**General Improvements:** As mentioned above, making the framework an iterative process can help coming up with more options. During the second or third iteration the exploration phase can build on the knowledge that has already been created during the first or second iteration. Moreover, during the first demonstration it became obvious that a last phase with concrete actions was missing. Therefore, it is proposed to add an implementation phase, where short-term, mid-term, and long-term objectives to achieving the practices are developed. This timeline is especially important to create feasible milestones and unified objectives internally, but also externally across the SC.

| Area of Improvement | Improvement |
|---|---|
| Understanding Phase | Emphasize current state less and focus on potential areas for improvements or opportunities for circularity |
| Exploration Phase | Use innovation and creativity tools to enable out-of-the-box-thinking<br>Gamification of tables with practices and barriers |
| Critical Analysis Phase | Focus on communication and collaboration during this phase |
| Evaluation Phase | Emphasize importance of this phase |
| General Improvements | Add an iterative process from evaluation back to exploration<br>Add implementation phase with short-term, mid-term, and long-term actions to create unified objectives internally and externally across SC |

*Table 9 - Framework Evaluation*

## 5.4. Second Iteration

The second iteration of the framework is presented in Figure 20 based on the evaluation in the sections above. The decreased focus on the understanding phase is represented by a thinner outline while the increased focus on the evaluation phase and the new focus on the implementation phase is shown by a thicker outline. The short-term, mid-term, and long-term action examples are inspired by the actions proposed during the Deloitte LinkedIn Webinar[5] about resilience and sustainability in SCs. They help achieving a long-term objective by breaking it down into feasible short-term priorities to enable the mid-term and long-term goals as well as a higher importance and more attention to these issues. The focus for the second iteration however will be the exploration phase, where gamification should be used to enhance creativity. The development of small, gamified exercises is the therefore the key element to develop before reaching a complete second iteration. However, this game development is out of scope for this thesis and will therefore not be included in the second iteration.

Since the workshop improvements are already described in Table 8 they will not be mentioned in detail here again. Generally, the key take-aways are (1) more time, (2) more participants, such as internal and external stakeholder, and (3) focus on to-be supported by creativity tools and why-why questioning.

[5] https://www.linkedin.com/events/howcansupplychainsbebothsustain7053770301637083136/comments/

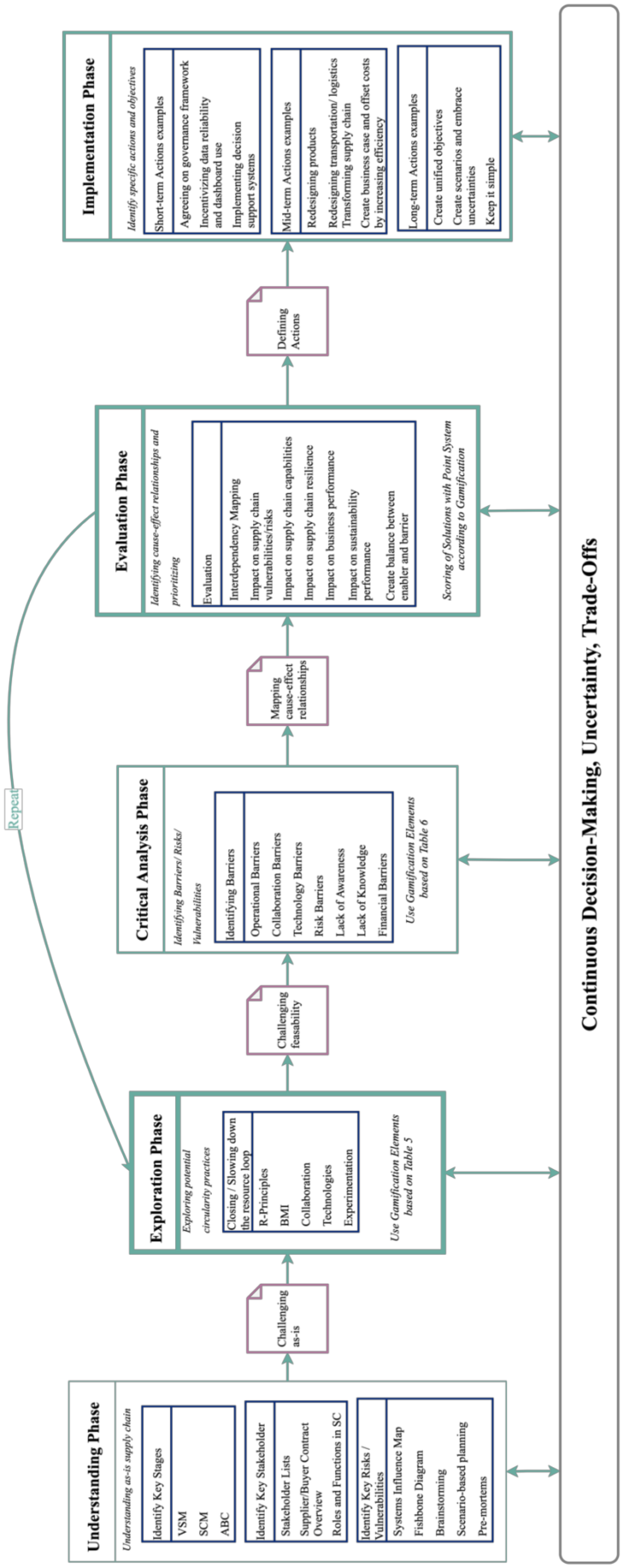


*Figure 20 - Second Iteration of CSC Implementation Process Framework*

# Chapter 6. Discussion

This chapter will discuss if and how the thesis objective is fulfilled by performed analysis and the designed solution. More specifically, to what extend the research questions are answered by the literature review and the relationships between these findings, the designed artifact, and the research objective. For this, the following structure is chosen: Firstly, the findings of the literature review are discussed in the context of the research questions and the theoretical background. Secondly, the designed solution for the objective of the thesis is discussed, followed by a critical evaluation on how the literature review supports this solution. Afterwards, the choice of methods for reaching the objective of the study are discussed. Lastly, the theoretical and managerial implications of the findings are presented and future work emerging from this thesis and relevant for this area is proposed.

## 6.1. Discussion of Findings (LR) in context of RQ

The first part of the literature review focused on practices to enable CSCs, and to support managing the CSCs. By this the following research question is aimed to be answered: “What are common practices and enablers specific for CSCs?” During the literature review, four main categories of these practices and enablers are identified, namely operational practices, collaboration, technology, and performance measurements. Operational practices are those, that are required for a circular resource flow outside and inside of the company borders, earlier called the “closing-the-loop” practice. These are the practices that are mentioned most as something that increases the complexity of the SC and require specific enablers for successful implementation and a high performing CSC (Mutha et al., 2022; Rezapour et al., 2015). This supports the findings of Chhimwal et al. (2021) who have identified 17 new risk events specifically for CSCs caused by the closing-the-loop practices. The enablers that are identified for the operational practices are collaboration, technology, and performance measurements. Most authors identified these as enablers and drivers of CE and CSCs, however, some authors argued that these enablers bring new complexity and new risks. Therefore, these categories are mentioned in both the practices and enabler section as well as the barrier section. These different perspectives, the inter-categorical relationship, and their impact on the resilience of a CSC is discussed below in section 6.1.1.

The second part of the literature review aimed at identifying barriers such as new risks or practices that increase the vulnerability of the SC. Firstly, the barriers and new risks emerging from the closing the loop practice were listed. Especially the redesign of the business model that can be required and the necessity for increased visibility and tracing in a CSC is a challenge for most companies. If the SC is not transparent enough, new risks and vulnerabilities such as a lack of control over product returns and an uneven supply demand balance can cause disruptions in a SC. As mentioned above, certain enablers such as collaboration, technology or new performance measurements can according to many authors, decrease these potential risks for disruptions. However, the implementation of these brings many challenges and new risks to a SC but also to the entire organization. Firstly, there are barriers to implementation of these practices, such as a lack of awareness or the right knowledge and skills. Additionally, the high investment into new technology is another barrier to especially the required technology. Secondly, it was found that collaboration can overcome barriers to CSCs such as the lack of transparency however, it also increases the network complexity of the SC due to many more stakeholders. Some authors argue that technology can simplify the complexity by utilizing innovative coordination technologies and big data (Kazancoglu et al., 2021) while others mention that utilizing I4.0 technologies can cause cybersecurity disruptions due to the risk of unreliable systems (Dulia et al., 2021).

### 6.1.1. CSC Resilience

The last research-question is investigating the impact of the findings related to the first two questions on the resilience of a SC. In Figure 12 is shown how the enablers and practices of managing a CSC positively influence the SC resilience while Figure 13 and Figure 14 visualize the negative impact of the barriers on SC resilience. However, these figures do not include that some of the practices and the barriers are the same or impact each other. These inter-categorical relationships and their impact on SC resilience are discussed here. The most mentioned enablers but also barriers for CSCs are the closing-the-loop practices, collaboration, and technology. However, these can have different levels of enabling or complexifying characteristics, depending on the SC environment. In a short and simple SC collaboration and coordination might be easier than in a cross-continental and complex SC (Chhetri et al., 2022). The same goes for the enabler technology; in a highly developed and mature industry the technological advantages might outnumber the technological risks.
When looking at the closing-the-loop practices academia has a divided opinion on if they have a positive or negative impact on the resilience of a SC. The findings during the literature review support this perspective since the circulation of resources increases an important SC capability which is resource efficiency while it also potentially creates an imbalance of supply and demand, which heightens SC risks. Therefore, the impact of circular practices on SC resilience needs to be seen differentiated in the context of the SC environment.

## 6.2. Discussion of Second Iteration (not tested)

The objective of this thesis was to create a structured process for firms to evaluate which circularity practices can be implemented in their SC and to identify the consequences for the resilience of the SC. Since the resilience of a SC is heavily depending on its environment (Kochan & Nowicki, 2018), different practices can have different impacts on the resilience of different SCs. Therefore, it was important to not to prescribe certain practices or ways to overcome the barriers for companies but to provide them with a tool that can help to identify the right practices and the balance between enabling and complexifying for their SC environment. To further define the objective of the artifact, specific requirements for the solution framework based on the knowledge base and the unstructured interview with Fibertex were developed. How and if these requirements are met by the first iteration is presented in Table 10.

| Requirement | Requirement | Artifact Solution |
|---|---|---|
| **Reduce complexity** | Create a systematic and structured process | Iterative Process with clear start and end point and 5 defined stages |
| | Show cause-effect relationships | Using knowledge base and flowcharts Simplifying these would reduce complexity even further |
| **Feasibility** | Feasible analysis of current SC | Best practice tools for analysis of current SC are provided |
| | Feasible ideation for new practices | Using knowledge base as foundation for gamified ideation exercises |
| | Feasible creation of scenarios to test and critically analyze practices according to risks, disruptions, and vulnerabilities | Using knowledge base as foundation for gamified ideation exercises |

*Table 10 - Reflection on Requirements*

The next step for the designed artifact would be to test the second iteration in a different industry for example a manufacturing industry with multiple locations and a more complex SC. This will increase the potential for improvements and feedback for a third iteration. With this gradually increase in complexity of the SCs it can be assured that the iteration that is tested in the company is sufficient to identify the improvements for the framework while providing value. Additionally, the continuous testing of the framework and a monitoring of results has the potential to show certain patterns and best practices in CSC implementation. This would create a new environment in terms of complexity for businesses following the Cynefin framework by Snowden and Boone (2007).

## 6.3. Limitations

As mentioned in Chapter Chapter 3 the research questions are answered through a literature review to build a theoretical knowledge base. An exclusion criterion during this literature review was to exclude process industries such as food and chemical industries due to their different characteristics during the production process. However, excluding certain industries limits the knowledge base and influences the solution framework to industry specific knowledge. Therefore, it could be argued that the solution framework, which is using this industry specific knowledge is limited to and can only be applied to these industries.

Moreover, for creating the knowledge base, a more time-efficient solution would have been to use an existing state-of-the-art literature review on this topic and focus more on identifying the business problem. However, this would have reduced the authors in-depth knowledge on the topic of CSC practices and barriers and might have harmed the holistic process-oriented solution framework that required not only knowledge about the practices and barriers but also a general understanding of the risks and vulnerabilities that can be created during the implementation of these practices. Furthermore, as mentioned in Chapter Chapter 3, the empirical business need was identified during an unstructured interview with the SC director of a non-woven production company. It was assumed, based on the theoretical background, that the identified problem during that interview is relevant for other companies implementing CSC practices too. However, since the objective of the thesis was to create a structured process for more than just one specific company, it can be argued that this choice of methodology is not sufficient due to the qualitative manner and the focus on one specific case. Therefore, triangulation would have been required to identify and verify a general business need. This triangulation could have been structured as follows: (1) Quantitative data collection through a survey sent out to different organizations to identify trends and patterns in companies, (2) Qualitative data collection through semi-structured interviews with SC actors to investigate trends and patterns, and (3) expert focus groups with researchers is this area to verify the findings.

Lastly, to fulfill the objective of the thesis, more iterations of the artifact design are required with different companies over the time of two to three years to enable the solution framework to be flexible and applicable to multiple different scenarios.

## 6.4. Theoretical Implications

The concept of CSCs and CSCM is still in an evolving phase, where both Accademia and practice struggle with the complexity of implementation. This thesis provides a structured overview of common practices, enablers and barriers based on a literature review that can be used for further analysis of CSCs. Additionally, it was attempted to map the cause-effect relationships of these findings and SC resilience. These findings provide a novel perspective to the CSC literature. Furthermore, the concept of using gamification for reducing the complexity during the implementation of CSC for companies is arguable a new solution design to dealing with the complex and uncertain environment. Concluding, this thesis provides a more systematic view on CSCs and the impact on companies and their SC resilience.

## 6.5. Managerial Implications

The findings of this thesis can help businesses to reduce the complexity of implementing CSCs. Firstly, the analysis showed that even though the complexity of practices and their barriers and risks is high, certain cause-effect relationships can be identified and the consequences of implementing the practices become more predictable. Additionally, the solution artifact maps a systematic process

- to understand the current SC and the opportunities for circularity in there,
- to explore with certain tools such as gamification and other ideation techniques what practices can be adopted and how they can be implemented,
- to analyze certain scenarios of how the implementation will affect business performance and SC resilience,
- to decide on unified objectives across the SC.

Based on this process, managers can set up workshops with relevant participants from across the SC and map out their more circular and sustainable future while being aware of the impact on resilience and business performance.

