H2020 MSCA-ITN-2018

ReTraCE Project

Realising the **Tra**nsition towards the **C**ircular **E**conomy

D1.2

Circular supply chains and related risk/uncertainty management practices

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

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Table of Contents

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List of acronyms

CE – Circular economy

CLSC – Closed-loop supply chain

CSC – Circular supply chain

DSS – Decision support system

GDP – Gross domestic product

ICT – Information and communication technology

IoT – Internet of Things

IT/IS – Information Technology/Information System

MCPs – Materials, components, and products

OLSC – Open-loop supply chain

OSCM – Operations and supply chain management

RL – Reverse logistics

SC – Supply chain

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1. General purpose and objectives of the report

Over the past three decades, the take-make-use-dispose economy has put pressure on ecosystems and contributed to climate change, the scarcity of raw materials, the loss of biodiversity, and excessive waste landfilling and incineration, amongst other adverse environmental effects. Linear production systems are undoubtedly unsustainable, to the detriment of natural resources and future human generations (World Economic Forum, 2020).

In the face of these challenges, the circular economy (CE) aims to optimise resource usage and extend the lifespan of products by simultaneously minimising energy and water consumption and reducing greenhouse gas emissions, plastics, and organic waste (Gonzalez et al., 2019). Bocken et al. (2016) categorise the characteristics of the Circular Economy by defining it as design and business model strategies that are slowing, closing, and narrowing resource loops. The CE paradigm establishes that materials, components, and products (MCPs) are restored in technical cycles while organic waste is regenerated via biological cycles, thereby rebuilding natural capital stocks and creating prolonged cyclic flows (Howard et al., 2019).

Recent research has highlighted that businesses are increasingly interested in introducing CE into their organisations and supply chains (SCs), whereby MCPs are designed and restored to continuously add, recreate, and preserve value at all times (Esposito et al., 2018). However, CE-inspired solutions require substantial changes in SC operations, including the redesign of products and services, technological changes, and manufacturers' willingness to incorporate CE into the organisation's culture (Bressanelli et al., 2018; Genovese et al., 2017; Turken et al., 2020). It becomes evident that to manage their increased complexity, circular supply chains (CSCs) require robust decision-making strategies. Thus, executives should be aware that if they want to transition towards CSCs, profit maximisation and cost minimisation are no longer the sole objectives of management (Ozkan-Ozen et al., 2020).

The ReTraCE Project is geared towards the successful implementation of the CE in Europe, where practitioners, academics, policymakers, and many other stakeholders will benefit from this project. Innovative discussions, methodologies, and evaluations will be developed by employing a holistic approach to tackling CE-related issues and addressing environmental, social, and economic objectives, especially in the context of CSCs. A comprehensive analysis of CSCs and related risk/uncertainty management practices represents a critical gap which has been investigated by the ReTraCE Work Package 1 (WP1) titled 'Circular Production and Consumption Systems.' The adoption of circular solutions in SCs is prone to several risks and uncertainties, which can disrupt the SC itself. Analysing

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these issues is becoming a highly focused and increasingly adopted activity among companies hoping to ensure a smooth transition to CE (Ethirajan et al., 2020). Operations and supply chain management (OSCM) research is thus needed to analyse the challenges entailed in CSCs with regard to unveiling the degree of SC uncertainty (Lahane et al., 2020; Turken et al., 2020). To address this gap, this report adopts Simangunsong et al.'s (2012) work on SC uncertainty management to analyse 82 articles retrieved from a systematic review process; the term uncertainty is henceforth used. The purpose of this report is to systematically review SC uncertainty and the measures adopted to address it in the context of CSCs. Appendix A provides further information regarding the systematic review process and an overview of the analytical techniques used in this report.

Prior contributions addressing uncertainty are generally concentrated in the realm of closed-loop supply chains (CLSCs) and reverse logistics (RL), but they do not contemplate the opportunity to comprehend SCs in CE terms (Zhen et al., 2019). This report sheds light on this gap by developing a framework which considers the interplay between uncertainties and uncertainty management strategies in the CE landscape. This conceptualisation offers additional evidence about the effects of strategies on an organisation's competitive position (Simangunsong et al., 2012). Additionally, this report aims to guide academics to extend the research on CSC and unveil further implementation challenges, as well as to offer practitioners and policymakers a long-term outlook regarding the operationalisation of CE.

The remainder of this report is organised as follows. In Section 2, an overview of the CE paradigm and operationalisation of CSCs is presented. Section 3 then discusses the importance of adopting an uncertainty management approach to analysing CSCs. Section 4 presents a framework for uncertainty management in CSCs. The key contributions of this report and future directions are provided in Section 5.

2. The CE paradigm and the operationalisation of CSCs

In this section, introductory definitions at the foundation of CE are going to be provided, along with a characterisation of CSCs and challenges in their implementation.

2.1. The origins of CE and its applications in businesses

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The CE traces back to a variety of existing traditions and references, including cradle-to-cradle design, eco-efficiency, industrial ecology, and industrial symbiosis (Korhonen et al., 2018). However, the CE has only recently begun to attract increased business interest. Notable examples of CE implementation can be seen in different industries and sectors, including the following:

- In the automotive industry, Renault recovers materials from end-of-life vehicles and transforms them to supply the production of new vehicles, thereby retaining value, saving on energy, and reducing waste (Groupe Renault, 2020).

- In healthcare, Philips Diamond Select solutions give a second life to pre-owned components, such as magnetic resonance imaging systems. This business model allows for magnet reuse and provides a system which has the same serviceability as new systems (Philips Healthcare, 2014).

- Cisco recently launched a set of technology-related products that use post-consumer recycled plastic resin. This process closes the plastic loop, and by ensuring a stable supply of plastic and reducing the demand for new resources, it has both financial and environmental benefits (Cisco, 2020).

- In the food industry, Danone has adopted a packaging policy to co-build a CE of food packaging by sourcing sustainable materials and creating a second life for all plastics. As of 2017, 86% of Danone's total packaging (77% of which is plastic) is reusable, recyclable, or compostable (Danone, 2018).

- Luxury brand Stella McCartney has incorporated restorative and regenerative materials into its fashion products. For example, the company's handbags are lined with fabric made from recycled water bottles, thus enhancing economic benefits for the company and reducing the consumption of virgin materials (Stella McCartney, 2020).

- In the construction sector, Strukton has developed a mobile concrete recovery plant called Circuton, which separates demolished concrete into gravel, sand, and cement. These materials can then be reused to produce new concrete and consequently close the concrete chain (Strukton, 2020).

In the face of climate change and other societal challenges, CE aims to integrate economic, environmental, and social sustainability into production and consumption systems. Adopting CE

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principles means creating an economy that (a) is restorative and regenerative by design, (b) preserves ecosystems and increases their return across time, (c) creates financial advantages, and (d) captures more value from the existing infrastructure and products (Ellen MacArthur Foundation et al., 2015). According to Geissdoerfer et al. (2017), economic actors who implement CE practices can directly benefit from these; the environment is also seen to benefit through less resource depletion and environmental pollution, and society benefits from the environmental improvements and opportunities such as localised value chains and fair taxation (Geissdoerfer et al., 2017).

The European Commission (2020) estimates that the CE will have net positive benefits in terms of gross domestic product (GDP) growth and job creation because applying CE measures can increase Europe's GDP by 0.5% by 2030 and create approximately 700,000 new jobs. For European businesses in the mobile phone value chain, 'opportunities may arise from increased recycling and recovery of materials, and professional repairs and refurbishment' (Rizos et al., 2019, p. 46). Repair networks can boost employment rates and increase business activity in Europe. In this regard, Rizos et al. (2019) also noted that recovering materials from recycled mobile phones can provide opportunities to make secondary raw materials available on the market while their value in the European economy is retained. They moreover estimated that extending the lifespan of mobile phones by one year—from 21.6 months to 33.6 months—can save 20.3 million tonnes of carbon dioxide over 10 years; this is equivalent to 29% of the emissions in the baseline scenario.

A recent survey by Gartner (2020) indicated that 70% of SC leaders plan to invest in the adoption of CE-inspired practices in 2020–2021. However, academic efforts to understand the implications of CE for OSCM have only been made recently. The COVID-19 crisis has highlighted the fragility of many global SCs that faced supply shortages, such as the availability of medical equipment. In this scenario, CE can provide SC managers with feasible solutions: design and product policy factors, such as reusability, as well as the potential for local remanufacturing, which can offer considerable opportunities for resilience (stock availability) and competitiveness (Ellen MacArthur Foundation, 2020). Therefore, the integration of CE into SCs can be potentially viable for managing the supply risks of critical materials. The following subsection provides a brief discussion of the emergence of CSCs.

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2.2. Defining CSCs

The Ellen MacArthur Foundation (2015), a world-leading CE advocate amongst businesspeople, academics, and policymakers, proposes three principles that can be implemented by companies to guide CE cycles: (1) preserve and enhance natural capital by maintaining an equilibrium in the usage of finite and renewable resources, (2) optimise resource yields by circulating MCPs over time, and (3) foster system effectiveness by reducing negative externalities. These principles are integrated into six business actions, which constitute the ReSOLVE model:

- *Regenerate*. Production systems need to shift to renewable resources. Biological flows are enabled so that biological nutrients return to the biosphere. For example, organic waste can generate biogas and energy for other companies.

- *Share*. From the perspective of the sharing economy, products are shared among users and reused many times. The lifespan of products is prolonged through maintenance, repair, and design for durability.

- *Optimise*. Companies are required to use technologies, such as big data, automation, and remote sensing, to increase product performance and remove waste in the production processes.

- *Loop*. MCPs are remanufactured and recycled. For renewable materials, this means anaerobic digestion and extracting bio-chemicals from organic waste.

- *Virtualise*. Companies deliver utility virtually via dematerialised products, such as e-books, online shopping, and virtual offices.

- *Exchange*. Non-renewable materials are replaced with advanced and renewable materials. Moreover, new technologies, such as 3D printing, are used.

While the ReSOLVE model encourages CE implementation at the business level, an integrated SC perspective is needed to optimise resource conservation in cyclic loops (Sehnem et al., 2019). Notably, CSCs are a novel approach that allows managers to implement circular thinking into SC operations. Batista et al. (2018, p. 446) defined CSCs as follows: 'The coordinated forward and reverse supply chains via purposeful business ecosystem integration for value creation from products/services, by-products and useful waste flows through prolonged life cycles that improve the economic, social and environmental sustainability of organisations.' This definition suggests that a CSC entails the

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integration of the forward SC with the reverse SC, supporting the implementation of material recovery processes. Figure 1 illustrates a CSC archetype.

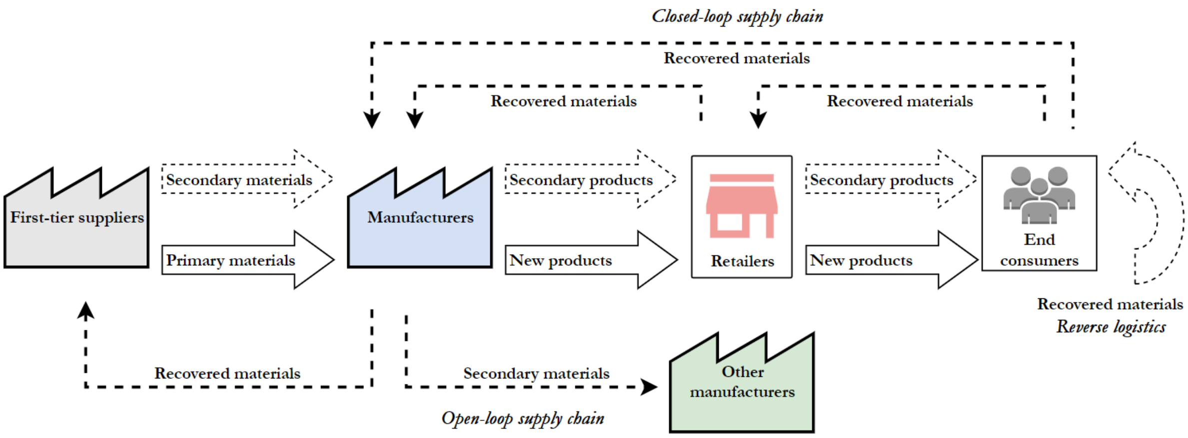

Figure 1. A CSC archetype, adapted from Batista et al. (2018, p. 447)

In Figure 1, the primary materials are used in the core production processes, and the secondary materials are used products, components, by-products, and recovered waste that can be employed in restorative processes to produce repaired, remanufactured, or recycled products (Batista et al., 2018). The recovered materials are the returned products, components, by-products, and recovered waste that can be used as input in different production processes (Batista et al., 2018). Moreover, the CLSC integrates the management of the entire life cycle of MCPs with dynamic value retention over time (Guide & Van Wassenhove, 2009). The open-loop supply chain (OLSC) also contributes to partially closing the loop of MCPs (Miemczyk et al., 2016). In OLSCs, 'the original company loses business control of its components after-sale, yet the component is still "looped" back to an independent remanufacturer for resale' (Kalverkamp & Young, 2019, p. 580). At the core of a CSC, RL is a crucial activity concerned with the collection of returned MCPs, which are reintroduced into the SC for value recovery (Bai & Sarkis, 2013).

Although CSCs provide managers with numerous possibilities to keep MCPs circulating over time, the redesign of SCs from linear to circular entails operational and decision-making challenges (Gonzalez et al., 2019). These issues are discussed in the next subsection.

2.3. Challenges in CSCs

While a traditional SC is likely to face demand uncertainty from its customers, a CSC goes beyond the delivery of products to the final customer. Thus, executives would be concerned not only with demand

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uncertainty but also with the fact that customers' returns are unknown and hence cause delays to take-back operations. He (2017) reinforced this observation by stating that the supply risk in a CLSC refers to the uncertainty in the quantity and quality of the recycled products; additional risks can be identified in the cost of products to be recycled and in their environmental impacts.

Moreover, Bressanelli et al. (2018) identified eight critical challenges that can hamper the redesign of SCs for the CE: (1) market cannibalisation (CE-oriented products can threaten future product sales); (2) the impact of fashion changes; challenges regarding (3) the misalignment between taxation and policy instruments, (4) metrics, and (5) lack of standards; (6) culture (managers can be reluctant to implement CE principles); (7) data privacy and security issues; and (8) consumers' unwillingness to pay for CE products.

Regardless of these contributions, there are some limitations. Accordingly, no research to date has adopted an uncertainty management approach in reviewing and discussing the challenges faced in CSCs. Compared to traditional SCs, CSCs have a different configuration, which is likely to increase operational, technological, and commercial uncertainty (Turken et al., 2020). There is also a need to consider the unique dimensions of uncertainty management in circular operations, as many studies have adopted a multitude of definitions that lead to confusion between terms such as risks, uncertainties, vulnerabilities, and sources of risks (Senthil et al., 2018). Therefore, the adoption of an uncertainty management approach becomes paramount. The next section presents the main building block of this report — that is, SC uncertainty management.

3. Towards an uncertainty management approach to CSCs

In this report, uncertainty is defined as decision-making situations in the SC in which the manager is not able to make decisions due to their lack of information, knowledge, and awareness of a managerial situation. Specifically, the manager may lack information about the organisation's internal processes (e.g., inventory planning), SC dynamics (e.g., suppliers' performance), and external factors (e.g., political and macroeconomic changes). Uncertainty will likely reduce the manager's ability to predict the impact of possible control actions on SC behaviour (Van der Vorst & Beulens, 2002). Therefore, it becomes crucial for companies to adopt an SC uncertainty management approach to identify the potential sources of uncertainty and to implement appropriate actions to avoid or contain SC uncertainty (Vilko et al., 2014). This is especially relevant in the context of CSCs. As discussed, circular

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operations can cause managers to struggle with designing, managing, and controlling the flows of MCPs, thus posing greater uncertainty.

Simangunsong et al. (2012) developed a comprehensive list of 14 uncertainties and 21 uncertainty management strategies. It is worth mentioning that Simangunsong et al.'s (2012) study is employed herein as a theoretical lens because of its recognition in the OSCM field (Ben-Ammar et al., 2020; Sauer & Seuring, 2018). Consequently, it allows for a structured analysis and discussion of the management of CSCs under uncertainty as 'there is likely to be a significant degree of uncertainty surrounding many supply chain situations' (Ritchie & Brindley, 2007, p. 310).

The upcoming analysis will be conducted according to the steps shown in Figure 2: The uncertainties and uncertainty management strategies will first be identified, and then the interplay between them will be explored in CSCs.

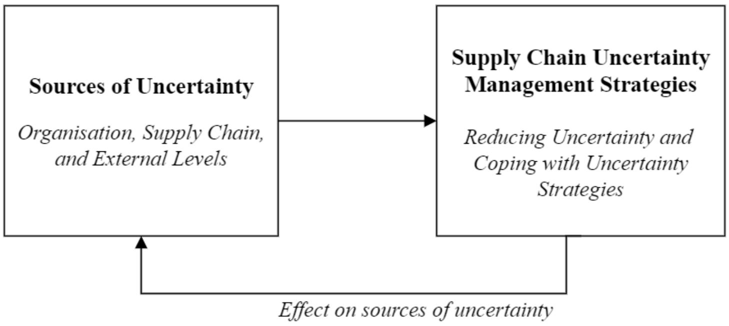

Figure 2. SC uncertainty management, adapted from Simangunsong et al. (2012, p. 4505)

The sources of uncertainty (see Table 1) can either come from the focal company (U1–U6), its SC (U7–U12), or factors that are external to both the focal company and its SC (U13–U14) (Simangunsong et al., 2012). For example, a focal company can face *U1/Product characteristics uncertainty*. Product specifications, such as colour, length, size, and packaging, can lead to uncertainty in processing times—for example, when a product is new and the specification is not yet clarified (Simangunsong et al., 2012). At the SC level, it is worth mentioning *U8/Demand amplification uncertainty*. As information moves up and down in the SC, it can be distorted. This issue is also known as the bullwhip effect, which is associated with poor material and information flow (Geary et al., 2006). As external factors, environmentally unsuitable activities and the overuse of non-renewable resources have contributed to greenhouse emissions and climate change. As a result, extreme weather conditions and global warming negatively impact SC operations in the form of *U14/Disruption/natural uncertainties*, which affect the demand and supply of goods, food, water, energy, and agricultural products (Ghadge et al., 2020).

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In Table 1, there are two groups of uncertainty management: strategies to manage uncertainty aim to *reduce* or *cope* with it. Reducing uncertainty strategies (R1–R10) enables organisations to decrease uncertainty at its source (Simangunsong et al., 2012). For example, organisations implement *R2/Product design* to address consumer preferences and strategic environmental regulations. As such, managers need to invest in product design aspects to reduce manufacturing-related issues and environmental damage (Jain & Hazra, 2020). Regarding *R10/Redesign of chain configuration or infrastructure*, managers should understand the network that connects the business to its suppliers and their suppliers, as well as to its downstream customers. Therefore, managers need to reconfigure the SC by identifying geographical locations, suppliers, relationships, and dependencies with minimum exposure to vulnerabilities (Christopher & Peck, 2004). Coping with uncertainty strategies (C1–C11) does not involve attempts to influence or alter the source of uncertainty; rather, it entails efforts to find ways to adapt and hence minimise the impact of uncertainty (Simangunsong et al., 2012). For example, *C6/Strategic stocks* are inventories at strategic locations—such as warehouses, logistic hubs, and distribution centres—that can be deployed quickly in case of SC disruptions and are often shared by multiple SC partners (Jahre, 2017). Regarding *C10/Financial risk management*, it is interesting to note that investment options such as bonds can expand financial protection in the form of catastrophe insurance coverage for climate-exposed organisations and SCs (Busch, 2020).

Table 1. SC uncertainty management, adapted from Simangunsong et al. (2012)

Constructs		Description
Sources of uncertainty (U)		
U1	Product characteristics	Product life cycle, packaging, perishability, mix, or specification
U2	Process/manufacturing	Machine breakdowns, labour problems, process reliability, etc.
U3	Control/chaos/response uncertainty	Uncertainty as a result of control systems in the SC—e.g., inappropriate assumptions in material requirements planning systems
U4	Decision complexity	Uncertainty arising because of multiple dimensions in decision-making process—e.g., multiple goals, constraints, and long-term plans
U5	Organisation structure and human behaviour	Organisation culture
U6	Information Technology/Information System (IT/IS) complexity	Technology- and information-related issues—e.g., computer viruses, technical failure, and data and privacy issues
U7	End-customer demand	Irregular purchases or irregular orders from the final recipient of the product or service
U8	Demand amplification	Amplification of demand due to the bullwhip effect
U9	Supplier	Supplier performance issues, such as quality problems and late delivery
U10	Parallel interaction	The situation in which there is interaction between different channels of the SC in the same tier