## 6.6. Future Work

As briefly mentioned above, the second iteration needs to be further defined by developing specific game elements that can help the ideation during the exploration phase. Afterwards, the solution process framework needs to be tested again in a different context to evaluate the feasibility. If the feasibility aspect is fulfilled, further long-term testing in multiple companies with different SCs can be started to monitor if the complexity is reduced for companies while maintaining resilience and a sustainable performance. Besides the work on the solution process framework, further research on the impact of CSC risks on SC resilience is necessary. This could involve a quantitative study that investigates if CSC are increasing the resilience of a SC as commonly argued in the current literature or if it reduces the resilience. Additionally, parameters that influence this outcome such as length of SC or industry type need to be investigated. Furthermore, a study on how current SCM concepts increase the resilience of a SC such as extended enterprises and the applicability of these to CSC could be a future research area.

# Chapter 7. Conclusion

The objective of this thesis was to design a feasible process framework that supports businesses in the implementation of CSCs to reduce the complexity and uncertainty. In conclusion, this thesis addresses the objective by creating a structured and systematic process to find and evaluate circularity practices in SCs as well as to assess their impact on SC resilience. Through a combination of the theoretical knowledgebase, based on a literature review and a specific SC case, the thesis contributes to a more successful implementation of CSCs in businesses.

The literature resulted in a diverse range of practices, enablers, and barriers of CSC and their implementation such as collaboration, new technologies, closing the loop practices, and a new performance measurement system. During the analysis of these the complexity and lack of structure for implementation of CSCs was identified which emphasizes the importance of overcoming these challenges. To solve this identified problem, the thesis proposes a solution design based on DSRM that draws from the knowledge base to develop a systematic process that can help companies to implement circular practices. Incorporating gamification principles to enhance creativity during this process was found as an important aspect to overcoming initial ideation challenges. Gamification promises to make the process more user-friendly and enhances many important aspects of CSC practices such as collaboration and development of new knowledge and skills as well as the creation of awareness. These findings contribute to both theoretical and practical aspects of CSC implementation. The theoretical knowledge base provides a comprehensive understanding of different practices and barriers and their influence on SC resilience which can be used for further research in this area, while the process model and the gamification approach offers a practical tool for companies to reduce the complexity of including circular practices in their SCs without harming the resilience and business performance.

Concluding, the thesis addressed a very relevant problem regarding CSCs and proposes a practical tool to support the process of creating CSCs. However, it is important to acknowledge the dynamics and uncertainties in the business environment which will always impact SCs. Therefore, the findings of the thesis need to be seen in the specific context of a company and can have different limitations depending on the industry or the SC characteristics.

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# Appendices

A – Critical Synopsis Template

## Critical Synopsis Template

Title:
Author:
Publication Year:
Journal:

### Why am I reading this?

- What are the main objectives and findings of the article?

### What methods are used?

- How did the authors analyze the problem and conclude on the findings?

### Which findings are relevant to my work?

- What practice are mentioned?
- What barriers are mentioned?
- What risks are mentioned?
- What resilience impact is mentioned?

### Do I agree with the findings?

- Am I convinced?

### Code

(1) = Return to this for detailed analysis;
(2) = An important general text;
(3) = Of minor importance;
(4) = Not relevant.

## B – Coding Table Literature Review

This table includes quotes from the literature, the content in column called “Segment” is not own work but copied from the articles stated in column “Dokumentname”

| Dokumentname | Code | Segment | Topic 1 | Topic 2 | Topic 3 | Topic 4 |
|---|---|---|---|---|---|---|
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Barriers | Opeational and technological risks in the CSC context can be defined as the risks that hamper the adoption of circular oper-ations, existing technologies, the labor force, coordination among supply chain members, etc. | Definition | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Barriers | Table 1 | Overview | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | repair and remanufacturing will need higher labour intensity than the recycling process. Compared to new product production, the remanufacturing process is time-consuming, requiring more skilled and experienced labour | Skill and knowledge | labour intensity | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | High quality standards are essential for the products made from recycled materials because eventually they will be compared to normal products (Sabaghi, Mascle, and Baptiste 2016). | Quality | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | Each party within the supply chain should have obtained environmental labels and certifications such as ISO 14000 to meet certain standards and to implement the required CE practices. However, a unified standard set of indicators is essential to audit the development of the CE within the supply chain across different parties and different countries . | Certification and regulation | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | The main risk of a CE in a sustainable supply chain is the lack of environmental awareness of the suppliers, who do not understand the benefits of the CE | awareness | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | high costs of environmental-friendly prod-ucts and the long return time on investments are risks for green business adaptation | ROI | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Barriers | suppliers are reluctant to be involved in integration, co-creation and partnership, espe-cially within the product design process, due to the confi-dentiality, trust and competition among individual parties within the supply chain and through the product life cycle | Knowledge sharing | trust | confidentiallity | |
| **Main_Dimensions_in_the_Buildin** | Barriers | require considerable investment in resources, and then development of a collection system which takes back the product at its end-of-life | ROI | | | |

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| **Main_Dimensions_in_the_Buildin** | Barriers | This problem involves “a variety of stakeholders, demands behavioral changes, and requires a complete rethinking of the current waste management systems and the dominant linear economic model | change | awareness | | |
| **Main_Dimensions_in_the_Buildin** | Barriers | One problem to consider is the inventory–location and routes [62,86], so it would be convenient to consider a smaller number of trips and with shorter routes. | | | | |
| **Closed loop supply chains 4.0** | Barriers | , closing the loop of a SC is a very complex process, and many risks arise when a nonlinear structure is replaced by a circular or multi-circular structure with several reverse flows of goods/parts/materials | complexity | | | |
| **Closed loop supply chains 4.0** | Barriers | The number of risks increases when companies decide to close the loop of the SC (Battini et al., 2017; Sol-eimani et al., 2014), and they can be generated by the uncertainty that the complex nature of CLSCs creates influencing the overall performance of the SC (Peng et al., 2020) | complexity | uncertainty | | |
| **What servicizing demands of a company** | Barriers | A part is purchased once but is remanufactured and reused several times before a new replacement part is purchased. This makes supplier relationships inherently more difficult but necessary to manage in the servicizing model | supplier relationship | | | |
| **What servicizing demands of a company** | Barriers | OEMs cannot perform remanufacturing oper-ations, leaving the field open to independent third-party remanufacturers or competitors. This exposes the OEM's intellectual property and technology and often affects the image and brand value of the OEM | confidentiallity | trust | 3rd party involvement | |
| **What servicizing demands of a company** | Barriers | Suppliers may (and do) retaliate with designs that are difficult to remanufacture ( | product design | supplier relationship | | Sheet1!D15 |
| **What servicizing demands of a company** | Barriers | On one occasion, a state-of-the-art mailing sys-tem incurred almost $20,000 in damages from the product being improperly secured during transportation. When confronted with the damages, the vendor replied, “Wasn't this garbage anyway?” Adopting a remanufacturing-centric servicizing business model may cause the need to consider making more processes in-house, rather than outsourcing. | | | | |
| **Towards a more circular economy exploring the awareness practic** | Barriers | transition to a CE implies a change at the strategic level of business model innova-tion, with modifications in terms of product design, supply chain design and commercial strategy | change | BMI | | |
| **Towards a more circular economy exploring the awareness practic** | Barriers | Table 3 | Overview | | | |
| **Towards a more circular economy exploring the** | Barriers | highlights the difficulty of implementing supply chain prac-tices characterised by broader arcs of integration | change | | | |

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| **awareness practic** | | | | | | |
| **Towards a more circular economy exploring the awareness practic** | Barriers | Finally, it is interesting to observe that 65.33% of the participant organisations declared they were aware of the CE concept, while 34.67% were not. In this context, the result of this study shows a discrepancy between awareness and practices, as previously observed by Liu and Bai (2014). | awareness | | | |
| **Sustainable supply chain management of automotive sector** | Barriers | Table 1 | Overview | | | |
| **Sustainable supply chain management of automotive sector** | Barriers | lack of top management<br>commitment is at the bottom of the hierarchy, with high driving<br>power | commitment | awareness | top management | |
| **Sustainable supply chain management of automotive sector** | Barriers | The next<br>level in ISM model consists of two important barriers, viz., lack of CSR<br>and measurement and monitoring of suppliers' environmental<br>activities. | regulation | measurement | | |
| **Sustainable supply chain management of automotive sector** | Barriers | barriers can be arranged in descending order as lack of aware-ness about reverse logistics adoption (B5) ><br>expenditure on collecting<br>used products (B6) > lack of top management commitment (B1)<br>> lesser ROI (B8) > lack of government support. Lack of awareness<br>about reverse logistics adoption (B5) has the highest D R value and<br>is placed at top of the digraph | Overview | | | |
| **Sustainable supply chain management of automotive sector** | Barriers |  | Overview | | | |
| **Supply chain collaboration for a circular economy** | Barriers | However, the ability to share knowledge and learn from other organizations, thereby circumventing the risk of opportunism, is considered to be rare among companies | Knowledge sharing | confidentiallity | | |
| **Supply chain collaboration for a circular economy** | Barriers | geographic distances and logistical costs, and collaboration between partners within and between supply chains, especially in reverse flows, were emphasized as being relevant in CSCM. | logistics | | | |
| **Supply chain collaboration for a circular economy** | Barriers | collaborative and coordinating relation-ships between partners in the chain were among the many barriers to a CE which need to be better investigated | supplier relationship | coordination and collaboration | | |
| **Strategic opportunities for produc** | Barriers | Difficulty in matching materials | product design | | | |

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| **Strategic opportunities for produc** | Barriers | Lack of technical skills | Skill and knowledge | | | |
| **Strategic opportunities for produc** | Barriers | Optimal facility design | facility design | | | |
| **Moving toward a circular economy in manufacturing organizations** | Barriers | a lack of knowledge along the supply chain on product design and production, lack of suitable partners and customer disinterest, as well as a lack of supply chain coordination and interaction with suppliers and customers | Skill and knowledge | product design | coordination | awareness |
| **Moving toward a circular economy in manufacturing organizations** | Barriers | Such an expansion of stakeholder engagement, however, does not necessarily enable the implementation of CE if knowledge and awareness on CE and sustainability topics remain within the sustainability department. | Skill and knowledge | awareness | | |
| **Measuring_Circular_Supply_Chai** | Barriers | CSCs are more vulnerable to risk than conventional linear supply chains, as these have more points of possible disruption, due to an extended chain of partners. | complexity | more partners can lead to more vulnerabilities | | |
| **Introducing an application of an industry 4.0 solution for circ** | Barriers | consideration of environmental, social and economic issues (Hassini et al., 2012). The complex and dynamic characteristics of these factors increase the uncertainty in supply chains | complexity | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Barriers | Supply chain and business relationships are managed via traditional communication means and there is lack of automa-tion that leads to time losses and increased costs for negotiation processes. | automation | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Barriers | There are specific traceability issues. The lack of an automated and trusted waste tracking and tracing leads to the lack of vis-ibility in different phases of the circular supply chain. | traceability | visibility | automation | |
| **Introducing an application of an industry 4.0 solution for circ** | Barriers | There is lack of a marketplace or ecosystem for collecting and selling industrial waste in closed loop supply chains. | | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Barriers | The complex collaboration procedures, rules and diversity of IT systems within the supply chain is also a challenge that needs to be addressed. | collaboration | complexity | | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Barriers | involves complex sys-tems and dynamic changes due to factors linked with both internal and external stakeholders | complexity | | | |
| **Integrating circular economy and** | Barriers | trade-off of increasing traceability, transpar-ency and sustainability practices, and the difficulty of control-ling the complex and reflexive system | traceability | visibility | complexity | |

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| **Industry 4 0 for sustainable s** | | | | | | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Barriers | Operations uncertainty and security issues are other sig-nificant barriers that companies face when implementing CE and Industry 4.0 | uncertain ty | securit y | operati ons | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Barriers | e high uncertainty regarding operations com-petencies in inventory, logistics (Bag, Gupta, et al. 2021) and returns on investment | uncertain ty | skills and knowle dge | ROI | operati ons |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Barriers | great demands on flexibility and agility to facilitate the dynamic construction of temporary processes and net-work transparency of the supply chain | flexibility | agility | transpa rency | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Barriers | uncertainty and risks will increase as inefficient use of innovative technology and information system may increase the system's complexity | uncertain ty | technol ogy | comple xity | |
| **Impact_of_the _Quality_of_R etur** | Barriers | s the returned-used products are derived from sales, rather than market demand. | supply and demand | uncerta inty | | |
| **Impact_of_the _Quality_of_R etur** | Barriers | customers perceive that new products (products produced from raw materials) have higher quality than remanufactured ones | Quality | awaren ess | | |
| **Impact_of_the _Quality_of_R etur** | Barriers | The considered issues are: remanufactured products are distinguishable from new ones, both machines are subject to random repairs and failures, demands for new products and remanufactured ones are stochastic, the quantity of returned-used products is proportional to the sales in the previous periods, returned-used products are sorted in three quality levels, and carbon emissions | Quality | supply and deman d | uncerta inty | |
| **Identification_ of_critical_fac** | Barriers | barriers include difficulty with supply chain members, lack of the necessary technical skills and uncertain profitability | Skill and knowledg e | ROI | supplie r relation ship | |
| **Identification_ of_critical_fac** | Barriers | the minimal interest of top management and insufficient commitment | commitm ent | top manag ement | | |
| **Identification_ of_critical_fac** | Barriers | Issues related to damaged goods and quality problems present substantial challenges for RL processes. | Quality | | | |
| **Identification_ of_critical_fac** | Barriers | Different points at which cost is involved is not easily understood | | | | |
| **Identification_ of_critical_fac** | Barriers | The distribution channels are exception driven | | | | |

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| **Identification_ of_critical_fac** | Barriers | The process of pricing product is not uniform | pricing | | | |
| **Identification_ of_critical_fac** | Barriers | Issues related to financial management are not clear | | | | |
| **Identification_ of_critical_fac** | Barriers | The type of involvement of negotiation between different parties is less straightforward | coordinat ion | | | |
| **Identification_ of_critical_fac** | Barriers | Previous research identified uncertainty regarding quality, quantity and timing from product returns as influencing the success of remanufacturing | Quality | supply and deman d | uncerta inty | |
| **Identification_ of_critical_fac** | Barriers | the lack of a system to monitor returns hurts the implementation of remanufacturing | technolog y | tracabil ity | | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Barriers | Activities linked with production planning and control are being challenging within any remanufacturing firm due to stochastic nature of old product returns and unknown quality of those products | Quality | supply and deman d | uncerta inty | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Barriers | challenge for any remanufacturing firm lies in the variation in product types with low volumes involving varying processing times ( | product design | | | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Barriers | scarcity of skilled labor and lack of competency which influences the inspection, refurbishing and reassembly operations | Skill and knowledg e | operati ons | | |
| **Critical factors for enhancing the** | Barriers | Table 2 | Overview | | | |
| **Critical factors for enhancing the** | Barriers | Table 3 | Overview | | | |
| **Critical factors for enhancing the** | Barriers | Table 4 | Overview | | | |
| **Critical factors for enhancing the** | Barriers | Table 5 | Overview | | | |
| **Critical factors for enhancing the** | Barriers | hesitant company culture and therefore traditions and mindset were iden-tified as key barriers | change | awaren ess | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | technology constraint | technolog y | | | |
| **Conception of circular economy** | Barriers | resource availability | supply and demand | | | |