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U11	Order forecast horizon/lead-time gap	The longer the horizon, the larger the forecast errors and, hence, the greater the uncertainty in the demand forecasts
U12	Chain configuration, infrastructure, and facilities	The number of parties involved, facilities used, or location, etc.
U13	Environment	Government policy, macroeconomic and social issues, competitor behaviour, etc.
U14	Disruption/natural uncertainties	Earthquakes, tsunamis, hurricanes, etc.
Reducing uncertainty strategies (R)		
R1	Lean operations	Making a process leaner so that it becomes simpler and has less inherent uncertainty
R2	Product design	Establishing a robust design or changing the design of a product to enable a better and more sustainable manufacturing process
R3	Process performance measurement	Using process performance measures—e.g., quality measures, machine performance indicators, and key performance indicators— to detect and hence reduce uncertainty
R4	Decision support system (DSS)	The use of DSS as a problem-solving strategy for complex decision-making situations
R5	Collaboration	Proactive initiatives, whereby people play a dominant role, to reduce uncertainty within the scope of the following activities: (a) Internal integration to provide synchronised decision and control functions in the organisation (b) Vertical integration to control supply or demand uncertainties (c) Contractual agreements with suppliers or buyers to reduce uncertainty (d) Voluntary restraint of competition by alliances, joint ventures, franchising agreements, technology licensing agreements, and participation in consortia (f) Partnership programmes by working more closely with suppliers or customers—e.g., in terms of collaborative planning, forecasting, and replenishment initiatives—to reduce uncertainty regarding problems of other SC members (g) E-intermediation to facilitate information sharing so that adequate information is available for key tasks
R6	Shorter planning period	Runs a planning system in a shorter period than the forecast horizon, thereby reducing the number of last-minute changes to the schedule
R7	Decision policy and procedures	The use of better decision policy and procedures to improve SC processes
R8	Information and communication technology (ICT) system	Strategy of using application software, computer hardware, and communication technology to improve technological-related processes and hence reduce uncertainty
R9	Pricing strategy	The use of pricing strategy or other incentives to reduce demand uncertainty

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R10	Redesign of chain configuration or infrastructure	The process of redesigning the SC configuration or infrastructure—i.e., the plants, distribution centres, transportation modes, production processes and network relationships—which will be used to satisfy customer demands
Coping with uncertainty strategies (C)		
C1	Postponement	Delaying activities or processes until the latest possible point in time, making it possible to manufacture products according to known rather than forecast demand
C2	Volume/delivery flexibility	The agility to manufacture a product despite changes to volume and mix
C3	Process flexibility	The flexibility of the workforce, plant, and equipment enabling a company to cope with the uncertainty caused by frequent product changeovers on the shop floor
C4	Customer flexibility	Exploiting relationships with customers that are less sensitive to uncertainty issues and can adapt their plans
C5	Multiple suppliers	Exploiting the availability of potential suppliers and their willingness to help an organisation manage its sources of uncertainty
C6	Strategic stocks	The use of inventory to buffer against uncertainty
C7	Collaboration	Basic or limited information sharing internally within an organisation or with SC partners (suppliers and customers); strategy does not affect the source of uncertainty, in contrast to R5
C8	ICT system	The availability of a computer-based information system to provide information transparency between SC partners, enabling better and faster information flow but without reducing the source of uncertainty, in contrast to R8
C9	Lead-time management	The quoting of longer lead times for customer orders compared with expected manufacturing lead times
C10	Financial risk management	Techniques of financial risk mitigation, such as purchasing insurance (e.g., business interruption insurance) and buying and selling financial instruments (e.g., forward and futures contracts)
C11	Quantitative techniques	Employing operations research techniques—e.g., forecasting, simulation, and mathematical modelling—to reduce the impact caused by a source of uncertainty

3.1. Identifying uncertainties in CSCs

Figure 3 presents the frequency results of uncertainty constructs based on the literature that was reviewed. Refer to Appendix A for further details regarding frequency analysis.

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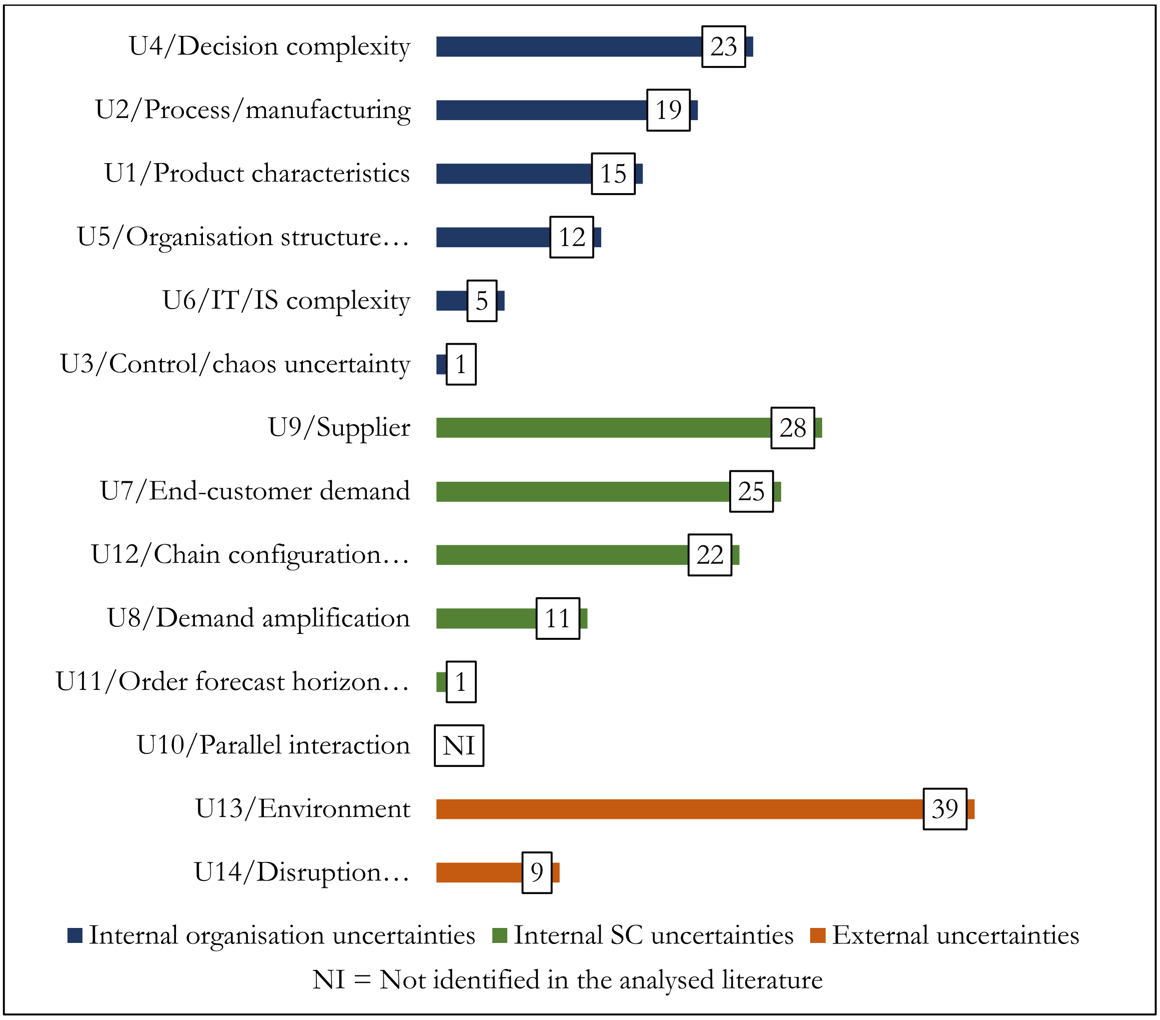

Figure 3. Frequency results of uncertainties in CSCs (number of analysed articles = 82)

The analysis of uncertainties in CSCs is divided into three subsections: 3.1.1. Internal organisation uncertainties, 3.1.2. Internal SC uncertainties, and 3.1.3. External uncertainties.

3.1.1. Internal organisation uncertainties

The most frequently discussed uncertainty was *U4/Decision complexity*, which refers to decision-making problems that can impede successful CE implementation in companies. For example, Akinade and Oyedele (2019) studied construction waste from building designs in the CE and found that in architecture, engineering, and construction companies, stakeholders usually have conflicting goals in decision-making, leading to cost and time uncertainties. This requires executives to appropriately define the firm's objectives in CE terms to reduce internal conflicts and facilitate a shared understanding of CE principles.

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Next, it was found that *U2/Process/manufacturing uncertainty* can affect circular production systems; this is mainly due to the technical difficulties that arise when dealing with recycled materials in manufacturing processes (Lapko et al., 2019) and the disassembly of returns (Bag et al., 2019). According to Veleva and Bodkin (2018), extending the SC to include remanufacturing, repairing, and refurbishing activities creates an additional level of complexity (and need for additional capacity), which can lead to negative impacts on quality, cost, and delivery times. Hence, to reduce manufacturing uncertainty, companies need to implement training activities, invest in employees' qualifications, acquire adequate technical capacity and capabilities.

Another frequently quoted uncertainty was *U1/Product characteristics*. In this regard, it is worth noting that complex product characteristics and packaging design can prevent proper reuse, recycling, and the like (Veleva & Bodkin, 2018). Thus, manufacturers should assess the benefits and impacts of using, for example, recycled components and materials for their products/packaging to reduce these issues. If not managed appropriately, additional product life cycles can increase the degree of core fallout and the need to replace parts with virgin materials, thereby increasing costs and environmental impacts (Krystofik et al., 2018).

U5/Organisation structure and human behaviour uncertainty mainly refers to managers' resistance to changing their corporate strategy towards the CE; this is often due to financial or technical limitations (Agyemang et al., 2019).

The analysis of *U6/IT/IS complexity* identified only a few contributions linking this uncertainty to the CE. Regarding the CE, Kouhizadeh et al. (2019) pinpointed transparency and security issues in SCs. In this situation, the sensitivity of the information is critical to whether it should be shared. Moreover, although original equipment manufacturers in the automotive industry have a legacy for IT infrastructure and data management, the big data integration process can be complicated, and many factors affect the corporations' final decisions (Ge & Jackson, 2014). Hence, organisations may face difficulties in integrating IT/IS systems amongst SC partners and may lack technical knowledge of the CE and the so-called Industry 4.0 technologies, such as additive manufacturing (3D printing), the Internet of Things (IoT), and cloud manufacturing (Jabbour et al., 2018).

U3/Control/chaos uncertainty was discussed solely by Kurilova-Palisaitiene et al. (2018), who argued that a non-existent, out-of-date, complex, or non-flexible material requirements planning system can disrupt remanufacturing operations.

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3.1.2. Internal SC uncertainties

The most frequently quoted uncertainty at the SC level was *U9/Supplier*. This uncertainty refers primarily to heterogeneous quality, timing, and availability of supply (waste as input or customers' returns) (Islam & Huda, 2018). Uncertainty is amplified especially in the case of commercial and municipal waste as they typically comprise waste types with different properties (e.g. plastics, metals, glass, biodegradable waste), thus requiring longer times to reach a form in which they could be recovered due to sorting or pre-treatement. Specifically, managers need to plan and control end-of-life flows, which are highly uncertain due to unpredictable consumer returns/discards and mixed properties stemming from economic cycles, varying personal income, origin (municipal or industrial), health considerations, ecological and energy efficiency features of the product, and so on (Tsiliyannis, 2016).

U7/End-customer demand also received significant attention. One key reason for such uncertainty is consumers' willingness to pay for refurbished, remanufactured, and recycled products, as they might have poor opinions of the quality and performance of these CE products (Wang & Hazen, 2016).

Another frequently mentioned uncertainty was *U12/Chain configuration, infrastructure, and facilities*. The most critical issue in redesigning SCs for the CE seems to be the dispersed location of facilities due to globalisation trends. In the CE, SC partners and customers need to be connected through an integrated RL infrastructure to close the loop of MCPs (Masi et al., 2017).

Moreover, it was observed that *U8/Demand amplification uncertainty* is attributed to the bullwhip effect. This issue occurs when companies face amplified order variability—that is, the variance of orders may be larger than that of sales, and the distortion tends to increase as one moves upstream (Lee et al., 1997). Braz et al. (2018) found that the bullwhip effect can occur in both forward and reverse flows in SCs, and its underlying causes are demand and information distortion. However, the authors noted that the quality of the returns is different and adds more complexity to CLSCs, thus causing higher variability and the bullwhip effect. From a forward flow perspective, amplifications of demand are responsible for a considerable generation of waste.

U11/Order forecast horizon/lead-time gap was evidenced in only one article. Dominguez et al. (2020) argued that CLSCs with variable lead times might not experience a substantial negative impact on their

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performance. However, the authors observed that in some cases, information transparency is paramount to forecasting further ahead.

U10/Parallel interaction was not identified in the analysed literature, thereby pointing out a gap that should be investigated by future empirical research in the CE context.

3.1.3. External uncertainties

U13/Environment was the most frequently discussed uncertainty in the CE context, often referring to fragmented or non-existent institutional frameworks (De Jesus & Mendonça, 2018) and external factors that challenge the transition towards the CE—for example, legal barriers to market exit or entry (Veleva & Bodkin, 2018). Moreover, Ren et al. (2020) found that carbon price uncertainty might affect the establishment of the SC, costs, emissions, choices of facility locations, and product flows.

Only a few contributions discussed *U14/Disruption/natural uncertainty*. Yazdani et al. (2019) addressed the impacts of hurricanes, thunderstorms, and floods vis-à-vis support for agricultural SCs in the CE to prevent collapses in food production and supply. Agricultural businesses can use the proposed model to identify risk drivers and suitable zones in order to forecast the highest impacts of flooding risks. According to Bleischwitz (2020), it becomes urgent to incorporate adaptation and resilience within planning, especially for the built environment. Planners, investors, policymakers, and other key stakeholders have no choice but to face risks and prepare for disruptions related to climate change. In this respect, CE is vital to bolstering innovative business solutions, reducing the use of environmentally intensive materials, and lowering greenhouse gas emissions.

3.2. Managing uncertainties in CSCs

Figure 4 presents the frequency of uncertainty management strategies in the context of the reviewed CSCs literature.

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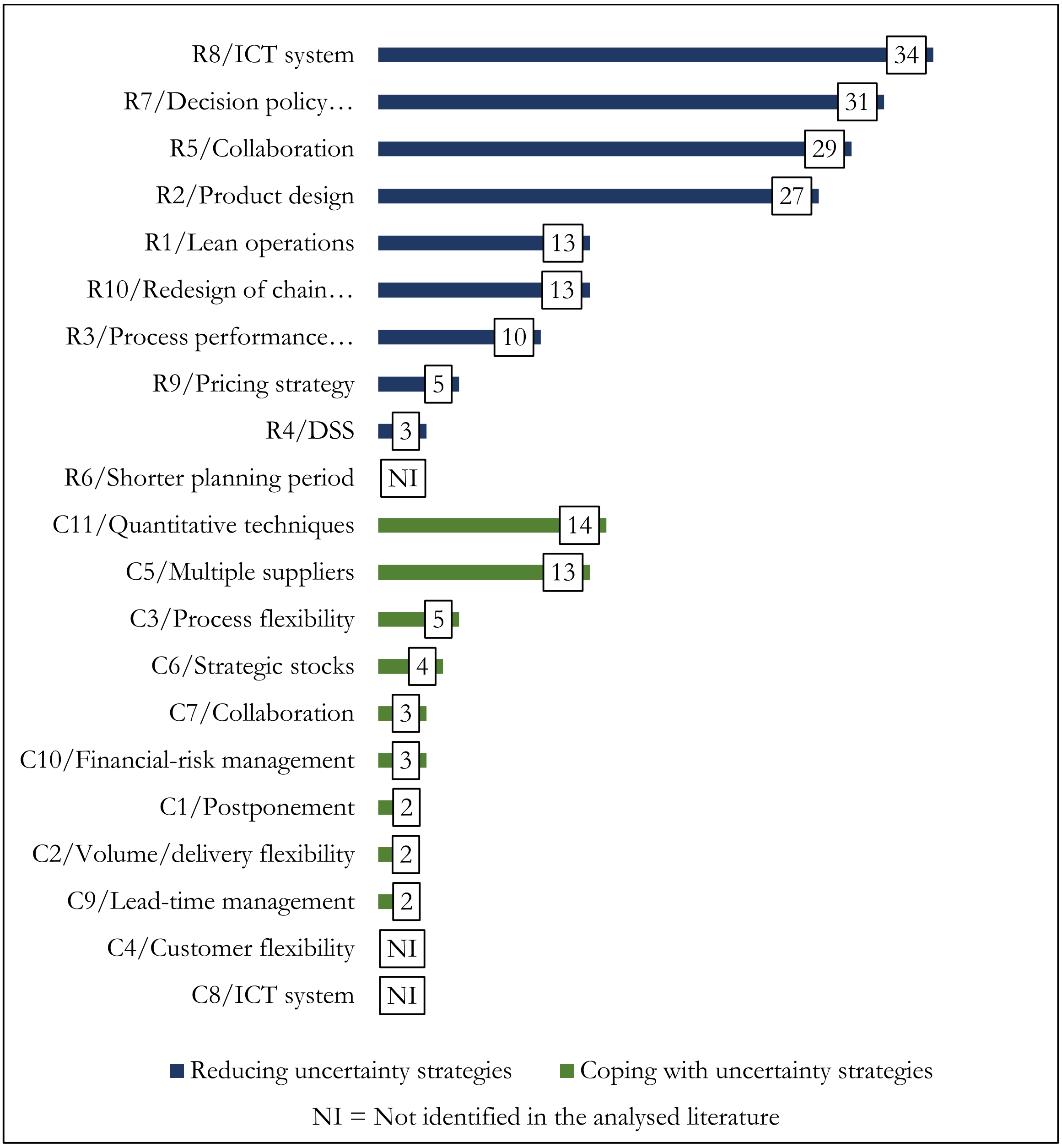

Figure 4. Frequency of uncertainty management strategies in CSCs (number of analysed articles = 82)

The analysis of uncertainty management strategies in the context of CSCs is divided into the two following subsections.

3.2.1. Reducing uncertainty strategies

It can be observed in Figure 4 that reducing uncertainty strategies is the most frequently discussed management practice in CSCs. Following this pattern, the burgeoning firms' interest in *R8/ICT systems* is mainly attributed to the importance of technologies in reducing uncertainties in CSCs. For example,

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near-infrared detection technologies can enable better waste sorting (Iacovidou et al., 2019); real-time data analytics facilitate adaptive calibration in the automotive industry and CE development (Ge & Jackson, 2014); and 3D printers can be utilised to manufacture modules, parts, and even products on demand with minimised logistics costs and demand uncertainty (Nascimento et al., 2019).

R7/Decision policy and procedures are mainly implemented to guide decision-making tasks and enhance the operational performance of CSCs. Kurilova-Palisaitiene et al. (2018) found that employee cross-training and learning through problem-solving can be employed as *R7/Decision policy and procedures* to address the issue of insufficient information sharing within remanufacturing companies. Circular operations demand the implementation of novel practices and procedures such as education and training. According to Govindan and Hasanagic (2018, p. 304), 'not only university education is important, but also virtual education is essential to educate and prepare the workforce for the new shift in the manufacturing industry.' *R7/Decision policy and procedures* can also be adopted in recycling activities. Accordingly, effective recycling requires proper control of recycling operations to remove the impurities created during the disposal, collection, and sorting process stages (Iacovidou et al., 2019).

Another frequently quoted strategy for reducing uncertainty was *R5/Collaboration*. In the CE context, businesses play a crucial role in integrating suppliers, partners, and other key stakeholders to secure production and ultimately respond to customer demands (Kalverkamp, 2018). Moreover, this strategy has been implemented to maximise the opportunities for high-volume production (De Angelis et al., 2018) and manage waste streams through strategic alliances (Sandvik & Stubbs, 2019). Veleva and Bodkin (2018) also pinpointed the example of Circular Blu, entrepreneurs who repurpose high-quality polypropylene material into tote bags and create environmental and social benefits by hiring people with disabilities to make the bags through a partnership with a charity. Circular Blu then sells the bags to the healthcare industry and thus helps to close the loop for the material.

Regarding *R2/Product design*, it was observed that robust designs further enhance product circularity. This strategy likely reduces the uncertainties at the end-of-use phase of MCPs so that they can be easily reprocessed (Barbaritano et al., 2019). Analysing the case of a furniture company, Krystofik et al. (2018) argued that adaptive remanufacturing provides a degree of insulation against SC uncertainty because it generates economic viability under present market structures. While this viability is critical to succeeding in new markets, adaptive remanufacturing also holds promise with regard to serving as

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a transformative design strategy to be employed in pursuit of a more comprehensive CE (Krystofik et al., 2018).

Under *R1/Lean operations*, Gaustad et al. (2018) suggested the application of Lean manufacturing, Lean Six Sigma, total quality management, eco-efficiency, and dematerialisation to address material criticality concerns in the CE. These strategies can help manufacturers improve material efficiency—that is, more material services with less production and processing (Allwood et al., 2011). Material efficiency is regarded as an essential objective due to supply risks, environmental implications, and vulnerability to supply restrictions, all of which are directly related to the global challenge of resource scarcity (Lieder & Rashid, 2016).

R10/Redesign of chain configuration or infrastructure is regarded as a crucial strategy in CLSCs. As such, managers need to decide on the SC location (factories, distribution, and sorting centres) and manage the operation planning decisions to reduce uncertainties, such as transportation costs, product demand, and the availability and quality of returned products (Baptista et al., 2019). Moreover, Govindan et al. (2020) developed a model that can assist businesses with their supplier selection and order allocation in CLSCs. As suppliers have a considerable impact on the efficiency of the whole CLSC, selecting the right supplier can reduce both environmental damage and costs and lead to the circularity of used materials (Govindan et al., 2020). This concern is reinforced by Kannan (2018), who argued that it is essential for organisations to consider their stakeholders' demands and interests with regard to sustainability. Thus, to reduce the complexity of the supplier selection process, organisations need to identify the most critical success factors in terms of economic (e.g., quality, technology capability, and costs), environmental (e.g., environmental certifications), and social sustainability (e.g., human rights and health/safety standards).