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| **obstacles in context of supply c** | | | | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | casual behavior | | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | non-cooperation | cooperati on | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | quality of produced remanufactured goods | Quality | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | incapability in production required volume | supply and demand | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | e obstacle of the skilled workforce is also a concerning issue that influences various operations like remanufacturing, an inspection of used products and remanufactured products, and reassembly processes | Skill and knowledg e | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | technological, financial, policy and regulatory, managerial, social, performance indicators and technological | Overview | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | financial, organizational, operative, attitudinal and technical | Overview | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | o social, economic, environmental, political and institutional, supply chain, technical and informational, and structural factors. | Overview | | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | Table 1 | Overview | | | |

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| **Conception of circular economy obstacles in context of supply c** | Barriers | lack of consumer knowledge and consciousness towards environmental sustainability (O11) had attained the highest priority | Skill and knowledge | awareness | | |
| **Conception of circular economy obstacles in context of supply c** | Barriers | the challenge for the consistency of return products (O14) stood last in the tally | supply and demand | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Barriers | discarded products do not enter the same original supply chain but enter a different one, typically, a secondary market that may cannibalise some sales in the primary market | markets | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Barriers | the problem of making the demand and the return flow meet, which is critical in CLSC of RA | supply and demand | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Barriers | structural losses are typically a concern in RA systems. They are more difficult to control than quality losses, because they take place in the unobservable part of the supply chain. Owing to the lack of control over the structural losses, quantifying precise figures of the return rates is not straightforward | coordination | quality | supply and demand | |
| **Circular supply chain orchestration to overcome Circular Econom** | Barriers | predominant linear mindset of the companies operating in the value chain, and by obstructing regulations and laws. | change | awareness | regulation | |
| **Circular supply chain orchestration to overcome Circular Econom** | Barriers | – Systematization of challenges for circular textile supply chains, based on the framework by Bressanelli et al. (2019). | Overview | | | |
| **Circular supply chain orchestration to overcome Circular Econom** | Barriers | – Challenges and responses emerging from the empirical study. | Overview | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | defi-ciency of knowledge regarding the circular transformation of current operations and a workforce that is not prepared to use these advanced techniques are barriers to CSC implementation | Skill and knowledge | technology | | |
| **Building a data-driven circular supply chain** | Barriers | while other practices, such as reuse and remanufacturing, have narrowed due to the lack of legal regulations | regulation | | | |

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| **hierarchical struc** | | | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | Nevertheless, numerous firms have not capitalized on their potential for resource management in the global market as they have been unaware of basic resource cir-cularity principles ( | Skill and knowledge | awareness | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | Ozkan-Ozen et al. (2020) claimed that uncertain returns are obstacles to CSC implementation. | supply and demand | uncertainty | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | the lack of knowledge, expertise, and necessary skills concerning circular transformation is a barrier to CSC implementation | Skill and knowledge | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | few intrinsic incentives for a thorough adjustment in attitude and behavior with regard to CSC practices, which directly affects business leadership and causes stake-holders to be hesitant when it comes to generating a comprehensive transformatio | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | limitations based on the shortage of structured data management systems as well as the adversity involved in designing both software and hardware for inter-operability and adaptability. | technology | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | lack of awareness of the advantages of CSCs inhibits their employment as resource-efficient operations are deemed a supple-mentary difficulty | awareness | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | varying business models within the CSC cause firms to struggle with the increased complexity within this shift | complexity | BMI | change | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | legal framework, especially the composition and execution of the legislative documents governing circular transformation, has a tre-mendous influence on the speed and efficiency of the CSC transition | regulation | | | |

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| **Building a data-driven circular supply chain hierarchical struc** | Barriers | crucial barriers to the implementation of tech-nological adjustments in CSCs include data inadequacy, missing access methods, and the lack of experts to utilize these data | technology | data | skills and knowledge | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | n information structure comprising various types of data in a range of digital formations is considered to be an opportunity as well as a challenge | data | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | costly equipment | ROI | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | absence of knowledge and the lack of capacity to perform periodic machinery modifications | Skill and knowledge | operations | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | transition to CSC in the context of I4.0 with the requirement of digi-tizing operating stages requires high expenditure; | ROI | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | , the benefits from invest-ment in technology are not clearly defined, and operational efficiency is uncertain, which becomes a barrier to the adoption of I4.0 and digi-tization for developing CSCs | ROI | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | deal with technological dangers that could occur from outside. Cybersecurity, for example, is another critical challenge in I4.0, as modern technologies require large amounts of data to be shared among supply chain stakeholders | data | cybersecurity | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | many firms are deficient in terms of enhancing technological procedures that enable them to become circular and competitive due to knowledge shortages and poor leadership styles. | Skill and knowledge | top management | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | RSC management is considered to be a new challenge for managers when recovered products are handled through multiple stages with multiple actors and numerous recovery options | complexity | | | |

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| **Building a data-driven circular supply chain hierarchical struc** | Barriers | , the reality is that many firms have faced obstacles in applying information technology and innovative devices to operate RSC practices | technology | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | due to its com-plexity, the presence of a collection of metrics, and diverse maturity levels in assessing three pillars. In practice, LCSA demands a large amount of data and time-consuming, troublesome gathering, and compilation. | complexity | data | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | Handling procedures are chal-lenging because of the absence of operational awareness, the lack of regulatory and environmental frameworks related to recovering materials, and unconnected supply chain design and planning | Skill and knowledge | regulation | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | However, the need for broad data compilation and resources, high computational demands, and AI model ambiguity still present challenges to the AI approach | data | technology | | |
| **Building a data-driven circular supply chain hierarchical struc** | Barriers | The implementation of the ML technique in CSC has also pres-ented multiple challenges related to nontechnical barriers. The non-technical difficulties come from a shortage of analytical-skill human resources, a lack of specific understanding of regulations, high expense in proceeding with ML, and less stakeholder involvement. | Skill and knowledge | | | |
| **Identification and analysis of circular supply chain management** | Barriers | In the  absence of effective technology and infrastructure, it is not possible to achieve the goal of  CSCM | technology | | | |
| **Identification and analysis of circular supply chain management** | Barriers | Most of the public have little knowledge about repaired and remanufactured products. | Skill and knowledge | awareness | | |
| **A survey on reverse logistics system** | Barriers | reverse logistics are generally poorly managed  due to the fact that more than one company may get involved in the reverse logistics  process, and thus a holistic approach is required | top management | complexity | | |
| **A survey on reverse logistics system** | Barriers | importance of reverse logistics relative to other issues | priorisation | | | |
| **A survey on reverse logistics system** | Barriers | company policies | regulation | | | |
| **A survey on reverse logistics system** | Barriers | lack of systems | technology | | | |

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| **A survey on reverse logistics system** | Barriers | financial resources | ROI | | | |
| **A survey on reverse logistics system** | Barriers | personnel resources; | labour intensity | | | |
| **A survey on reverse logistics system** | Barriers | legal issues | regulatio n | | | |
| **A survey on reverse logistics system** | Barriers | Unawareness of the benefits of reverse logistics | awarenes s | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | Lack of economic benefits in short-run (A2), lack of industry incentive toward sustainable practices (A4), and high costs related to recycled products in CSC (A14) | ROI | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | Lack of awareness within society toward product recovery and CSC | awarenes s | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | lack of collaboration from supply chain performers | collabora tion | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | , organi-zation of reverse infrastructure | coordinat ion | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | take-back from other organizations | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | High purchasing cost of environmental friendly products ( | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | , ineffec-tive product recovery policies | regulatio n | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | design challenges to reuse and recover products | product design | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | and existing loose environmental regulations | regulatio n | | | |

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| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | Unclear vision regarding product recovery in CSC | top management | objectives | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | , lack of suc-cessful business models to implement product recovery in CSC | BMI | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | lack of appropriate training and development programs for CSC | Skill and knowledge | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | lack of tax policies for facilitating CSC models ( | regulation | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | d lack of ade-quate waste infrastructure | coordination | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | Product technology improvement for recovery activities ( | technology | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | , lack of<br>information regarding product tracking in CSC | traceability | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | limited expertise,  technology and information CSC practices | Skill and knowledge | technology | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | requirements for<br>data integration | data | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | lack of<br>cooperation as a barrier to integrating CE strategies | cooperation | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | inadequate regulations as one of the main<br>barriers toward CE and recommend governments intervene with suit-able policy measures | regulation | | | |

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| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | Tracking issues and accurate information play a critical part in maximizing value from the product recovery process. | traceability | visibility | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Barriers | need for more successful business models that can be taught and practiced by others. | BMI | | | |
| **2019_ICCAD_ An Extended Circular Supply Chain Model Including Re** | Barriers | Brissaud and Zwolinski [11] highlight that repurposing-based circular production systems raises new challenges on supply chain management and optimization | Overview | | | |
| **Bridging economy and ecology** | Barriers | economic constructs into the supply chain management to address the economic barriers in global, distributed markets. | | | | |
| **Admitting risks towards circular economy** | Barriers | . CSC's selection and implementation rates are low because of the considerable risks associated with it | risks | | | |
| **Admitting risks towards circular economy** | Barriers | companies are not enthusiastic enough towards CSC because they see the risks as detri-mental to the environmentally friendly benefits of CSC | priorisation | risks | | |
| **Admitting risks towards circular economy** | Barriers | no universal method to assess the risks, | Skill and knowledge | | | |
| **Admitting risks towards circular economy** | Barriers | Summarized categories of risks associated with CSCs. | Overview | | | |
| **Admitting risks towards circular economy** | Barriers | technicalities of doing so are frequently ignored, as these are very challenging to tackle. | | | | |
| **Admitting risks towards circular economy** | Barriers | Lack of proper vision such as goals, objectives, targets, and indicators in regards to CSC | top management | objectives | | |
| **Admitting risks towards circular economy** | Barriers | Lack of consideration of the need of whole SC | complexity | skills and knowledge | | |
| **Admitting risks towards circular economy** | Barriers | a lack of specific conditions for properly managing sub-suppliers | regulation | | | |
| **Admitting risks towards circular economy** | Barriers | Lack of upfront cost invested in CSC | ROI | | | |

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| **Admitting risks towards circular economy** | Barriers | upfront cost of making the supply chains circular may discourage | ROI | | | |
| **Admitting risks towards circular economy** | Barriers | Difficulties in making product disassembly operation easier and safe during reverse chain’ | complexity | security | operations | |
| **Admitting risks towards circular economy** | Barriers | some government procurements have actually excluded the use of such re-sold products, which significantly hinders CSC | regulation | | | |
| **Admitting risks towards circular economy** | Barriers | ‘Lack of successful business models and frameworks to implement CSC | BMI | | | |
| **Admitting risks towards circular economy** | Barriers | they think that new products have better quality than reproc-essed products | Quality | awareness | | |
| **Admitting risks towards circular economy** | Barriers | consumers are unwilling to adjust their perception towards remanu-factured products | awareness | change | | |
| **Admitting risks towards circular economy** | Barriers | Developing a take-back mechanism from other companies is discussed as a barrier | | | | |
| **Admitting risks towards circular economy** | Barriers | implying that CSCs are burdened with the many technological risks | technology | | | |
| **Admitting risks towards circular economy** | Barriers | great deal of time-consuming manual operation is required during remanufacturing. | operations | | | |
| **Admitting risks towards circular economy** | Barriers | to capture customer attention are another concern | awareness | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Enablers | adoption of a well-designed reverse logistics network influences CSC operational activities and performance. | networks | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Enablers | e involvement of all stakeholders, such as suppliers, cus-tomers, supply chain members, and employees of the organiza-tion, plays a crucial role in CSC adoption | coordination and collaboration | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Enablers | risks pertinent to supply, demand, and social as-pects should be reduced by conducting seminars and awareness programs to educate stakeholders about CSC activity and sustain-able benefits | creating awareness | | | |

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| **“Evaluation and ranking of solutions to mitigate circular suppl** | Enablers | Governments should form stringent laws and regulatory policies based on environmental factors to promote or enhance sustainable CSC practices | creating regulatio ns | | | |
| **Main_Dimensi ons_in_the_Bu ildin** | Enablers | a circular business model could provide managerial practices for design and implementation of supply chain | business model innovatio n | | | |
| **Main_Dimensi ons_in_the_Bu ildin** | Enablers | product service systems (PSS) business models have the potential to trigger and enhance the circularity features of supply chains, which can be complemented by other tools, such as the sustainable value analysis tool, to assist practitioners | business model innovatio n | | | |
| **Main_Dimensi ons_in_the_Bu ildin** | Enablers | in order to encourage the implementation of circular supply chains, that regulatory intervention at government and European Commission level brings clarity to the law so that it does not prevent CE collaboration [41]. | creating regulatio ns | | | |
| **Main_Dimensi ons_in_the_Bu ildin** | Enablers | The design of a new legislative, fiscal, and cultural framework positively affects environmental and economic performance of circular supply chains. | creating regulatio ns | | | |
| **Main_Dimensi ons_in_the_Bu ildin** | Enablers | (1) greater intensity in the relationships established in the supply chain, (2) adaptation of logistics and organizational, (3) disruptive and smart technologies, and (4) a functioning environment. | Overview | | | |
| **Closed loop supply chains 4.0** | Enablers | The use of these technologies can be beneficial to collect, store, and facilitate expansive data available along the entire SC in order to correct errors committed by human workers, track product quantity and storage locations, and reduce product damage and loss | technolog y | error correcti on | | |
| **Closed loop supply chains 4.0** | Enablers | “advanced and digital manufacturing technologies are able to unlock the circularity of resources within SCs”, | technolog y | | | |
| **What servicizing demands of a company** | Enablers | Supply of used prod-ucts needs to be coordinated with the manufacturing decisions. As such, systems to evaluate the condition of the used product need to be developed | technolog y | quality control | | |
| **Sustainable supply chain management of automotive sector** | Enablers | For developing sustainable supply chain practices, incentives, stakeholder pressures and support from supply chain partners are identified as the most important enablers. | common objective s | top manag ement support | | |
| **Supply chain collaboration for a circular economy** | Enablers | supply chain collaboration has been identified as a key element in the evolution of a CE | collabora tion | | | |
| **Supply chain collaboration for a circular economy** | Enablers | geographic distances and logistical costs, and collaboration between partners within and between supply chains, especially in reverse flows, were emphasized as being relevant in CSCM. | collabora tion | | | |

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| **Supply chain collaboration for a circular economy** | Enablers | collaborative and coordinating relation-ships between partners in the chain were among the many barriers to a CE which need to be better investigated | collaboration | | | |
| **Moving toward a circular economy in manufacturing organizations** | Enablers | stakeholder engagement has been found crucial to implementing CE practices, as it can help to align interests, create a shared vision and build relationships based on trust that allow the sharing of knowledge and information | stakeholder engagement to overcome trust barrier | | | |
| **Moving toward a circular economy in manufacturing organizations** | Enablers | In addition, stakeholder engagement can enable sharing of risk, better access to resources, co-constructing knowledge for political decision-making and developing the industry | stakeholder engagement to share risk | | contrary to: | |
| **Moving toward a circular economy in manufacturing organizations** | Enablers | mainly governmental, supply chain stakeholders and employees encourage organizations to start working with CE and implement it in their supply chain | stakeolder engagement for awareness | | | |
| **Measuring_Circular_Supply_Chai** | Enablers | Risk management is inevitable for achieving a high degree of circularity in SC | risk management | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Enablers | Reliable information must be shared in a real-time manner throughout the whole supply chain to enable a quick response to changes | data | reliability | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Enablers | Industry 4.0-based supply chains meet the need to build a comprehensive tracking and tracing system for improving operational efficiency in the contemporary supply chain | | | | |
| **Impact_of_the_Quality_of_Retur** | Enablers | As the lost sale costs are high, thus, the optimal strategy is to favor the production of RPFUP over the production of NPFUP | | | | |
| **Critical factors for enhancing the** | Enablers | market drivers, such as price volatility and resource scarcity related to increasing resource consumption, savings in material costs, competitive advantages and new markets | | | | |
| **Conception of circular economy obstacles in context of supply c** | Enablers | a long-term relationship is needed among the supplier partners for better coordination | | | | |
| **Conception of circular economy obstacles in context of supply c** | Enablers | r a healthier implementation of CSCM, the collaboration of the manufacturing sector, reverse logistics sector and waste management sectors should be there | | | | |

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| **Conception of circular economy obstacles in context of supply c** | Enablers | implications of CSCM would result in offering cheaper products that might entice the customers to involve in this paradigm successively | | | | |
| **Conception of circular economy obstacles in context of supply c** | Enablers | e expansion of sustainability awareness campaigns would also need to reach every customer and eliminate their cognitive biases towards this notion. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | technologies provide more efficient solutions and help overcome the<br>problems of existing technologies | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | artificial<br>intelligence (AI), machine learning (ML), blockchain technology, and<br>internet-of-things technology, conveniently enable data management, thereby facilitating product collection for recycling | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | the development of eco-nomic drivers, such as expanding the market for recycled products<br>and boosting consumer demand, will stimulate the implementation of<br>CSCs | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | RSC prac-tice should be prioritized to implement CSC, resource recovery<br>implementation, I4.0 and digitalization. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | n information structure comprising various<br>types of data in a range of digital formations is considered to be an<br>opportunity as well as a challenge | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | technologies are considered to be major elements in successfully pro-moting CSCs as they decrease operating costs, develop supply chain<br>collaboration, help close loops with waste minimization, build a regen-erative economy, and achieve harmonization among the environmen-tal, economic, and social benefits of CSCs | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | f I4.0 technologies in<br>optimizing resource utilization and controlling product life cycle<br>phases | | | | |
| **Building a data-driven** | Enablers | RSC practice is considered a driving force of CSC imple-mentation | | | | |

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| **circular supply chain hierarchical struc** | | | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | uncertainties and pressures<br>faced by the company can only be overcome through close coopera-tion among supply chain stakeholders under unified objectives. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | Financing capability and collaboration in the CSC are essential to maximize the positive effects of IT for firms implementing<br>reverse logistics | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | blockchain proposes a promising prospect for con-quering the abovementioned difficulties by ensuring data validity, accuracy, transparency, and a reduction in information uncertainty, providing better data inputs with outputs, lessening time for data<br>gathering, allowing enhanced data quality, and ensuring the traceabil-ity of data sources | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Enablers | stakeholders in CSCs need to cooperate with<br>laboratories to industrial extents for WTE technology to enlarge com-munity acceptance | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | The use of emerging technologies also helps in removing possible hurdles in CSCM implementation | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | policies and laws are framed by government to direct organisations towards sustainability when adopting CSCM | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | robust laws and policies framed by government help in adoption of the circular concept by organisations in their supply chains | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | support and commitment of top-level managerial staff of organisations for adoption/promotion of the circular SCM concept | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | 3 Refurbishment product quality standards. A large variety in product quality and standards is produced; this gives identification to organisations and customers for refurbished products; consumers have greater choice | | | | |

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| **Identification and analysis of circular supply chain management** | Enablers | workplace environment and technological capability of firms should be redesigned to minimise hazardous waste with a view to eliminating it altogether | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | Effective information system for material tracking in recycling activity. Monitoring and tracking of recycled material through circular activities are needed. | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | Education and training on recycling, remanufacturing and reuse | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | To achieve successful implementation of a CSC model, consumers must be persuaded to relocate their opinions from a linear to a circular system | | | | |
| **Identification and analysis of circular supply chain management** | Enablers | e importance of both government and top management, as both have a great influence on the policies and decisions made in any organisation | | | | |
| **Changeable manufacturing systems** | Enablers | For instance, capitalizing on recycling, reuse, de-manufacturing and re-manufacturing requires manufacturing systems that can match the dynamics of the product life-cycles and different end-to-life product strategies in a very changeable and unpredictable market and context | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Enablers | environmental-oriented supply chain cooper-ation (ESCC), or cooperation with suppliers and customers emphasizing environmental concerns, is considered a viable management approach for enterprises towards achieving envi-ronmental and productivity gains (Georgiadis and Besiou, 2008). Such desired performance outcome can be a key initiative for an enterprise to implement ESCC practices. | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Enablers | preferential policies similar to previous subsidies for ISO 14001 certification, the Chinese government can encourage these pioneering companies to proactively implement ESCC practices which can further promote their CE practices | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Enablers | List of measurement items for evaluating environmental-oriented supply chain cooperation. | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Enablers | Appendix B<br>List of measurement items for evaluating circular economy practices. | | | | |

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| **An investigation into circular economy practices in the traditi** | Enablers | environmental-oriented supply chain cooperation | | | | |
| **An investigation into circular economy practices in the traditi** | Enablers | Moreover, since the green purchasing will involve the collaboration with the supplier, Hollos, Blome, and Foerstl (2012) argue that in order to get a better environmen-tal performance, supplier collaboration should be combined with internal green supply chain management efforts. | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Enablers | requirement of enhanced regulatory atten-tion for accountability and new education initiatives to address the lack of environmental education | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Enablers | upskilling managers in the early phase, insertion of supportive govern-ment policies, development and adoption of the standard, sensitiza-tion of the public, increased use of advanced IT applications, and increased investment in sustainable product design. | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | While the CSC management involves structural adjustment within firms, the collaboration among supply chain members is considered | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | develops the knowledge base and vision on both the identification and implementation of this activity. | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | business model as a critical attribute in the strategic plan to integrate all supply chain members in a new procedure targeting circularity. | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | technology development and government regulations in the reverse logistics field are argued to be necessarily examined to obtain collaboration in CSC | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | This study includes two alternative aspects throughout the process of organisational change to enhance CSC collaboration, they are reverse logistics policies, and enabling collaboration by infor-mation technology | | | | |
| **Healthcare industry circular supply chain** | Enablers | to indicate collaboration among organisations as one of the drivers for developing CSC management. | | | | |

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| **collaboration in Viet** | | | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Enablers | Regulatory pressure for product return/recovery | | | | |
| **Main_Dimensions_in_the_Buildin** | Outcome | Shifting toward a circular model may offer enormous opportunities, including cost savings through waste reduction, better supply chain management, lower sensitivity to resource price volatility, and longer, better relationships with customers” | | | | |
| **Identification_of_critical_fac** | Outcome | In the best circumstances, the implementation of RL may lead to reduced operational costs and higher sales revenue | | | | |
| **Identification_of_critical_fac** | Outcome | Product routing is ambiguous | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Outcome | s by separating value formation from resource usage, leading to lower resource consumption and higher economic value acquisition from waste flows | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Outcome | promote CSCs because they can help address resource scarcity, decrease environmental effects, and create long-term economic benefits | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Outcome | successful implemen-tation of CSCs allowed firms to reduce their operating and production costs by saving resources, decreasing the cost of raw materials through replacement with recycled inputs, and controlling waste disposal costs. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Outcome | increasing profit margins and creating the potential for innova-tion and growth | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Outcome | effective RSC enables the low-cost collection and circulation of used products | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Outcome | environmental-oriented supply chain cooper-ation (ESCC), or cooperation with suppliers and customers emphasizing environmental concerns, is considered a viable management approach for enterprises towards achieving envi-ronmental and productivity gains | | | | |

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| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Outcome | new complexities emerge when organizations adopt product recovery and CSC. | | | | |
| **Bridging economy and ecology** | Outcome | lead to higher product sales and high societal acceptance | | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain capabilities | network to enable circularity in their supply chains | network | --> increased complexity | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain capabilities | e involvement of all stakeholders, such as suppliers, cus-tomers, supply chain members, and employees of the organiza-tion, plays a crucial role in CSC adoption | stakeholder engagement | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Supply chain capabilities | Knowledge and information sharing are essential factors in decision-making within the supply chain. Further, communi-cation among partners is supported by information technol-ogy infrastructure | knowledge sharing and technological infrastructure | --> D9 | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | Strategic networks are stable inter-organizational links which are of importance to the company and which express these links through various forms, such as strategic alliances or long-term buyer-supplier partnerships | network | Long term relationship to overcome | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | Integrating the customer behavior approach into the supply chain would lead to a more evolved model that they have called the extended sustainable supply chain, which considers both environmental factors and strategies for change | | | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | . Collaboration within the supply chain network positively affects environmental and economic performance of circular supply chains. | collaboration | increases performance | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | The adaptation of organizational and productive structures positively affects environmental and economic performance of circular supply chains. | | | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | Smart technologies implemented with sustainable practices positively affect environmental and economic performance of circular supply chains. | technology | increases performance | but | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | (1) greater intensity in the relationships established in the supply chain, (2) adaptation of logistics and organizational, (3) disruptive and smart technologies, and (4) a functioning environment. | Overview | | | |

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| **Closed loop supply chains 4.0** | Supply chain capabilities | The use of these technologies can be beneficial to collect, store, and facilitate expansive data available along the entire SC in order to correct errors committed by human workers, track product quantity and storage locations, and reduce product damage and loss | technology | overcoming errors | increase product quality and traceability | |
| **Closed loop supply chains 4.0** | Supply chain capabilities | Using data capturing, sensors and monitoring and control systems, companies can reduce risks related to the demand for final products (1). | technology to forecast demand | reduce | but increasing complexity | |
| **Closed loop supply chains 4.0** | Supply chain capabilities | From simulations, case studies, and theoretical works we can see how big data can help companies to create new forecasting methods, new pricing strategies, improve the flexibility of the SCs, all while paying attention to the possible difficulties and costs that big data can generate | big data | flexibility, pricing, forecasting | but complexity and knowledge and skills | |
| **Closed loop supply chains 4.0** | Supply chain capabilities | possibility of running cloud computing applications in almost all devices, like computers, laptops, and smartphones, together with the opportunity to increase (or decrease) the cloud computing resources based on necessity makes this technology ideal for managing the complexity of a CLSC. | cloud computing flexibiltiy | manage complexity | | |
| **What servicizing demands of a company** | Supply chain capabilities | Close coordination between product development and supply chain functions is needed to better manage the supplier relationships and to treat them as partners | coordination for better relationships | | | |
| **What servicizing demands of a company** | Supply chain capabilities | OEMs should aim to make product development and manufacturing functions a part of their core competency and competitive advantage | | | | |
| **Supply chain collaboration for a circular economy** | Supply chain capabilities | relationship governance in the ability to coordi-nate the actions and expectations of partners was one of the most recurrent themes in collaboration for a CE | RELATIONSHIP GOVERNANCE | | | |
| **Supply chain collaboration for a circular economy** | Supply chain capabilities | e alignment of interests (same objectives), and behavior (same attitude) between partners | common objectives | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Supply chain capabilities | . Manavalan and Jayakrishna (2019) found that real-time information exchange enables supply chain integration in the industry 4.0 domain. I | | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply chain capabilities | barcodes, radio frequency identification (RFID) and WSN in logistics and operations systems, essen-tially enhance real-time information collection for supply chain monitoring and improvement | barcodes, technology | Sheet1!D39 | | |
| **Integrating circular economy and** | Supply chain | stake-holder expectation and collaboration is an ultimate driver for sustainable supply chain operations in the concepts of CE and Industry 4.0. | | | | |

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| **Industry 4 0 for sustainable s** | capabiliti es | | | | | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Supply chain capabiliti es | the use of advanced technology and information system can substantially reduce the system errors; for example, it can reduce transportation processes, unnecessary material flows and delivery mistakes, and increase data transparency throughout the whole supply chain via smarter logistics | technolog y to reduce errors | | | |
| **Integrating circular economy and Industry 4 0 for sustainable s** | Supply chain capabiliti es | account knowledge assessment, partner development, co-evolving, reflexive supply chain control, and supply chain re-conceptualization, | | | | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Supply chain capabiliti es | Evidence has been provided that remanufacturing firms may reduce quality issues and minimize associated risks by strictly following standard operating procedures and quality assurance plans at every step of remanufacturing operations | standardi sation | | | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Supply chain capabiliti es | Flexible orientation in a remanufacturing environment is vital for its ability to cope up with uncertainties | flexibility | | | |
| **Examining the role of dynamic remanufacturi ng capability on sup** | Supply chain capabiliti es | Dynamic remanufacturing capabilities will enable a firm to return back to normal operations after occurrence of disruption events and will still be capable to meet customer demands. | dynamic remanufa cturing capabiliti es | recover fast | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabiliti es | d CSC principles<br>to enhance resource efficiency | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabiliti es | s enhances<br>resource efficiency, expands resource lifetime, and<br>decreases<br>resource consumption | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabiliti es | increasing profit margins and creating the potential for innova-tion and growth | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabiliti es | enhancing cooperation between firms<br>and satisfying all customer and stakeholders' requirements. | | | | |