The least discussed uncertainty management strategies were *R3/Process performance measurement*, *R9/Pricing strategy*, and *R4/DSS*. In this respect, some practical guidance is worthy of attention.

Regarding *R3/Process performance measurement*, companies can implement regenerative practices to reverse environmental degradation and restore ecosystems. Therefore, they can help realise the transformation from a business-oriented approach to a system-oriented, biocentric approach in the path towards regenerative development (Souza et al., 2019). This represents an opportunity to show how companies can implement CE to increase their natural capital stock, safeguard their production systems against resource scarcity, and protect the productive capacity of natural systems (Howard et al., 2019).

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R9/Pricing strategy can be paramount for managers who charge reasonable prices to attract price-sensitive clientele and loss-averse consumers to preferred CE products (Liao, 2018). Attention should be also placed on the economic incentives that could facilitate the transition of consumer behaviours towards more circular practices (e.g. discount prices of close to expiration food products, glass bottle returns), as the optimality of prices should take into consideration the avoidance of potential rebound effects.

In terms of *R4/DSS*, Lechner and Reimann (2019) argued that the use of integrated DSS in the RL and CLSC contexts is limited but is a crucial element to bolster managers' interest in acting sustainably in their decision-making.

Finally, the frequency analysis revealed no evidence of *R6/Shorter planning period* in CSCs; therefore, further empirical research should explore this topic.

3.2.2. Coping with uncertainty strategies

This subsection discusses the frequency results regarding coping with uncertainty strategies in the context of CSCs (see Figure 4).

The analysis revealed that *C11/Quantitative techniques* received relatively significant attention. This strategy refers to the use of quantitative models for coping with uncertainty—for example, forecasting demand, models based on artificial intelligence, and mathematical simulation (Peidro et al., 2009). Tsiliyannis (2018) presented a statistical simulation that can be used in the CLSC to forecast consumers' returns, which are usually random and unobservable for many products, ranging from vehicle components to mobile phones. In the reverse SC of the automotive industry, by accurately predicting the recycling volume of end-of-life vehicles, firms can adjust their production, operation, and inventory plans to reduce costs (Hao et al., 2018).

For *C5/Multiple suppliers*, a company can increase its supply source by means of multiple sourcing options. According to Fraccascia et al. (2020), by exchanging waste (input) in symbiotic relationships, companies should balance the costs associated with the management of relationships with other firms and environmental outcomes (e.g., the additional amount of waste not landfilled and input not purchased). Another interesting example is provided by Machacek et al. (2015), who analysed the Solvay business case of closing the loop with rare earth element recycling. They illustrated how

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Solvay's core competence is reiterated in a strategy that addresses two objectives: augmenting resilience against supply criticality and further increasing competitiveness. The case was enabled by the European legislation which has attached societal value to recycling by committing producers to collect and recycle waste products, thus limiting the landfilling of hazardous waste and promoting closed-loop opportunities. It is vital for Solvay to have access to a well-developed domestic secondary supply of rare earth elements (i.e., multiple sources).

Although some methods of coping with uncertainty strategies received scant attention, the analysis pointed out some interesting patterns, which are discussed below.

Regarding *C3/Process flexibility*, Low and Ng (2018) aimed to address the uncertainties of remanufacturing systems by applying the concept of flexibility. Regarding remanufactured laptop computers in the Cambodian market, Low and Ng (2018) demonstrated that a flexible design strategy can be employed to satisfy market demand by increasing operation hours to compensate for the shortfall in production volume; this can be achieved through the use of overtime shifts at the cost of paying workers double the normal wage.

In terms of *C6/Strategic stocks*, Rogetzer et al. (2019) analysed a strategy for sourcing critical materials comprising both virgin and recycling raw materials. In the case of demand uncertainty, the authors argued that the manufacturer could benefit from the decision to reserve a larger quantity than would normally be reserved at the recycler than to order the remaining material from the more expensive spot market source at a later date.

It is noteworthy that managers can employ *C7/Collaboration* to foster information sharing between SC actors, but this strategy does not fully mitigate the uncertainty at its source. For example, in the CLSC context, information sharing was found to improve the manufacturers' dynamic performance by allowing them to obtain significant benefits from increased return rates in the form of reduced order and inventory variability. However, there might be a slight increase in the average inventory (Dominguez et al., 2020).

For *C10/Financial risk management*, Gaustad et al. (2018) pointed out that Volkswagen AG used market conditions and supply risk evaluations to examine long-term trends in raw material markets, driving the company, for example, to pursue market hedging and long-term contracts. These instruments (and funds) can minimise the risk of investment projects that are executed in compliance with the CE (Górecki et al., 2019).

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Regarding *C1/Postponement*, when dealing with rare materials, some manufacturers do not take a long-term perspective on recycling and closing the loop; they prefer to do so when there is known demand or benefits in the short term (Lapko et al., 2019). It must be emphasised that executives need to evaluate the features of this strategy by considering the nature and impact of the uncertainties they face (De Angelis et al., 2018).

C2/Volume/delivery flexibility refers to a company's ability to respond to market dynamics, such as product demand, with minimal penalties in performance. In the CE context, this translates to the balance between SC responsiveness and environmental sustainability. Bai et al. (2019) underscored that flexibility considers not only green product production processes but also emissions, energy use, and other environmental protection practices.

It was found that *C9/Lead-time management* can be an important strategy in OLSCs in the sense that reduced lead times and an overall increase in cores on the supply side would improve the competitiveness of remanufacturers in the aftermarket (Kalverkamp, 2018).

Finally, it is noteworthy that *C4/Customer flexibility* and *C8/ICT system* were not identified in the analysed literature. This gap can be explored in future studies addressing uncertainty management in CSCs.

4. Developing a framework of uncertainty management in CSCs

In addition to the frequency counts of uncertainty management constructs within CSCs, contingency analysis was performed to identify the relationships between them. Figure 5 displays the framework of uncertainty management in CSCs, which was developed based on the statistically significant connections between the analysed constructs (phi coefficient [φ] higher than 0.3). Further information regarding contingency analysis can be found in Appendix A.

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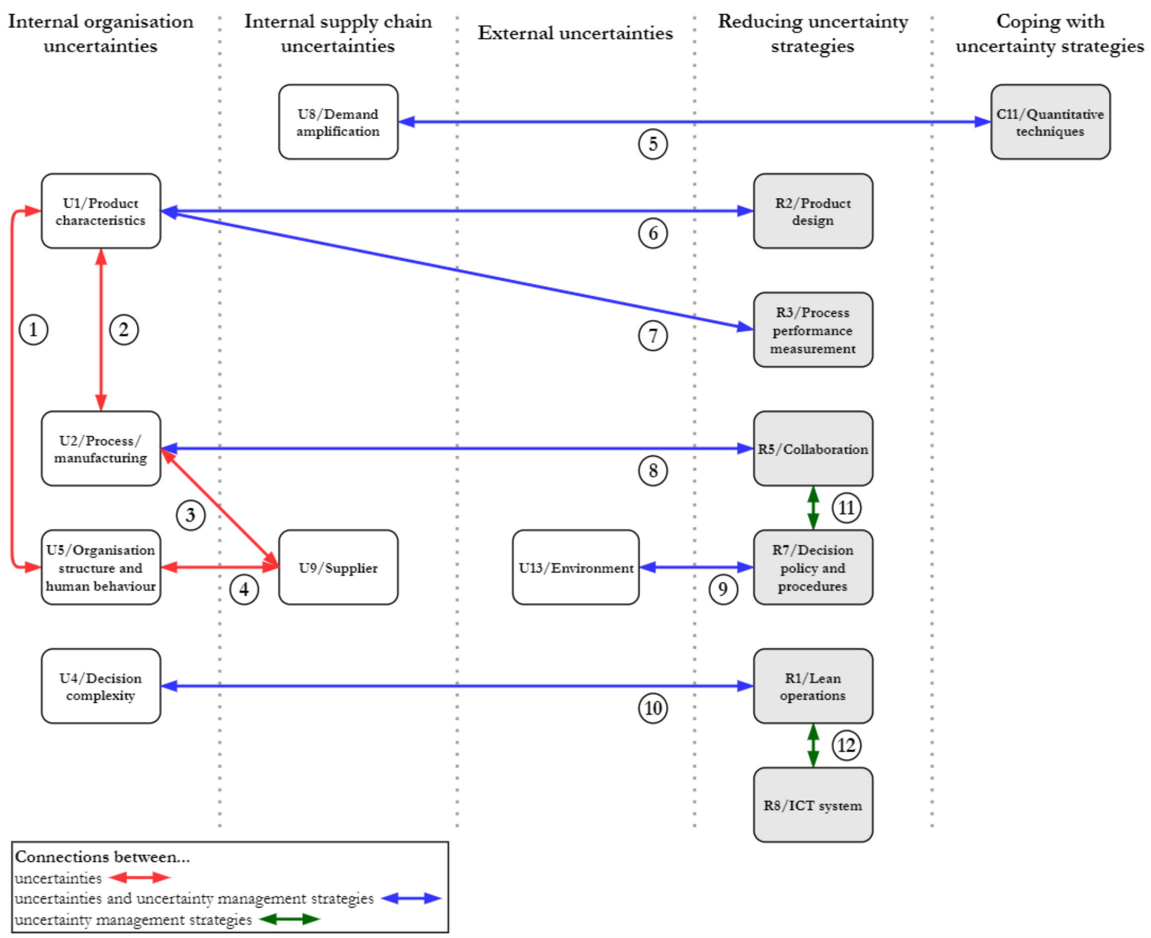

Figure 5. A framework for managing uncertainties in CSCs

A contingency analysis of uncertainty management constructs yielded a total of 12 connections. As can be seen in Figure 5, there are four connections (1–4) between different uncertainties, six connections (5–10) between uncertainties and uncertainty management strategies, and two connections (11–12) between uncertainty management strategies.

The first connection is between *U1/Product characteristics* and *U5/Organisation structure and human behaviour*. A few scholars have argued that resistance to change and the lack of perception between interested parties regarding the characteristics of CE products impede the successful implementation of the CE. Money, time, and resources are acknowledged as critical factors in this regard (Nascimento et al., 2019; Velenturf & Jopson, 2019). In the manufacturing of unconventional materials, such as pallets, some entrepreneurs recognised that there would have been more opportunities for production and growth if companies were open to supply chain integration (Silva et al., 2019). It is therefore necessary to work closely with the company's internal stakeholders and SC partners to inform them about the main characteristics of the CE products.