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| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabilities | innovative techniques are used to meet the CSC requirements related to supply flexibility, the innovation of methods and processes to increase productivity, cleaner production, and sustainable consump-tion. | innovation | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabilities | technologies are considered to be major elements in successfully pro-moting CSCs as they decrease operating costs, develop supply chain collaboration, help close loops with waste minimization, build a regen-erative economy, and achieve harmonization among the environmen-tal, economic, and social benefits of CSCs | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabilities | uncertainties and pressures faced by the company can only be overcome through close coopera-tion among supply chain stakeholders under unified objectives. | common objectives | cooperation | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain capabilities | Information technology has recently become the center of RSC practices, enhancing the flexibility and effective-ness of operating processes | IT center of practices | | | |
| **Identification and analysis of circular supply chain management** | Supply chain capabilities | Performance indicators on 3R | performance indicators on 3R | | | |
| **Identification and analysis of circular supply chain management** | Supply chain capabilities | support and commitment of top-level managerial staff of organisations for adoption/promotion of the circular SCM concept | top management cmomitment | for awareness | | |
| **Identification and analysis of circular supply chain management** | Supply chain capabilities | Effective information system for material tracking in recycling activity. Monitoring and tracking of recycled material through circular activities are needed. This helps decision managers to deal quickly and precisely with standards through circular activities | technology for traceability | | | |
| **A survey on reverse logistics system** | Supply chain capabilities | more than 20 percent of the returned goods could be resold as is | | | | |
| **A survey on reverse logistics system** | Supply chain capabilities | first mover in this regard could gain competitive advantages, and hence practicing reverse logistics could be a strategic move | | | | |
| **Changeable manufacturing systems** | Supply chain capabilities | reconfigurability | | | | |
| **Circular economy practices among Chinese** | Supply chain capabilities | CE approach promotes continuous economic development without posing significant environmental and resource challenges. | | | | |

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| **manufacturers varying** | | | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Supply chain capabilities | List of measurement items for evaluating environmental-oriented supply chain cooperation. | performance measurement | | | |
| **Circular economy practices among Chinese manufacturers varying** | Supply chain capabilities | Appendix B<br>List of measurement items for evaluating circular economy practices. | performance measurement | | | |
| **An investigation into circular economy practices in the traditi** | Supply chain capabilities | environmental-oriented supply chain cooperation (ESCC) | cooperation | | | |
| **An investigation into circular economy practices in the traditi** | Supply chain capabilities | ECO has a positive significant effect on the economic performance | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain capabilities | shared responsi-bility system across the supply chain for better recovery and fewer disruptions. | shared responsibilities to reduce disruption | Sheet1!E182 | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain capabilities | model that analyses the impact of non-availability of parts and<br>cost of recovery for the supplier after a sudden, unpredictable disrup-tion | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain capabilities | complex interactions require innovative cooperation practices | innovation | coordination of complexity of network | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain capabilities | use of emerging technology for<br>improving coordination | technology | Sheet1!F288 | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain capabilities | coordination<br>and collaboration among stakeholders | | | | |
| **Healthcare industry** | Supply chain | collaboration | | | | |

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| **circular supply chain collaboration in Viet** | capabilities | | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | requires an interconnected network of relationships among members in the supply chain and the value creation for the network of stakeholders | network | complexity | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | the collaboration between firms and stakeholders in CSC is necessary and needs to be intensified through regulating vision and learning, building connections and new business models, framing policies, and applying innovative technologies. | collaboration | innovation | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | to indicate collaboration among organisations as one of the drivers for developing CSC management. | collaboration | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | Dev, Shankar, and Qaiser (2020) proposed a roadmap to the operational excellence for the supply chain in the circular economy by the joint implementation of Industry 4.0 principles and the ReSOLVE model (including regenerate, share, optimise, loop, vir-tualise, and exchange), as a result, collaboration was argued as a key performance dimension. | Overview | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | shared vision and a shift of defining problems in CSC ( | common objectives | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | , the existence of alternative rule sets, and leadership | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | managing data transparency (C5) regulates the level of transparency in the exchange of information can predict the level of a company collaboration. | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Supply chain capabilities | enhancing the effectiveness in production and consumption is the motivation for supply chain collaboration | | | | |
| **Bridging economy and ecology** | Supply chain capabilities | Green SCM measures give companies cost and risk advantages such as benefits in productivity, property value, and the environment | | | | |

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| **Bridging economy and ecology** | Supply chain capabilities | the company’s image can be improved, | | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Supply Chain Disruptions | Supply risks are associated with the supply of appropri-ate ecological friendly materials (circular materials). Supply risks directly affect the quality and durability of finished products and may reduce organizations’ environmental and financial gains (Ethirajan et al., 2020). Demand risks are pull-based. The demand for remanufactured or recycled (recovered) products will signifi-cantly influence organizations | push and pull (supply/demand) | | | |
| **“Evaluation and ranking of solutions to mitigate circular suppl** | Supply Chain Disruptions | Table 1 | Overview | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Supply Chain Disruptions | maintaining quality throughout the product lifecycle, and within the returned products in the sustainable supply chains | quality degradation | | | |
| **Main_Dimensions_in_the_Buildin** | Supply Chain Disruptions | essential to make a correct selection of the suppliers to guarantee lower costs of treatment of the materials and a lower environmental impact, reducing the distribution centers and the vehicles used | | | | |
| **Closed loop supply chains 4.0** | Supply Chain Disruptions | Risks related to the demand for final products: These apply when companies are not able to fully satisfy the demand for final products due to a lack of organisation and external disturbances | | | | |
| **Closed loop supply chains 4.0** | Supply Chain Disruptions | a lack of organisation and external disturbances. This is different from the previous risk (Eslamipoor et al., 2015) as it involves different markets and characteristics of the products. It also involves the attitudes of customers towards buying second-hand products | demand uncertainty | | | |
| **Closed loop supply chains 4.0** | Supply Chain Disruptions | Risks related to returned products: These arise when the quantity and quality of the returned products are not as expected, and when the time over which the products are returned and collected is unpre-dictable. Although the quantity of returned products in some cases can be known in advance, it may be random and uncertain for many consumer products ( | supply uncertainty | | | |
| **Closed loop supply chains 4.0** | Supply Chain Disruptions | While it is possible to create some forecast methods for the number of returned products, predicting their quality is more difficult | quality and supply uncertainty | not only have to predict quantity but also which R loop is required | | |

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| **Closed loop supply chains 4.0** | Supply Chain Disruptions | disposal of returned products is variable in terms of time, cost, effi-ciency, and impact on the environment | | | | |
| **Closed loop supply chains 4.0** | Supply Chain Disruptions | when distribution is not properly scheduled, is unreliable or time-inefficient, and when there is an impact on the environment | | | | |
| **What servicizing demands of a company** | Supply Chain Disruptions | Order quantities for new parts and modules are then dependent on the product recovery rates. This feature makes procurement and supplier management more complex. | supply uncertainty leads to demand uncertainty of new products | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Balancing returned supply and demand | | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Uncertainty in returned product type supply | | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Uncertainty in returned product quality | | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Uncertainty in returned product volume | | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Uncertainty in returned product timing | | | | |
| **Strategic opportunities for produc** | Supply Chain Disruptions | Uncertainties in production yields | | | | |
| **Measuring_Circular_Supply_Chai** | Supply Chain Disruptions | CSCs are more vulnerable to risk than conventional linear supply chains, as these have more points of possible disruption, due to an extended chain of partners. | more partners: more possible disruptions | | | |
| **Measuring_Circular_Supply_Chai** | Supply Chain Disruptions | dis-ruptions of other internal activities | | | | |
| **Measuring_Circular_Supply_Chai** | Supply Chain Disruptions | loss of the competitive base, opportunistic behaviors, rising transaction and coordination costs, and higher procurement costs. | | | | |

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| **Introducing an application of an industry 4.0 solution for circ** | Supply Chain Disruptions | consideration of environmental, social and economic issues (Hassini et al., 2012). The complex and dynamic characteristics of these factors increase the uncertainty in supply chains | focussin not only on economical and social factors but also on environmental --> adds complexity | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply Chain Disruptions | involves complex sys-tems and dynamic changes due to factors linked with both internal and external stakeholders | | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply Chain Disruptions | , the quality of used products is a critical factor that influences the incentive paid to custom-ers, remanufacturing cost, collection rate and lead time | quality uncertainty | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply Chain Disruptions | Operations uncertainty and security issues are other sig-nificant barriers that companies face when implementing CE and Industry 4.0 | | | | |
| **Impact_of_the_Quality_of_Retur** | Supply Chain Disruptions | s the returned-used products are derived from sales, rather than market demand. Of course, the number of products that were sold in previous periods is lower than market demand when a portion or all of the latter is not satisfied | uncertain demand and supply | | | |
| **Impact_of_the_Quality_of_Retur** | Supply Chain Disruptions | The authors have considered the quality of returned products as a stochastic variable, and based on this assumption, the salvage value, remanufacturing cost, and buy-back cost depend on the quality level of the returned products | quality is a stochastic variable | many cost factors depend on it | | |
| **Identification_of_critical_fac** | Supply Chain Disruptions | The quality of the product is not uniform | | | | |
| **Identification_of_critical_fac** | Supply Chain Disruptions | The option for disposition of a product is not clear | | | | |
| **Identification_of_critical_fac** | Supply Chain Disruptions | Forecasting for RL process is much more difficult | | | | |
| **Identification_of_critical_fac** | Supply Chain Disruptions | The visibility of the process is much less transparent | | | | |

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| **Identification_ of_critical_fac** | Supply Chain Disruptions | Previous research identified uncertainty regarding quality, quantity and timing from product returns as influencing the success of remanufacturing | quality and supply uncertainty | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | Activities linked with production planning and control are being challenging within any remanufacturing firm due to stochastic nature of old product returns and unknown quality of those products | stochastic nature of product returns and unknown quality | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | improbability in timing and amount of returned products; imbalances in returned products with the demands; dissembling of returned products; doubtfulness in components regained from returned products; reverse logistics; technical complications from machining perspective; and, finally, the issues with uncertain flow of input for remanufacturing and extremely varying processing timings | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | Post-disruption events, it is vital for firms to quickly restore back to normal operating conditions. However, uncertainty in quantity and quality of input supply poses continuous risks and threats of disruption in the remanufacturing supply chain network which may result in huge financial loss and market share loss for the remanufacturing firm | uncertain demand and supply | network complexity | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | . Another concern for remanufacturing firms relates to poor control over inventory due to a lack of visibility which leads to overstocking or understocking and further attracts business losses | inventory control | due to visibility lack and supply uncertainty | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | common problems are low forecasting accuracy leading to poor visibility, which ultimately translates into poor planning of available resources and underutilized plant capacity | poor visibility | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply Chain Disruptions | unprofessional supplier behaviors may occur such as suppliers becoming unresponsive after receiving quotation requests for remanufacturing of some critical components; such supplier unresponsiveness may be due to involvement of specialized machines, low volumes and high variations of remanufactured parts | | | | |
| **Critical factors for enhancing the** | Supply Chain Disruptions | Rapid changes in markets, e.g. restrictions on exports or costs for recovering wood waste (D). | Sustainability as a disruption | change in regulations etc | | |
| **Conception of circular economy obstacles in context of supply c** | Supply Chain Disruptions | poor forecast accuracy, which means poor management of existing resources and under-utilized plant capacity | wrong forecasting | more difficult due to stochastic nature of | | |

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| | | | | product return and quality | | |
| **Conception of circular economy obstacles in context of supply c** | Supply Chain Disruptions | quality of produced remanufactured goods | | | | |
| **Conception of circular economy obstacles in context of supply c** | Supply Chain Disruptions | incapability in production required volume | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply Chain Disruptions | the problem of making the demand and the return flow meet, which is critical in CLSC of RA | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply Chain Disruptions | after a certain unknown time, they will return to a facility where they will be reconditioned and then reused. This unknown time may be described by a statistical distribution, although a non-stationary description may be necessary | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply Chain Disruptions | the time from issue to return of each RA is a random variable with a distribution that includes a finite probability of not reintegrating the forward flow (Kelle and Silver 1989a, Toktay et al. 2000). | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply Chain Disruptions | t the return rate is very high but do not have full control or visibility over how many RA will eventually return and when and where they will return. | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply Chain Disruptions | . Depots need to ensure that they are able to fulfil demand by depending heavily on returned articles | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply Chain Disruptions | Ozkan-Ozen et al. (2020) claimed that uncertain returns are obstacles to CSC implementation. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply Chain Disruptions | deal with technological dangers that could occur from outside. Cybersecurity, for example, is another critical challenge in I4.0, | technology disruption | since I4.0 is an enabler for CSC | | |

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| **Building a data-driven circular supply chain hierarchical struc** | Supply Chain Disruptions | management of<br>the RSC is quite complex and uncertain as it involves various partici-pants in the supply network | links to barrier | Some say network reduces risks other say it increases risks | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | higher product variety | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | higher unpredictability in processing requirements | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | multiple product generations | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | higher variability of the post-use product conditions | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | fluctuating capacity requirements | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | repairs for extending product lifetimes, certain components with shorter lifetime will over time be in higher demand than those with longer lifetimes. | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | demand profiles for different components will change, where the most durable components may at some point not need to be manufactured at all, while other will be in steady demand | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | companies are unlikely to be in full control of the quantities of products being taken back, which means that there is likely a volatile supply of EOL products | | | | |
| **Changeable manufacturing systems** | Supply Chain Disruptions | . It must be expected that EOL products are in very different shape, depending on their age and usage. | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply Chain Disruptions | , the opportunity of abandoned products is<br>strained by the demand for the primary product | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply Chain Disruptions | CSC is viewed as a strategic approach to resolving several issues, including waste generation, resource scarcity, | | | | |

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| **Admitting risks towards circular economy** | Supply Chain Disruptions | , 'Quality degradation of recycled products' | | | | |
| **Admitting risks towards circular economy** | Supply Chain Disruptions | Obstacles faced by service providers to legally retain ownership of a sold product' | | | | |
| **Admitting risks towards circular economy** | Supply Chain Disruptions | 'Lack of proper mechanism for take-back | | | | |
| **Admitting risks towards circular economy** | Supply Chain Disruptions | maintaining the quality of products made from recovered materials | | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain risks | CSC's risks primarily involve operational and technological risks, economic risks, supply risks, demand risks, product recovery risks, environmental risks, and social risks. | Overview | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain risks | Operational and technological risks in the CSC context can be defined as the risks that hamper the adoption of circular oper-ations, existing technologies, the labor force, coordination among supply chain members, etc. | definition | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain risks | Economic risks are based on macroeconomic circumstances that may result in a significant loss for a business organization. Such risks may include inflation exchange rates, new government regulations and policies, | definition | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain risks | Supply risks are associated with the supply of appropri-ate ecological friendly materials (circular materials). Supply risks directly affect the quality and durability of finished products and may reduce organizations' environmental and financial gains (Ethirajan et al., 2020). Demand risks are pull-based. The demand for remanufactured or recycled (recovered) products will signifi-cantly influence organizations | uncertain demand and supply | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain risks | Table 1 | Overview | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Supply chain risks | In particular, insuffi-cient skills in the reuse, reproduction, repair and recycling of products may lead to inadequate product design and pro-duction in a CE | skill barrier leads to risk in product design and production | | | |

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| **Closed loop supply chains 4.0** | Supply chain risks | a list of risks that can occur in reverse logistics in the retail sector. The most relevant ones relate to the logistic activities planning and efficiency level due to the high levels of uncertainty in return time, quantity, quality, and site. | risks in logistics planing due to possible disruptions in supply and demand and quality | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | inventory risk is prioritised as the most serious one and should be treated with care. | inventory risk | related to | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to the demand for final products: These apply when companies are not able to fully satisfy the demand for final products due to a lack of organisation and external disturbances | supply and demand risk | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to the demand for used products: These arise when com-panies are not able to fully satisfy the demand for used products | demand uncertainty | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to returned products: These arise when the quantity and quality of the returned products are not as expected, and when the time over which the products are returned and collected is unpre-dictable. Although the quantity of returned products in some cases can be known in advance, it may be random and uncertain for many consumer products ( | returned product risks | quality, quantity, timing | | |
| **Closed loop supply chains 4.0** | Supply chain risks | , this deficiency can compromise the ability of meeting the demand for used products and for all components derived from the returned products. | uncertain supply of returned products leads to risk of not meeting demand | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to the reprocessing of returned products: | | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to the disposal of returned products: | disposal of products | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | Risks related to suppliers: | | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | supplier is unreliable in terms of costs, quantity, quality, capacity, time etc. Supplier selec-tion is a really difficult decision | | | | |
| **Closed loop supply chains 4.0** | Supply chain risks | . Risks related to distribution: | | | | |

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| **Closed loop supply chains 4.0** | Supply chain risks | when distribution is not properly scheduled, is unreliable or time-inefficient, and when there is an impact on the environment | | | | |
| **What servicizing demands of a company** | Supply chain risks | OEMs cannot perform remanufacturing oper-ations, leaving the field open to independent third-party remanufacturers or competitors. This exposes the OEM's intellectual property and technology and often affects the image and brand value of the OEM | third party involvement risk of losing intellectual property | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | Enterprises planning to switch towards CSC need to involve more partners, thus exposing the supply chain to several risks | more partners: more possible risks | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | CSCs are more vulnerable to risk than conventional linear supply chains, as these have more points of possible disruption, due to an extended chain of partners. | more partners: more possible risks | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | waste management risk that involves health-associated risk to society [52], and heavy penalties imposed on the organization, due to the improper disposal of waste | Sustainability regulations as a risk ? | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | e 6R (reuse, repair, refurbish, remanufacture, recycle, redesign) operations can be performed in house or outsourced to a specialized outsourcing partner. Outsourcing of these operations involves a variety of risks | third party involvement risk of losing intellectual property | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | loss of the competitive base, opportunistic behaviors, rising transaction and coordination costs, and higher procurement costs. | costs? | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | CSCs are exposed to a variety of coordination risks that may include distortion during the sharing of valuable information, issues of trust among the partners, commitment failure, and a lack of risk sharing among the partners | coordination risks | looks for def | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | demand of new and long-lasting products increases, and it may lead to reduced sales of the previous products, which is commonly referred to as the risk of cannibalization | cannibalization | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks |  | Overview | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain risks | | Overview | | | |

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| **Introducing an application of an industry 4.0 solution for circ** | Supply chain risks | consideration of environmental, social and economic issues (Hassini et al., 2012). The complex and dynamic characteristics of these factors increase the uncertainty in supply chains | Sustainability aspects create uncertainties | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply chain risks | involves complex sys-tems and dynamic changes due to factors linked with both internal and external stakeholders | network complexity | more partners=more risks | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply chain risks | Operations uncertainty and security issues are other sig-nificant barriers that companies face when implementing CE and Industry 4.0 | | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Supply chain risks | uncertainty and risks will increase as inefficient use of innovative technology and information system may increase the system's complexity | risk that missing skills and knowledge increase system complexity leading to system failures and technology issues | | | |
| **Identification_of_critical_fac** | Supply chain risks | Forecasting for RL process is much more difficult | forecasting difficulties lead to uncertainty | demand and supply risk | | |
| **Identification_of_critical_fac** | Supply chain risks | The visibility of the process is much less transparent | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain risks | Post-disruption events, it is vital for firms to quickly restore back to normal operating conditions. However, uncertainty in quantity and quality of input supply poses continuous risks and threats of disruption in the remanufacturing supply chain network which may result in huge financial loss and market share loss for the remanufacturing firm | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain risks | . Another concern for remanufacturing firms relates to poor control over inventory due to a lack of visibility which leads to overstocking or understocking and further attracts business losses | visibility and tracing issues leade to uncertain supply and | | | |

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| | | | demand which leads to inventory over or understocking | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain risks | . For instance, common problems are low forecasting accuracy leading to poor visibility, which ultimately translates into poor planning of available resources and underutilized plant capacity (Seitz and Peattie, 2004; Andrew-Munot and Ibrahim, 2013). Also, other problems include unavailability on the market of suppliers having desired ability to meet both technical specifications and requirements. Moreover, unprofessional supplier behaviors may occur such as suppliers becoming unresponsive after receiving quotation requests for remanufacturing of some critical components; such supplier unresponsiveness may be due to involvement of specialized machines, low volumes and high variations of remanufactured parts. Furthermore, most suppliers take a long lead time to complete machining of remanufactured parts leading to remanufacturing firm's loss of competitiveness in the market (Kim et al., 2006). Literature also discusses scarcity of skilled labor and lack of competency which influences the inspection, refurbishing and reassembly operations (Guide and Van Wassenhove, 2001; Abbey et al., 2015). Such risks make vulnerable remanufacturing supply chains, and increase chances of disruptions and delay in restoration of normal operations. | | | | |
| **Conception of circular economy obstacles in context of supply c** | Supply chain risks | poor forecast accuracy | forecasting difficulties lead to uncertainty | demand and supply risk | | |
| **Conception of circular economy obstacles in context of supply c** | Supply chain risks | incapability in production required volume | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply chain risks | RA travel across the boundaries of the organisations that make up the supply-chain network, so in some stages of article life-cycle, the focal company (that owns the reusable articles) has very limited or no control over a part of the articles | loss of control due to wide network | information sharing ? | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply chain risks | after a certain unknown time, they will return to a facility where they will be reconditioned and then reused. This unknown time may be described by a statistical distribution, although a non-stationary description may be necessary | uncertain demand and supply | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Supply chain risks | the time from issue to return of each RA is a random variable with a distribution that includes a finite probability of not reintegrating the forward flow (Kelle and Silver 1989a, Toktay et al. 2000). | uncertain demand and supply | | | |

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| **Closed loop supply chains of reusable articles a typology groun** | Supply chain risks | structural losses are typically a concern in RA systems. They are more difficult to control than quality losses, because they take place in the unobservable part of the supply chain. Owing to the lack of control over the structural losses, quantifying precise figures of the return rates is not straightforward. | | | | |
| **Circular supply chain orchestration to overcome Circular Econom** | Supply chain risks | : governmental, economic, techno-logical, knowledge and skills, organizational, social and cultural, market, financial, and finally logistics risk. | Overview | | | |
| **Circular supply chain orchestration to overcome Circular Econom** | Supply chain risks | quality degradation of recycled products, the lack of a proper regulatory CE vision and the lack of consideration of the needs of the whole textile SC are the risks with the highest perceived priority | quality and supply uncertainty | uncerta in regulatory environment | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain risks | varying business models within the CSC cause firms to struggle with<br>the increased complexity within this shift | BMI risks | change management | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain risks | deal with technological dangers that could<br>occur from outside. Cybersecurity, for example, is another critical<br>challenge in I4.0, | cyberrisks | due to I4.0 | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain risks | management of<br>the RSC is quite complex and uncertain as it involves various partici-pants in the supply network | network complexity | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain risks | main threat is data integrity<br>such as missing data and imprecise data in database management | data integrity risks | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of employee's proficiency regarding CSC | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | escalating production costs | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of client awareness | | | | |
| **Admitting risks towards** | Supply chain risks | insufficient information for tracking materials or resources in CSC | | | | |

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| **circular economy** | | | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of upfront cost invested in CSC | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of proper safety for workers during recycling hazardous materials, lack of successful business models and frameworks to implement CSC | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of proper organizational structure to implement CSC | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of continuous customer interest and attention. | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | risks can be governmental, technological, economic, and others and can negatively impact the performance, quality, and motivation of the companies | Overview | | | |
| **Admitting risks towards circular economy** | Supply chain risks | Summarized categories of risks associated with CSCs. | Overview | | | |
| **Admitting risks towards circular economy** | Supply chain risks | , 'Quality degradation of recycled products' | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | payback period for implementing CSCs may also be excessive. Usually, the payback period regarding CSC projects is 5–10 years, which can be too long for most people who are generally risk-averse | high investment uncertain ROI | | | |
| **Admitting risks towards circular economy** | Supply chain risks | Obstacles faced by service providers to legally retain ownership of a sold product' | regulatory barrier | | | |
| **Admitting risks towards circular economy** | Supply chain risks | particularly in terms of risks in the implementation of successful CSC models | Overview | | | |
| **Admitting risks towards circular economy** | Supply chain risks | Company executives do not know how the market would remunerate their actions if consumers are in-clined to spend money on cleaner products | | | | |
| **Admitting risks towards circular economy** | Supply chain risks | implying that CSCs are burdened with the many technological risks. CSC adoption is a challenge due to risks such as technology transfers in which the latest technology is transferred from the inventor (developed nation) to a secondary user (developing country) to increase its usefulness towards CSC | technology disruption | | | |
| **Admitting risks towards circular economy** | Supply chain risks | lack of accurate information regarding the tracing of materials through reprocessing is another issue limiting CSC adoption | information accruacy | | | |

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|---|---|---|---|---|---|---|
| **Closed loop supply chains of reusable articles a typology groun** | Supply chain risks > Control Risk | the focal company (that owns the reusable articles) has very limited or no control over a part of the articles | loss of control due to wide network | | | |
| **Admitting risks towards circular economy** | Supply chain risks > Control Risk | Obstacles faced by service providers to legally retain ownership of a sold product' | ownership loss of control | | | |
| **Admitting risks towards circular economy** | Supply chain risks > Control Risk | maintaining the quality of products made from recovered materials | material quality | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain vulnerabilities | Economic risks are based on macroeconomic circumstances that may result in a significant loss for a business organization. Such risks may include inflation exchange rates, new government regulations and policies, | wider macroeconmic influence | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Supply chain vulnerabilities | Table1 | Overview | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Supply chain vulnerabilities | This new business model affects all the business processes (design, production, distribution, consumption, repairing and remanufacturing), and the infra-structure of the whole supply chain | BMI - unknown structured | | | |
| **Framework for a sustainable supply chain to overcome risks in t** | Supply chain vulnerabilities | Outsourcing new knowledge through collaboration with sup-pliers is problematic in situations of technology privacy (Govindan et al. 2014) because it could harm their competi-tiveness (Rizos et al. 2016). | information sharing | | | |
| **Main_Dimensions_in_the_Buildin** | Supply chain capabilities | Collaboration in the supply chain enables a network of actors to be connected in their supply chain by managing the transparency of data, flows and exchanges of material, responsibilities, predictability, and benefit sharing | collaboration for sharing, transparency etc. | | | |
| **Closed loop supply chains 4.0** | Supply chain vulnerabilities | e reprocessing of returned products is variable in terms of time, cost, efficiency, and impact on the environment. | process uncertainty | | | |
| **Closed loop supply chains 4.0** | Supply chain vulnerabilities | capacity of the manufacturing systems only impacts the forward flow, the capacity of the reprocessing systems affects the dynamics of both flows, forward and revers | process uncertainty | | | |
| **Closed loop supply chains 4.0** | Supply chain vulnerabilities | all while paying attention to the possible difficulties and costs that big data can generate. | vulnerability of big data | | | |
| **What servicizing demands of a company** | Supply chain vulnerabilities | Order quantities for new parts and modules are then dependent on the product recovery rates. This feature makes procurement and supplier management more complex. | | | | |

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| **Measuring_Circular_Supply_Chai** | Supply chain vulnerabilities | e interdependency among the partners, plan for these disruptions, and redesign their SC accordingly. | interdependencies between partners and redesign of SC | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain vulnerabilities | in a CSC there are numerous SC partners that are involved in achieving circularity of the flow of ma-terial [54], a high level of coordination has to be maintained in order to achieve improved circularity | many partners, many vulnerabilities especially due to high coordination need | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain vulnerabilities | Being unable to respond to agile changes is another potential issue while introducing a circular business model. This is also sometimes termed as agile vulnerability | agile vulnerability | | | |
| **Measuring_Circular_Supply_Chai** | Supply chain vulnerabilities | In the case of the circular supply chain, all the partners are connected through a cycle. Therefore, if any disruptive event occurs, it will affect each of the partners that are involved in the cycle. | cycle will influence everyone | | | |
| **Identification_of_critical_fac** | Supply chain vulnerabilities | design of RL networks, where quantity, quality and arrival time of returns are of paramount importance | | | | |
| **Identification_of_critical_fac** | Supply chain vulnerabilities | The management of inventory is not consistent | inventory vulnerabilities due to supply and demand uncertainty | | | |
| **Identification_of_critical_fac** | Supply chain vulnerabilities | The life cycle of the product in this process is less likely to be managed | lifecycle management difficult | | | |
| **Identification_of_critical_fac** | Supply chain vulnerabilities | Forecasting for RL process is much more difficult | | | | |
| **Identification_of_critical_fac** | Supply chain vulnerabilities | The visibility of the process is much less transparent | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain vulnerabilities | g manufacturing planning and control actions more complex | | | | |