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The second connection is between *U1/Product characteristics* and *U2/Process/manufacturing* uncertainties. It can be inferred from the analysed literature that the complexity of the product design may pose operational difficulties for manufacturing companies. Lapko et al. (2019) argued that the small concentration and complex mixes of materials affect the thermodynamic viability of recycling processes. An example is given by Habib (2019), who showed that it can be technologically and economically challenging to extract valuable and rare magnets from end-of-life products in an efficient manner. From a technical perspective, it is difficult to separate the magnets from their assemblies because of the former's small size and strong adhesives; any attempt to disassemble them can destroy their coating, leading to the deterioration of their magnetic properties. Thereafter, it is usually necessary to mechanically shred the end-of-life products, and during this process, the magnets are smashed into dust. This dust retains its magnetic properties and adheres to all ferrous surfaces within the electronic waste pre-processing facilities. On the economic side, electronic waste-handling companies may be reluctant to invest in manual disassembly procedures, especially in the case of complex products (e.g., smartphones, electric toothbrushes, and body shavers), because of the high cost of recovering their magnets (Habib, 2019).

The third connection is between *U9/Supplier* and *U2/Process/manufacturing*, which implies that the uncertain quality, quantity, and timing of inputs can complicate or delay the manufacturing process (Islam & Huda, 2018). For example, plastic bottles need to be sorted appropriately because lids and labels contain chemicals and adhesives that contaminate the recycled output. External factors (exposure to sunlight) and misuse (they can be filled with oil or hazardous chemicals) can also contaminate plastic bottles, thereby making the recycling process economically and environmentally inviable. Moreover, companies that adopt a control orientation can coordinate their activities related to remanufacturing, disassembly, and recycling operations (Bag et al., 2019). The control mechanism is necessary to reduce quantity- and quality-related uncertainties. This is possible by adopting standard operating procedures and quality standards (Bag et al., 2019).

The fourth connection occurs between *U5/Organisation structure and human behaviour* and *U9/Supplier*. In this regard, risk-averse and risk-taker measures can affect the entire SC by causing delays and operation planning problems. Managers who introduce circular thinking into their businesses must establish clear parameters and mechanisms to help waste exchange and surplus products overcome the inertia resulting from business-as-usual practices and manufacturers' resistance to adopt CE (Veleva & Bodkin, 2018).

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The fifth connection is between *U8/Demand amplification* and *C11/Quantitative techniques*. This result suggests that managers might use forecasting techniques to cope with the bullwhip effect. However, it is worth emphasising that managers need to be aware of the main causes of the bullwhip effect (e.g., information distortion and errors/distortions in demand) to enable them to employ adequate forecasting countermeasures. Managers should invest in forecasting the volume of returns, especially when the CLSC experiences uncertainty in this regard (Ponte et al., 2020).

U1/Product characteristics uncertainty connects with both *R2/Product design* and *R3/Process performance measurement* strategies (see connections 6 and 7). A close analysis of this twofold connection suggests that it is vital for companies to consider quality standards in designing CE products. As these products often employ, inter alia, recycled materials and components, they require performance evaluations to avoid customer complaints, enhance product circularity, and reduce environmental impacts. In CSCs, companies should develop and implement standardised packaging to bolster their efficient recovery. Within this context, companies and governments have a crucial role in promoting customers' awareness of proper packaging disposal.

Regarding the eighth connection—that is, between *U2/Process/manufacturing* and *R5/Collaboration*—it is interesting to note the business interest in collaborating with universities, as they are a source of technical knowledge and research and development centres. Knowledge exchange can benefit companies with regard to an increased technical capacity to improve internal processes, as the CE requires knowledge which is beyond the business-as-usual model. In addition, logistics and SC managers should focus on developing skills related to the development of relationships with recycling companies to improve take-back solutions and the recycling process (Jabbour et al., 2019).

The ninth connection—that is, between *U13/Environment* and *R7/Decision policy and procedures*—may refer to the adoption of strategic, responsive, and well-designed decisions to reduce external uncertainties (e.g., increased sustainability demands). Bai et al. (2019) highlighted that strict environmental regulations and the increase in society's green concerns have caused companies to consider implementing various measures to become more CE capable. An interesting example refers to the integration of an environmental management system to accelerate the acquisition of environmental information. This has become an important strategic issue for many organisations facing regulatory, community, or economic pressure to adopt CE (Bai et al., 2019). In the face of complicated and fast-changing environments, wherein supply and demand uncertainties are high, a robust strategy is necessary for the survival of SCs. According to Rogetzer et al. (2019), having a

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sustainable and dual sourcing strategy, in which the manufacturer can have a second supply source to rely on in cases of unexpectedly high demands, supply risks, or other unforeseen incidents, proves to be an effective method of avoiding shortage situations. This is especially relevant in the case of critical materials, such as rare earth elements, which can be recovered from end-of-life products.

The strategic response to reducing uncertainties regarding decision-making situations is evident in the tenth connection—that is, between *U4/Decision complexity* and *R1/Lean operations*. The implementation of RL in CLSCs involves increased uncertainty due primarily to the heterogeneous condition of returns and the timely supply of different used products. In this process, executives should plan the reverse SC based on a joint approach (acquisition, sorting, and disposition) to maximise value, customer satisfaction, and environmental benefits (Lechner & Reimann, 2019). In remanufacturing systems, the Lean philosophy can be implemented to reduce unnecessary steps and enhance operational performance—for example, by controlling the inventory level at the remanufacturing site through a Kanban ordering system and implementing standards that are developed by the employees who are directly involved in remanufacturing (Kurilova-Palisaitiene et al., 2018).

Regarding the eleventh connection between *R5/Collaboration* and *R7/Decision policy and procedures*, it was found that circular fashion SCs in Scandinavia have pursued collaboration with various actors to enable textile recycling but, significantly, have sought to systematise the recycling process to enhance its quality and performance (Sandvik & Stubbs, 2019). Another critical strategy refers to increasing consumer acceptance of CE products. In the case of refurbished mobile phones, companies should build a strong product base, which relates to both the optimisation of the original product design for multiple life cycles and the integration of the product design into the refurbishment process to optimise the functional attributes that have a high chance of deterioration due to wear and tear (Van Weelden et al., 2016). This would allow for the easy repair and modification of product parts and components. Companies can also build awareness and market refurbished products as high-quality alternatives to new products by providing transparent information about the refurbishment process (Van Weelden et al., 2016). Further, companies need to implement post-consumption programmes through affordable maintenance services and warranty. A product warranty policy serves as insurance against potential dissatisfaction with the product and encourages purchases by reducing the risks for consumers; this marketing strategy can attract more clientele, thereby playing a pivotal role in stimulating demand for CE products (Liao, 2018).

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The twelfth connection—that is, between *R1/Lean operations* and *R8/ICT system* strategies—reinforces the adoption of Lean principles and Industry 4.0 technologies in the CE. It is noteworthy that 3D printing allows for manufacturing parts and modules on demand, thereby reducing the necessity of stocks, logistics, and complex manufacturing operations. The use of digital technology, such as online platforms, can facilitate the development of sustainable practices in CSCs. Regarding the recovery of food waste, for example, digital technology was found to provide a virtual space in which stakeholders can easily find one another and exchange relevant information about the food to be recovered. Moreover, it enables a much higher number of connections; actors with food waste have ample opportunities to ensure its valorisation because they can attract many potential recipients or users (Ciulli et al., 2019). Furthermore, the design and production decisions of sustainable operations management can be adapted based on data provided by IoT resources (Jabbour et al., 2018). In turn, this can reduce resource consumption, improve productivity, and extend the life cycles of products.

5. Conclusion

The CE has recently gained impetus because of its role in decoupling resource usage from economic growth. Within this context, CSCs are a novel approach which aims to create prolonged flows of MCPs (Batista et al., 2018). The management of CSCs is nevertheless challenging due to the uncertainties in product design, logistics, and organisational culture. Thus, CSCs will likely require a robust uncertainty management approach to reduce and cope with their increased complexities.

Against this background, this report aimed to provide a comprehensive review of uncertainties and uncertainty management strategies in the context of CSCs. The key managerial implications of this report are highlighted in the next subsection.

5.1. Managerial implications

This report showed the frequency with which uncertainties and uncertainty management strategies were considered in CSCs. It also developed a framework which integrated uncertainty management into CSCs. More practical examples could be of great relevance; however, most of the analysed scientific articles either concealed the organisations' identities owing to confidentiality reasons or provided little information about them. Nevertheless, the analysis painted a detailed picture of the

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field, as it was based on a comprehensive framework of uncertainty in the OSCM area. The proposed framework (Figure 5) was inspired by theory development, which is crucial for enriching managerial findings and implications. As Van de Ven (1989, p. 486) noted, 'Good theory is practical precisely because it advances knowledge in a scientific discipline, guides research toward crucial questions, and enlightens the profession of management.' In sum, this report presented valuable theoretical underpinnings that will enable executives and policymakers to understand not only the factors related to uncertainty management in CSCs but also how and why they are related.

In terms of managerial implications, CE products require robust quality standards to manage the usage of restored materials and components. The adoption of tighter standards is likely to reduce customer complaints and achieve resource circularity simultaneously. The use of 3D printing, IoT, and data analytics can help businesses implement CE practices, but they might increase information and technology-related issues. This reiterates the necessity of employing uncertainty evaluations to reduce the likelihood of SC disruptions and hence enhance the stability of circular operations.

Managers must pay attention to the multiple sources of uncertainty which can challenge the management of CSCs. As discussed, these issues range from managers' resistance to implementing the CE in the organisation culture to supplier issues, which can cause delays, disrupt processes, or increase costs if not managed appropriately. Hence, strategic decisions are needed to enhance the performance of CSCs.

As uncertainty is an inherent and inevitable characteristic of CSCs, managers will likely need to reduce the complexity of management practice (Peng et al., 2020). This points to the adoption of robust and well-tailored decisions. The implementation of the CE within SCs becomes even more difficult if it is aligned with a commercial strategy in the absence of government support (Masi et al., 2017). As a result, governments play an essential role in making the transition towards CSCs feasible and widespread.

Financial bottlenecks and technological limitations often represent a hurdle for companies entering the CE landscape and can exacerbate uncertainties. Policies are therefore necessary to introduce environmental taxes and charges, which make it more feasible for companies and related SCs to adopt the CE (Govindan & Hasanagic, 2018). In addition, governments and policymakers should develop directives for responsible changes in SCs and adjust legal barriers and inconsistencies (Schraven et al., 2019).

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5.2. Future directions

The adopted uncertainty management approach will inform the upcoming research with the ReTraCE partners, who are from the industrial world and non-European countries that are leading the way in terms of CE implementation. These partners will enrich this work by exchanging CE best practices and real-world applications.

A Delphi study will be conducted to gather experts' views on risks/uncertainties and collaboration practices in CSCs (*in progress*). The ReTraCE consortium and partners were formally invited to take part in this study. This group consists of a panel of experts established in July 2019 (Milestone 1: Establishment of an expert group for investigating risk and relationship management practices in CSCs). To gain further feedback, the methodology of the Delphi study was discussed at the Dresden Nexus Conference 2020: Circular Economy in a Sustainable Society (early June 2020). A survey will be launched, and the collected data will be analysed and interpreted based on some of the theoretical developments presented in this report. It should be noted that the upcoming Deliverable 1.3 will discuss the collaboration practices in CSCs (due in April 2021).