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|---|---|---|---|---|---|---|
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain vulnerabilities | lack of visibility which leads to overstocking or understocking and further attracts business losses | lack of visibility creates vulnerabilities in forecasting | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain vulnerabilities | common problems are low forecasting accuracy leading to poor visibility, which ultimately translates into poor planning of available resources and underutilized plant capacity | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain vulnerabilities | include unavailability on the market of suppliers having desired ability to meet both technical specifications and requirements | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Supply chain vulnerabilities | most suppliers take a long lead time to complete machining of remanufactured parts leading to remanufacturing firm's loss of competitiveness in the market | | | | |
| **Critical factors for enhancing the** | Supply chain vulnerabilities | Unclear if waste materials will be available if legislation changes | dependency on legislation and regulation | | | |
| **Critical factors for enhancing the** | Supply chain vulnerabilities | Worries about data security violations in smart waste management or who bears responsibility when using secondary materials (D). | | | | |
| **Critical factors for enhancing the** | Supply chain vulnerabilities | Uncertainties about the impact of different regulations on CE operations (I). | dependency on legislation and regulation | | | |
| **Conception of circular economy obstacles in context of supply c** | Supply chain vulnerabilities | a longer lead time taken by the supplier for remanufacturing a product leads to failure in the business competition | | | | |
| **Conception of circular economy obstacles in context of supply c** | Supply chain vulnerabilities | The obstacle of the skilled workforce is also a concerning issue that influences various operations like remanufacturing, an inspection of used products and remanufactured products, and reassembly processes, the absence of which leads to the vulnerabilities of CSCM functioning | vulnerabilities increase due to necessary skills and knowledge regarding CSC | | | |

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| **Closed loop supply chains of reusable articles a typology groun** | Supply chain vulnerabi lities | discarded products do not enter the same original supply chain but enter a different one, typically, a secondary market that may cannibalise some sales in the primary market. | | | | |
| **Circular supply chain orchestration to overcome Circular Econom** | Supply chain vulnerabi lities | lack of a proper regulatory CE vision | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain vulnerabi lities | legal framework, especially the composition and execution of<br>the legislative documents governing circular transformation, has a tre-mendous influence on the speed and efficiency of the CSC transition | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain vulnerabi lities | deal with technological dangers that could<br>occur from outside. Cybersecurity, for example, is another critical<br>challenge in I4.0, | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain vulnerabi lities | , the reality is that<br>many firms have faced obstacles in applying information technology<br>and innovative devices to operate RSC practices | complexi ty of technolog y | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain vulnerabi lities | design and planning of RSC operations are challeng-ing and complicated since this indicator includes various activities for<br>recovered products that have changed in value or other parameters<br>after the use process | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Supply chain vulnerabi lities | the lack<br>of regulatory and environmental frameworks related to recovering<br>materials, and unconnected supply chain design and planning | | | | |
| **Changeable manufacturing systems** | Supply chain vulnerabi lities | repairs for extending product lifetimes, certain components with shorter lifetime will over time be in higher demand than those with longer lifetimes. | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain vulnerabi lities | e design for CSC must consider a comprehensive per-spective that combines the different types of circular movements that<br>enable product recovery | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain vulnerabi lities | new complexities emerge when organizations adopt product recovery and CSC. | | | | |

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|---|---|---|---|---|---|---|
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Supply chain vulnerabilities | complexities that arise during product recovery and the role of diverse stakeholders at a global level | | | | |
| **2019_ICCAD_ An Extended Circular Supply Chain Model Including Re** | Supply chain vulnerabilities | Table Overview | Overview | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | Regu-latory risks incorporate the vague nationwide objective (program), goal (strategy), target (project), an indicator (plan), and vision (policy), which are the challenges of appropriate policy formulation and gov-ernment authority allocation | Overview | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | a lack of specific conditions for properly managing sub-suppliers | | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | based on frequent manual operations; there are significant difficulties in implementing a disassembly process that is safe and reliable that make this process quite expensive compared to the potential profits it creates. | | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | 'Lack of sufficient law implementation in CSC' | | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | rules and laws for CSC adoption are not well structured. In the absence of proper tools, it difficult to assess the efficacy of these regulations. | | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | lack of research and adequate attention on this issue make the CE framework weak, and consequently, CSC also remains in a vulnerable position | | | | |
| **Admitting risks towards circular economy** | Supply chain vulnerabilities | lack of accurate information regarding the tracing of materials through reprocessing is another issue limiting CSC adoption | | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Tools / Mechanisms | integration of industrial ecology in the supply chain helps with the adoption of CSC practices to achieve sustainable develop-ment | | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Tools / Mechanisms | adoption of a well-designed reverse logistics network influences CSC operational activities and performance. | | | | |
| **"Evaluation and ranking of solutions to mitigate circular suppl** | Tools / Mechanisms | advanced IT system for tracking end-of-life products (EOL) | | | | |

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| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | The resource-based view (RBV) [63–65] contributes to a better understanding of how the company as a whole works, as well as the resources and competencies fundamental for the company to redesign its operations in response to a change in competitive conditions. | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | Companies need certain dynamic capabilities and organizational routines to deal with the increased complexity of managing innovation from a sustainable perspective” | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | Industrial ecology (IE) c | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | e IE enables understanding how the industrial system works, how it is regulated, and what interactions it presents, to restructure it in order to make it similar to natural systems” | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | Strategic networks are stable inter-organizational links which are of importance to the company and which express these links through various forms, such as strategic alliances or long-term buyer-supplier partnerships | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | a circular business model could provide managerial practices for design and implementation of supply chain | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | product service systems (PSS) business models have the potential to trigger and enhance the circularity features of supply chains, which can be complemented by other tools, such as the sustainable value analysis tool, to assist practitioners | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | Smart enabling technologies in a circular framework can help both to facilitate efficient monitoring, collection, separation and transport of waste for value recovery and proper disposal, as in recent years, to data acquisition and communication technologies | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | new technological tools now allow predictive analysis and the exchange of information with stakeholders | | | | |
| **Main_Dimensions_in_the_Building** | Tools / Mechanisms | computer tools based on collaborative platforms building waste analytics to report in the supply chains is important to ensure that the value of materials is sustained within the economic circle | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | The use of these technologies can be beneficial to collect, store, and facilitate expansive data available along the entire SC in order to correct errors committed by human workers, track product quantity and storage locations, and reduce product damage and loss | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | “advanced and digital manufacturing technologies are able to unlock the circularity of resources within SCs”, | | | | |

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| **Closed loop supply chains 4.0** | Tools / Mechanisms | Using data capturing, sensors and monitoring and control systems, companies can reduce risks related to the demand for final products (1). | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | These methods and strategies can use both data collected in real time and historical data in order to keep demand plans and prices always updated. The objective is to better satisfy the demand of the customers and increase the profits and image of the companies that adopt them | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | A cloud database was developed to track each product and each component of the product over their lifetimes with the objective of making the end of life treatment of these products easier, better satisfying the consumers' demand, and reducing the disposal of electric and electronic equipment. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | possibility of running cloud computing applications in almost all devices, like computers, laptops, and smartphones, together with the opportunity to increase (or decrease) the cloud computing resources based on necessity makes this technology ideal for managing the complexity of a CLSC. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | CPSs can allow companies to reduce risks related to the demand for a product, new (1)8 or used (2), since the machines and systems are connected together via the Internet. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | AM enables companies to mitigate risks related to the demand for final products (1).11 With this technology, companies can produce a product that is different from the last one each time. Using AM, com-panies can easily create a prototype of a product that can also be used in real applications, thus reducing the time to market and increasing customer satisfaction. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | The possibility of guaranteeing the provenance and traceability of products in a SC using blockchain technology is examined through qualitative case studies and theoretical works (Kim and Laskowski, 2018; Sylim et al., 2018; Montecchi et al., 2019; Rogerson and Parry, 2020; Bumblauskas et al., 2020). This could provide reliable information to companies and consumers about the origin and all the movements of different products in the SC. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | A blockchain can reduce risks related to the demand for products, new (1)13 or used (2). | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | AI can reduce risks related to the demand for products, new (1)15 or used (2). Algorithms can be created to analyse data and to create fore-casts of demand for both new products and those likely to be returned. | | | | |
| **Closed loop supply chains 4.0** | Tools / Mechanisms | AI can mitigate risks related to the reprocessing of used products (4),16 suppliers (6), and manufacturing (7) since it can be used to determine the quality of products, both new and used. The ability to determine quality not only improves the possibility of producing higher quality products but also enables the company to select the best sup-pliers each time. | | | | |

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| **Closed loop supply chains 4.0** | Tools / Mechanisms | Case studies reveal that collaborative robots can help in the execution of manufacturing and remanufacturing activities; however, it is important to pay attention to the safety of the human workers working in the same space with the robots. | | | | |
| **What servicizing demands of a company** | Tools / Mechanisms | Supply of used prod-ucts needs to be coordinated with the manufacturing decisions. As such, systems to evaluate the condition of the used product need to be developed; this may be facilitated by decisions made in the product development stage, for example, via sensors embedded in the product | | | | |
| **Strategic opportunities for produc** | Tools / Mechanisms | For PAR the economies of scale advantages are degraded by increased variety and a reliance on flexibility, but instead new economies of scope emerge in terms of the wider product range than can be accommodated in a single facility. Thus this increased product range supports opportunities for either continuing a centralised approach, or instead turning to decentralised remanufacturing. As noted in Section 3.5 centralisation strategies minimise the number of facilities to be maintained, and for PAR could be feasible by virtue of the breadth of products remanufactured. | | | | |
| **Strategic opportunities for produc** | Tools / Mechanisms | The collaborations enabled by PAR also supports redistribution of power within the supply chain | | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Tools / Mechanisms | twelve key enabling technologies (Internet of Things, Artificial Intelligence, Big Data, Autonomous Robots, Cybersecurity etc.) with 4 supply chain approaches (Lean, Agile, Resilience and Green) | | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Tools / Mechanisms | . Online bidding process | | | | |
| **Introducing an application of an industry 4.0 solution for circ** | Tools / Mechanisms | Blockchain application for wastes tracking in circular economy scenario | | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Tools / Mechanisms | Industry 4.0 enables the production system to make more intelligent decisions and enhances the collaborations across the supply chain | | | | |
| **Integrating circular economy and Industry 4 0 for sustainables** | Tools / Mechanisms | barcodes, radio frequency identification (RFID) and WSN in logistics and operations systems, essen-tially enhance real-time information collection for supply chain monitoring and improvement | | | | |
| **Identification_of_critical_fac** | Tools / Mechanisms | Jayaraman and Luo (2007) developed a model that determines the location for remanufacturing facilities and optimal quantities for remanufactured products and cores | | | | |

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| **Examining the role of dynamic remanufacturing capability on sup** | Tools / Mechanisms | Evidence has been provided that remanufacturing firms may reduce quality issues and minimize associated risks by strictly following standard operating procedures and quality assurance plans at every step of remanufacturing operations | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Tools / Mechanisms | DRC is the ability to create visibility and capacity through the reconfiguration of internal and external resources to build robustness and resilience in the supply chain network | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Tools / Mechanisms | Dynamic remanufacturing capabilities will enable a firm to return back to normal operations after occurrence of disruption events and will still be capable to meet customer demands. | | | | |
| **Examining the role of dynamic remanufacturing capability on sup** | Tools / Mechanisms | dealing with a volatile, uncertain, complex and ambiguous business environment, it is imperative to leverage flexibility and increase capabilities to execute expected sales orders on time. | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Tools / Mechanisms | | | | | |
| **Closed loop supply chains of reusable articles a typology groun** | Tools / Mechanisms | . Item-level tracking technologies, such as bar codes and RFID, can mitigate this lack of visibility | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | reverse<br>logistics as a critical component of the CSC | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | technologies provide more efficient solutions and help overcome the<br>problems of existing technologies. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | innovative techniques are used to meet the CSC requirements related<br>to supply flexibility, the innovation of methods and processes to<br>increase productivity, cleaner production, and sustainable consump-tion. | | | | |
| **Building a data-driven circular supply chain** | Tools / Mechanisms | artificial<br>intelligence (AI), machine learning (ML), blockchain technology, and<br>internet-of-things technology, conveniently enable data | | | | |

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| **hierarchical struc** | | management, thereby facilitating product collection for recycling | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | f I4.0 technologies in<br>optimizing resource utilization and controlling product life cycle<br>phases | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | Information technology has recently become<br>the center of RSC practices, enhancing the flexibility and effective-ness of operating processes | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | life cycle sustainability<br>assessment (LCSA) is still crucial for executing CSCs. | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | Digital progress, such as sensor network development and I4.0<br>execution, is utilized for CSC visibility | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | However, the<br>need for broad data compilation and resources, high computational<br>demands, and AI model ambiguity still present challenges to the AI<br>approach | | | | |
| **Building a data-driven circular supply chain hierarchical struc** | Tools / Mechanisms | The implementation of the ML technique in CSC has also pres-ented multiple challenges related to nontechnical barriers. The non-technical difficulties come from a shortage of analytical-skill human<br>resources, a lack of specific understanding of regulations, high<br>expense in proceeding with ML, and less stakeholder involvement. | | | | |
| **Identification and analysis of circular supply chain management** | Tools / Mechanisms | Performance indicators on 3R | | | | |
| **Identification and analysis of circular supply chain management** | Tools / Mechanisms | Training programs for SC members are also an important practice; using virtual education | | | | |
| **Changeable manufacturing systems** | Tools / Mechanisms | need for scalability in the virgin component manufacturing processes | | | | |