Moreover, case study research will be conducted to gather empirical data regarding the adoption of risk/uncertainty management practices in CSCs. This work will provide rich examples which may inform practitioners, policymakers, and scholars regarding the successful implementation of the CE in SCs. The key findings of the two studies mentioned above will be shared under Deliverable 1.4 (due in February 2022).

Contents of this deliverable are currently under review for publication in international journals

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Appendix A. The review process

A systematic review approach was adopted in this report because it can provide practitioners and policymakers with a reliable basis on which to formulate decisions and take action (Tranfield et al., 2003). This method is considered suitable for identifying the best management evidence in short cycle times while adopting a scientific and rigorous approach (Tranfield et al., 2003).

The research boundaries and gaps were first defined and then presented for academics, practitioners, and other stakeholders to gain validation at an academic conference in mid-September 2019 and at the ReTraCE Network School (early December 2019, Naples, Italy). The ongoing research process was also presented at other events. For example, the preliminary results of this report were discussed at the Online ReTraCE Industry and Policymaking Roundtable Event (early May 2020, Brussels, Belgium).

Tranfield et al.'s (2003) systematic approach was adapted into three stages, which are described below.

Stage I: The keywords and search strings were defined and then applied through Boolean operators and combinations of search strings on the Web of Science and Scopus databases. In keeping with Merli et al. (2018), only peer-reviewed English-language articles were retrieved. The search was applied to the title, keywords, and abstract. The search encompassed all years because CE discussions commenced before the 2000s (Ghisellini et al., 2016). In the initial search, 460 publications were retrieved. Next, articles that were duplicated and those that did not focus on CE-led operations and SCs were excluded. This step yielded 136 articles. Finally, these 136 full-text articles were scrutinised, but only 82 were selected for further analysis because they were considered relevant for the purpose of this report.

Stage II: The descriptive information was retrieved from the 82 selected articles and organised in Microsoft Excel to enable the identification of the formal characteristics of the reviewed literature (Durach et al., 2017). Moreover, using MAXQDA 2020 Analytics Pro (qualitative analysis software), the papers were content analysed against well-known theoretical constructs of uncertainty management, and the content was precisely organised in the shape of a coherent category system. In this step, frequency analysis was performed, as this technique is useful for identifying the most important issues and showing which ones have been neglected to date (Yawar & Seuring, 2017). Furthermore, a second analytical step (contingency analysis) was employed to identify the relationships between the analysed constructs. According to Gold et al. (2010), this technique detects positive

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association patterns between constructs which appear relatively more frequently together in one paper than the product of their single probabilities would suggest. The strength of these patterns is validated by the φ, which is calculated in SPSS Statistics by performing a chi-square test. To ensure statistically significant results, only constructs with frequencies of at least 10% of the base sample were considered, and the φ>0.3 (Fleiss et al., 2003). While the association between two constructs does not reveal any underlying causality, a positive association between them reveals a connection which must be explained against the related literature (Gold et al., 2010).

Stage III: The reporting of the results was performed. In this step, rounds of discussion aided in checking and refining the results further.

Figure 1A depicts each step mentioned above.

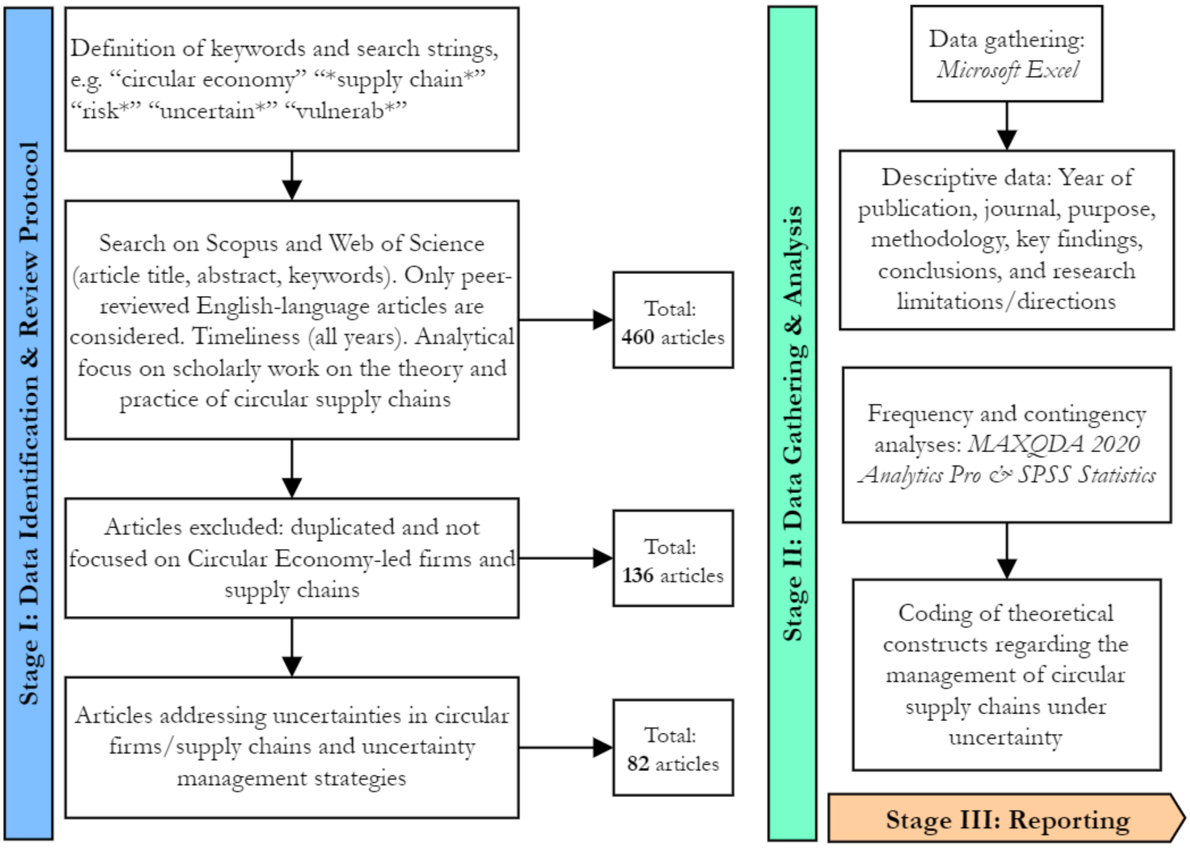

Figure 1A. The review process, adapted from Tranfield et al. (2003)

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References

Agyemang, M., Kusi-Sarpong, S., Khan, S. A., Mani, V., Rehman, S. T., & Kusi-Sarpong, H. (2019). Drivers and barriers to circular economy implementation. *Management Decision*, *57*(4), 971–994. Doi: 10.1108/MD-11-2018-1178

Akinade, O. O., & Oyedele, L. O. (2019). Integrating construction supply chains within a circular economy: an ANFIS-based waste analytics system (A-WAS). *Journal of Cleaner Production*, *229*, 863–873. Doi: 10.1016/j.jclepro.2019.04.232

Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: a white paper. *Resources, Conservation & Recycling*, *55*(3), 362–381. Doi: 10.1016/j.resconrec.2010.11.002

Bag, S., Gupta, S., & Foropon, C. (2019). Examining the role of dynamic remanufacturing capability on supply chain resilience in circular economy. *Management Decision*, *57*(4), 863–885. Doi: 10.1108/MD-07-2018-0724

Bai, C., & Sarkis, J. (2013). Flexibility in reverse logistics: a framework and evaluation approach. *Journal of Cleaner Production*, *47*, 306–318. Doi: 10.1016/j.jclepro.2013.01.005

Bai, C., Sarkis, J., Yin, F., & Dou, Y. (2019). Sustainable supply chain flexibility and its relationship to circular economy-target performance. *International Journal of Production Research*, 1–18. Doi: 10.1080/00207543.2019.1661532

Baptista, S., Barbosa-Póvoa, A. P., Escudero, L. F., Gomes, M. I., & Pizarro, C. (2019). On risk management of a two-stage stochastic mixed 0–1 model for the closed-loop supply chain design problem. *European Journal of Operational Research*, *274*(1), 91–107. Doi: 10.1016/j.ejor.2018.09.041

Barbaritano, M., Bravi, L., & Savelli, E. (2019). Sustainability and quality management in the Italian luxury furniture sector: a circular economy perspective. *Sustainability*, *11*(11), 1–22. Doi: 10.3390/su11113089

Batista, L., Bourlakis, M., Smart, P., & Maull, R. (2018). In search of a circular supply chain archetype– a content-analysis-based literature review. *Production Planning & Control*, *29*(6), 438–451. Doi: 10.1080/09537287.2017.1343502

Ben-Ammar, O., Bettayeb, B., & Dolgui, A. (2020). Integrated production planning and quality control for linear production systems under uncertainties of cycle time and finished product quality. *International Journal of Production Research*, *58*(4), 1144–1160. Doi: 10.1080/00207543.2019.1613580

Bleischwitz, R. (2020). Mineral resources in the age of climate adaptation and resilience. *Journal of Industrial Ecology*, *24*(2), 291–299. Doi: 10.1111/jiec.12951

Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308-320.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Braz, A. C., De Mello, A. M., de Vasconcelos Gomes, L. A., & de Souza Nascimento, P. T. (2018). The bullwhip effect in closed-loop supply chains: a systematic literature review. *Journal of Cleaner Production*, *202*, 376–389. Doi: 10.1016/j.jclepro.2018.08.042

Bressanelli, G., Perona, M., & Saccani, N. (2018). Challenges in supply chain redesign for the circular economy: a literature review and a multiple case study. *International Journal of Production Research*, *57*(23), 7395–7422. Doi: 10.1080/00207543.2018.1542176

Busch, T. (2020). Industrial ecology, climate adaptation, and financial risk. *Journal of Industrial Ecology*, *24*(2), 285–290. Doi: 10.1111/jiec.12938

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *International Journal of Logistics Management*, *15*(2), 1–13.