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| **Circular economy practices among Chinese manufacturers varying** | Tools / Mechanisms | List of measurement items for evaluating environmental-oriented supply chain cooperation. | | | | |
| **Circular economy practices among Chinese manufacturers varying** | Tools / Mechanisms | Appendix B<br>List of measurement items for evaluating circular economy practices. | | | | |
| **An investigation into circular economy practices in the traditi** | Tools / Mechanisms | green  purchasing (GP) on the upstream side | | | | |
| **An investigation into circular economy practices in the traditi** | Tools / Mechanisms | environmentally-conscious customer cooperation (CC) on the downstream  side | | | | |
| **An investigation into circular economy practices in the traditi** | Tools / Mechanisms | : internal environmental man-agement (IEM), eco-design (ECO), and corporate asset man-agement and recovery (CAMR) or investment recovery (IR). | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Tools / Mechanisms | shared responsi-bility system | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Tools / Mechanisms | model that analyses the impact of non-availability of parts and<br>cost of recovery for the supplier after a sudden, unpredictable disrup-tion | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Tools / Mechanisms | MILP model to per-form optimal decisions on selection of transportation mode while ana-lyzing the impact of supply chain uncertainties on sustainable supply<br>chain (SSC) design | | | | |
| **Sustainable Development - 2022 - Agrawal - Impediments of produ** | Tools / Mechanisms | use of emerging technology for<br>improving coordination | | | | |
| **Healthcare industry circular supply chain collaboration in Viet** | Tools / Mechanisms | resource-based view | | | | |

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| **Bridging economy and ecology** | Tools / Mechanisms | development of streamlined production processes which are designed to serve as an input for adequate return and recycling processes | | | | |
| **Bridging economy and ecology** | Tools / Mechanisms | product remanufacturing processes | | | | |
| **Bridging economy and ecology** | Tools / Mechanisms | . The assimilation concept may serve as a buffering capacity to achieve an optimal distribution of waste and recycling processes for a true closed-loop supply chain | | | | |
| **Admitting risks towards circular economy** | Tools / Mechanisms | integrate systemic thinking with technological improvements and conventions at all stages of the supply chain to increase the circularity of resources | | | | |
| **Admitting risks towards circular economy** | Tools / Mechanisms | technologies to make them easier and safe without increasing cost | | | | |

## C – Unstructured Interview Summary

Objective:

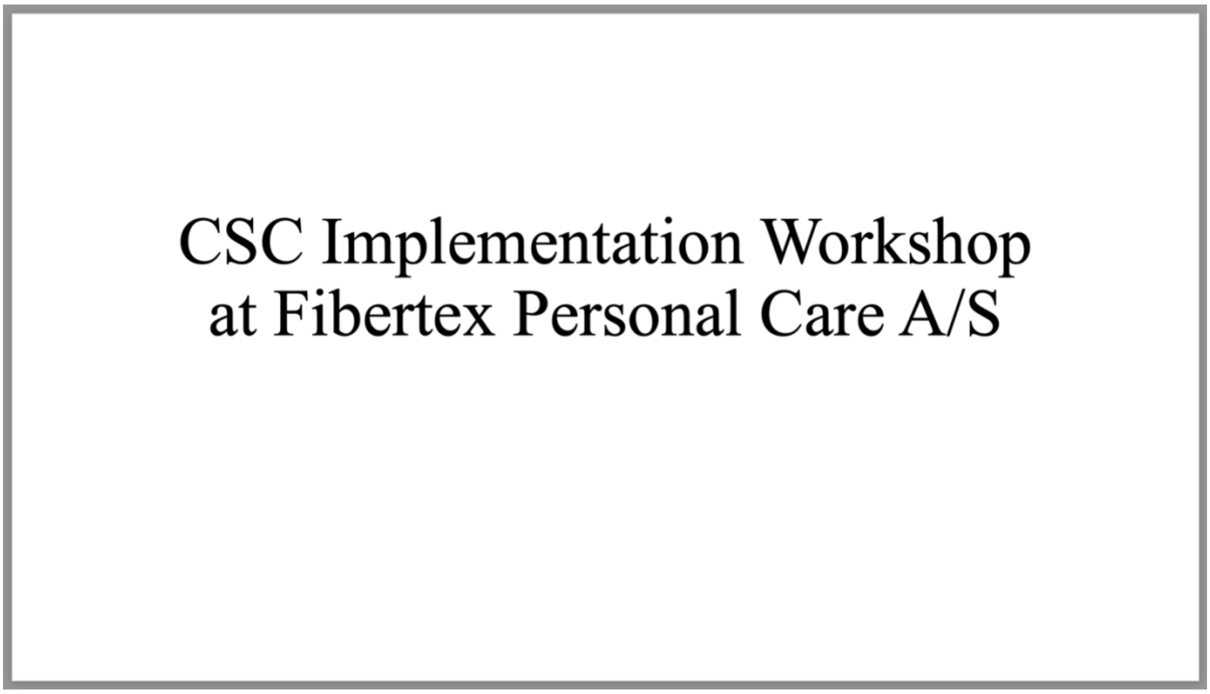
1. Get to know supply chain director and company as well as value chain
2. Identify their motivation and intentions towards sustainability
3. Evaluate their circularity
4. Identify barrier towards more circularity

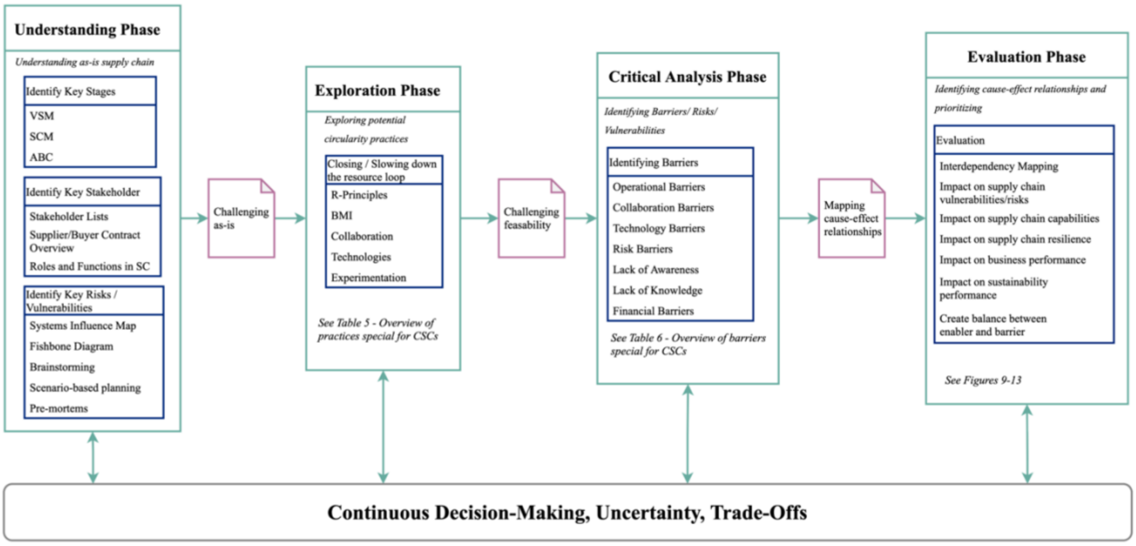
Findings relative to objectives

1. Get to know supply chain director and company as well as value chain
    a. Supply chain director responsible for sourcing, in the team for 7 years
    b. Company is producing non-woven based on plastic granulates for the hygiene and personal care industry
    c. Buying plastic granulates → melting → producing non-woven rolls → selling to customers
2. Identify their motivation and intentions towards sustainability
    a. Company is known as advanced and innovative in terms of technology
    b. Motivation is mainly customer and competition driven
3. Evaluate their circularity
    a. No usage of wooden pallets for storing of rolls
    b. Internal waste is reused through remelting or through third party remanufacturer
    c. Participation in industry wide conferences focusing on sustainability in plastics
4. Identify barrier towards more circularity
    a. New practices are difficult to implement since they involve external parties and changes in their value chain

b. High quality standards in industry for personal care, which limits possibilities and creates complexity
c. High competition, therefore, focus on low prices and not more sustainability
d. No unified objectives in industry and now unified problem-solving approach

## D - Fibertex Personal Care First Iteration Demonstration Workshop






## Understanding Phase: Fibertex Personal Care Supply Chain

- Can you describe the key stages and main stakeholders of Fibertex Personal Care's supply chain?
- What are some of the challenges or risks that you face in managing the supply chain?
- How does Fibertex Personal Care ensure transparency and visibility across the supply chain?

## Exploration Phase: Identifying New Practices for Resilient Circularity in the Fibertex Personal Care Supply Chain

- How can we close the loop of one of our raw materials/ resources/ components/ products?
- How can we collect these raw materials/ resources/ components/ products after use?
- How can we identify if R-principles should be used or how to manage the waste?
- How can we ensure visibility of the raw materials/ resources/ components/ products?
- What internal changes can we make to optimize the above?
    - Product design?
    - Production layout and capabilities?
- Who do we need to involve to enable the above?
    - How do we involve them?
    - When do we involve them?
- What technology can help us?
    - Can we use existing data to track and collaborate?
    - Do we need to invest in new technology?
- How can we create an incentive to implement CSC?
    - Do we have the right performance measurements in place?
    - What are better performance measurements?

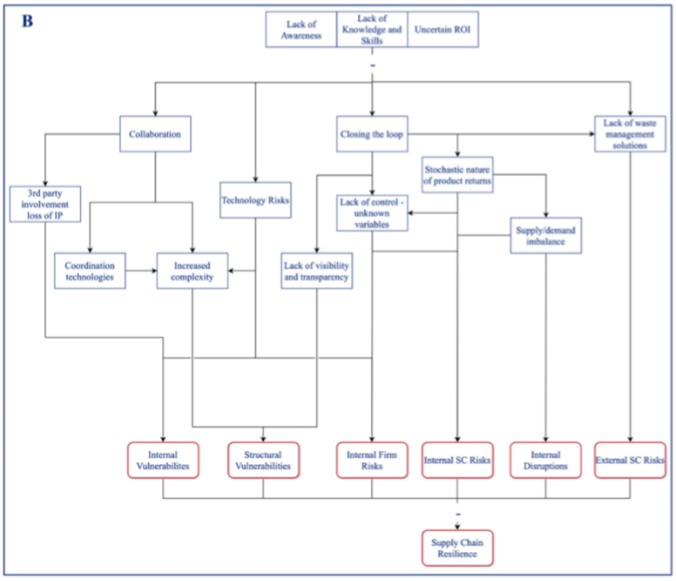
## Critical Analysis Phase: Identifying Barriers to Circularity in the Fibertex Personal Care Supply Chain

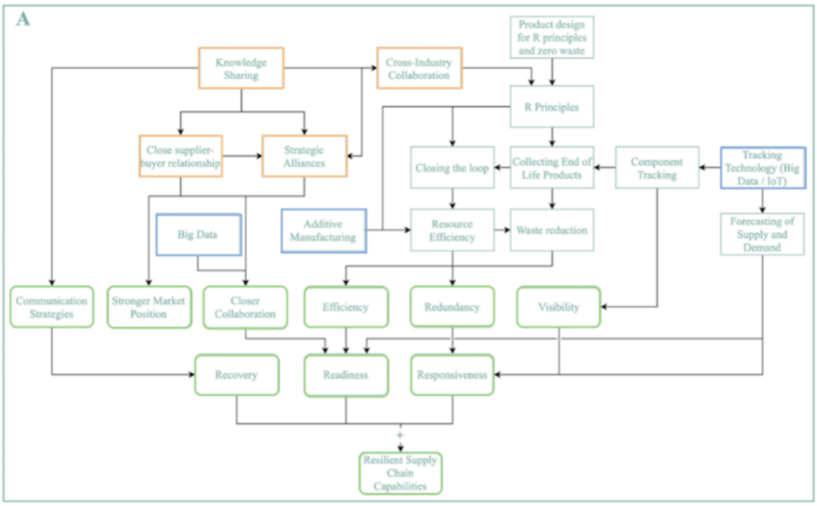
- What do you see as the biggest barriers (overview next slide) to achieving circularity in the Fibertex Personal Care supply chain?
- Are there any innovative solutions or approaches that you are considering to overcome these barriers?
- Are you collaborating with partners to overcome these barriers?

| Practice / Category | Barrier |
|---|---|
| Closing the loop | Potentially requires Business Model Innovation |
| | Lack of visibility and transparency |
| | Lack of control due to many unknown variables (product return number and quality) |
| | Stochastic nature of product returns leads to poor forecasting of supply and demand and inefficient use of resources |
| | Supply is derived from returns not from market demand |
| | Uncertain required manufacturing capacity since quality of returned products is unknown |
| | Lack of waste management solutions |
| Sustainable performance focus | Dynamic characteristics of sustainability create complexity and vulnerabilities |
| Collaboration | Increased number of stakeholders creates complexity and requires innovative coordination techniques for synchronization |
| | Third party involvement can risk intellectual property and requires knowledge sharing, might lead to loss of competitiveness |
| | Loyalty towards supplier is questioned |
| Technology | Data and Cybersecurity risks due to data sharing |
| | Different digital maturity levels in companies of different geographic regions → limits data sharing and tracking of components |
| | Lack of data and unreliable systems |
| | Inefficient use of technologies creates new risks and uncertainties |
| Lack of Awareness (Barrier to multiple practices) | Lack of prioritization relative to other issues |
| | Lack of top management commitment |
| | Lack of external awareness (customers, suppliers, government, other stakeholders) → can lead to misconceptions and conflicts |
| | Lack of regulations |
| | About 35% unaware of CE |
| Lack of Knowledge and Skills (Barrier to multiple practices) | "Closing the loop practices" need specific skills and experienced workforce |
| | Collaboration requires specific coordination skills |
| | Lack of technical skills to deal with complexity of I4.0 technology |
| | Lack of knowledge on risks management in CSCs |
| Financial | Uncertain ROI<br>High investment in technology<br>High investment in equipment<br>Investment in training<br>Investment in green purchasing |

## Evaluation Phase: Identifying cause-effect relationships and prioritizing

- Drawing flow charts for the selected practices and identified barriers based on the Figures on the next slides
- Create objectives and prioritize them


B
Lack of Awareness
Lack of Knowledge and Skills
Uncertain ROI
Collaboration
Closing the loop
Lack of waste management solutions
3rd party involvement loss of IP
Technology Risks
Stochastic nature of product returns
Lack of control - unknown variables
Supply/demand imbalance
Coordination technologies
Increased complexity
Lack of visibility and transparency
Internal Vulnerabilites
Structural Vulnerabilities
Internal Firm Risks
Internal SC Risks
Internal Disruptions
External SC Risks
Supply Chain Resilience


A
Product design for R principles and zero waste
Knowledge Sharing
Cross-Industry Collaboration
R Principles
Close supplier-buyer relationship
Strategic Alliances
Closing the loop
Collecting End of Life Products
Component Tracking
Tracking Technology (Big Data / IoT)
Big Data
Additive Manufacturing
Resource Efficiency
Waste reduction
Forecasting of Supply and Demand
Communication Strategies
Stronger Market Position
Closer Collaboration
Efficiency
Redundancy
Visibility
Recovery
Readiness
Responsiveness
Resilient Supply Chain Capabilities