Cisco. (2020). *Cisco Closed-loop Plastic Label.* Retrieved 08 October 2020, from https://www.cisco.com/c/dam/en_us/about/closed-loop.pdf

Ciulli, F., Kolk, A., & Boe-Lillegraven, S. (2019). Circularity brokers: digital platform organizations and waste recovery in food supply chains. *Journal of Business Ethics*, 1–33. Doi: 10.1007/s10551-019-04160-5

Danone. (2018). *Accelerating the Transition Towards the Circular Economy: Danone Packaging Policy.* Retrieved 08 October 2020, from https://www.danone.com/content/dam/danone-corp/danone-com/about-us-impact/policies-and-commitments/en/2018/Danone_Packaging_Policy.pdf

De Angelis, R., Howard, M., & Miemczyk, J. (2018). Supply chain management and the circular economy: towards the circular supply chain. *Production Planning & Control*, *29*(6), 425–437. Doi: 10.1080/09537287.2018.1449244

De Jesus, A., & Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. *Ecological Economics*, *145*, 75–89. Doi: 10.1016/j.ecolecon.2017.08.001

Dominguez, R., Cannella, S., Ponte, B., & Framinan, J. M. (2020). On the dynamics of closed-loop supply chains under remanufacturing lead time variability. *Omega*, *97*, 1–16. Doi: 10.1016/j.omega.2019.102106

Durach, C. F., Kembro, J., & Wieland, A. (2017). A new paradigm for systematic literature reviews in supply chain management. *Journal of Supply Chain Management*, *53*(4), 67–85. Doi: 10.1111/jscm.12145

Ellen MacArthur Foundation. (2015). *Towards a circular economy: Business rationale for an accelerated transition.*

Ellen MacArthur Foundation, SUN, & McKinsey Center for Business and Environment. (2015). *Growth within: A Circular economy vision for a competitive Europe.*

Ellen MacArthur Foundation. (2020). *Financing the circular economy: Capturing the opportunity.*

Esposito, M., Tse, T., & Soufani, K. (2018). Introducing a circular economy: new thinking with new managerial and policy implications. *California Management Review*, *60*(3), 5–19. Doi: 10.1177/0008125618764691

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Ethirajan, M., Arasu M, T., Kandasamy, J., KEK, V., Nadeem, S. P., & Kumar, A. (2020). Analysing the risks of adopting circular economy initiatives in manufacturing supply chains. *Business Strategy and the Environment*, 1–33. Doi: 10.1002/bse.2617

European Commission. (2020). *Changing how we produce and consume: New Circular Economy Action Plan shows the way to a climate-neutral, competitive economy of empowered consumers*. Retrieved 08 October 2020, from https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420

Fleiss, J. L., Levin, B., & Paik, M. C. (2003). *Statistical methods for rates and proportions* (3rd ed.). Wiley.

Fraccascia, L., Yazan, D. M., Albino, V., & Zijm, H. (2020). The role of redundancy in industrial symbiotic business development: a theoretical framework explored by agent-based simulation. *International Journal of Production Economics*, *221*, 1–23. Doi: 10.1016/j.ijpe.2019.08.006

Gartner. (2020). *Gartner survey shows 70% of supply chain leaders plan to invest in the Circular Economy*. Retrieved 08 October 2020, from https://www.gartner.com/en/newsroom/press-releases/2020-02-26-gartner-survey-shows-70--of-supply-chain-leaders-plan

Gaustad, G., Krystofik, M., Bustamante, M., & Badami, K. (2018). Circular economy strategies for mitigating critical material supply issues. *Resources, Conservation & Recycling*, *135*, 24–33. Doi: 10.1016/j.resconrec.2017.08.002

Geary, S., Disney, S. M., & Towill, D. R. (2006). On bullwhip in supply chains–historical review, present practice and expected future impact. *International Journal of Production Economics*, *101*(1), 2–18. Doi: 10.1016/j.ijpe.2005.05.009

Ge, X., & Jackson, J. (2014). The big data application strategy for cost reduction in automotive industry. *SAE International Journal of Commercial Vehicles*, *7*(2), 588–598. Doi: 10.4271/2014-01-2410

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The circular economy–a new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. Doi: 10.1016/j.jclepro.2016.12.048

Genovese, A., Acquaye, A. A., Figueroa, A., & Koh, L. S. C. (2017). Sustainable supply chain management and the transition towards a circular economy: evidence and some applications. *Omega*, *66*(Part B), 344–357. Doi: 10.1016/j.omega.2015.05.015

Ghadge, A., Wurtmann, H., & Seuring, S. (2020). Managing climate change risks in global supply chains: a review and research agenda. *International Journal of Production Research*, *58*(1), 44–64. Doi: 10.1080/00207543.2019.1629670

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. Doi: 10.1016/j.jclepro.2015.09.007

Gold, S., Seuring, S., & Beske, P. (2010). Sustainable supply chain management and inter-organizational resources: a literature review. *Corporate Social Responsibility and Environmental Management*, *17*(4), 230–245. Doi: 10.1002/csr.207

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Gonzalez, E. D. R. S., Koh, L. S. C., & Leung, J. (2019). Towards a circular economy production system: trends and challenges for operations management. *International Journal of Production Research*, *57*(23), 7209–7218. Doi: 10.1080/00207543.2019.1656844

Górecki, J., Núñez-Cacho, P., Corpas-Iglesias, F. A., & Molina, V. (2019). How to convince players in construction market? Strategies for effective implementation of circular economy in construction sector. *Cogent Engineering*, *6*(1), 1–22. Doi: 10.1080/23311916.2019.1690760

Govindan, K., & Hasanagic, M. (2018). A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. *International Journal of Production Research*, *56*(1–2), 278–311. Doi: 10.1080/00207543.2017.1402141

Govindan, K., Mina, H., Esmaeili, A., & Gholami-Zanjani, S. M. (2020). An integrated hybrid approach for circular supplier selection and closed loop supply chain network design under uncertainty. *Journal of Cleaner Production*, 242, 1–16. Doi: 10.1016/j.jclepro.2019.118317

Groupe Renault. (2020). *Groupe Renault's Circular Economy*. Retrieved 08 October 2020, from https://group.renault.com/en/our-commitments/respect-for-the-environment/circular-economy/

Guide, V. D. R., Jr., & Van Wassenhove, L. N. (2009). The evolution of closed-loop supply chain research. *Operations Research*, *57*(1), 10–18.

Habib, K. (2019). A product classification approach to optimize circularity of critical resources–the case of NdFeB magnets. *Journal of Cleaner Production*, *230*, 90–97. Doi: 10.1016/j.jclepro.2019.05.048

Hao, H., Zhang, Q., Wang, Z., & Zhang, J. (2018). Forecasting the number of end-of-life vehicles using a hybrid model based on grey model and artificial neural network. *Journal of Cleaner Production*, *202*, 684–696. Doi: 10.1016/j.jclepro.2018.08.176

He, Y. (2017). Supply risk sharing in a closed-loop supply chain. *International Journal of Production Economics*, *183*, 39–52. Doi: 10.1016/j.ijpe.2016.10.012

Howard, M., Hopkinson, P., & Miemczyk, J. (2019). The regenerative supply chain: a framework for developing circular economy indicators. *International Journal of Production Research*, *57*(23), 7300–7318. Doi: 10.1080/00207543.2018.1524166

Iacovidou, E., Velenturf, A. P., & Purnell, P. (2019). Quality of resources: a typology for supporting transitions towards resource efficiency using the single-use plastic bottle as an example. *Science of the Total Environment*, 647, 441–448. Doi: 10.1016/j.scitotenv.2018.07.344

Islam, M. T., & Huda, N. (2018). Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: a comprehensive literature review. *Resources, Conservation & Recycling*, *137,* 48–75. Doi: 10.1016/j.resconrec.2018.05.026

Jabbour, A. B. L. S., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, *270*(1–2): 273–286. Doi: 10.1007/s10479-018-2772-8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Jabbour, A. B. L. S., Luiz, J. V. R., Luiz, O. R., Jabbour, C. J. C., Ndubisi, N. O., de Oliveira, J. H. C., & Junior, F. H. (2019). Circular economy business models and operations management. *Journal of Cleaner Production*, *235*, 1525–1539. Doi: 10.1016/j.jclepro.2019.06.349

Jahre, M. (2017). Humanitarian supply chain strategies–a review of how actors mitigate supply chain risks. *Journal of Humanitarian Logistics and Supply Chain Management*, *7*(2), 82–101. Doi: 10.1108/JHLSCM-12-2016-0043

Jain, T., & Hazra, J. (2020). Optimal regulation and sustainable product design under uncertainties. *International Journal of Production Economics*, *225*, 1–14. Doi: 10.1016/j.ijpe.2019.107574

Kalverkamp, M. (2018). Hidden potentials in open-loop supply chains for remanufacturing. *The International Journal of Logistics Management*, *29*(4), 1125–1146. Doi: 10.1108/IJLM-10-2017-0278

Kalverkamp, M., & Young, S. B. (2019). In support of open-loop supply chains: expanding the scope of environmental sustainability in reverse supply chains. *Journal of Cleaner Production*, *214*, 573–582. Doi: 10.1016/j.jclepro.2019.01.006

Kannan, D. (2018). Role of multiple stakeholders and the critical success factor theory for the sustainable supplier selection process. *International Journal of Production Economics*, *195*, 391–418. Doi: 10.1016/j.ijpe.2017.02.020

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, *175*, 544–552. Doi: 10.1016/j.jclepro.2017.12.111

Kouhizadeh, M., Sarkis, J., & Zhu, Q. (2019). At the Nexus of Blockchain technology, the circular economy, and product deletion. *Applied Sciences*, *9*(8), 1–20. Doi: 10.3390/app9081712

Krystofik, M., Luccitti, A., Parnell, K., & Thurston, M. (2018). Adaptive remanufacturing for multiple lifecycles: a case study in office furniture. *Resources, Conservation & Recycling*, *135*, 14-23. Doi: 10.1016/j.resconrec.2017.07.028

Kurilova-Palisaitiene, J., Sundin, E., & Poksinska, B. (2018). Remanufacturing challenges and possible lean improvements. *Journal of Cleaner Production*, *172*, 3225–3236. Doi: 10.1016/j.jclepro.2017.11.023

Lahane, S., Kant, R., & Shankar, R. (2020). Circular supply chain management: a state-of-art review and future opportunities. *Journal of Cleaner Production*, *258*, 1–16. Doi: 10.1016/j.jclepro.2020.120859

Lapko, Y., Trianni, A., Nuur, C., & Masi, D. (2019). In pursuit of closed-loop supply chains for critical materials: An exploratory study in the green energy sector. *Journal of Industrial Ecology*, *23*(1), 182–196. Doi: 10.1111/jiec.12741

Lechner, G., & Reimann, M. (2019). Integrated decision-making in reverse logistics: an optimisation of interacting acquisition, grading and disposition processes. *International Journal of Production Research*, 1–20. Doi: 10.1080/00207543.2019.1659518

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: the bullwhip effect. *Management Science*, *43*(4), 546–558. Doi: 10.1287/mnsc.43.4.546

Liao, B. (2018). Warranty as a competitive dimension for remanufactured products under stochastic demand. *Journal of Cleaner Production*, *198*, 511–519. Doi: 10.1016/j.jclepro.2018.07.013

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, 115, 36–51. Doi: 10.1016/j.jclepro.2015.12.042

Low, J. S. C., & Ng, Y. T. (2018). Improving the economic performance of remanufacturing systems through flexible design strategies: a case study based on remanufacturing laptop computers for the Cambodian market. *Business Strategy and the Environment*, *27*(4), 503–527. Doi: 10.1002/bse.2017

Machacek, E., Richter, J. L., Habib, K., & Klossek, P. (2015). Recycling of rare earths from fluorescent lamps: Value analysis of closing-the-loop under demand and supply uncertainties. *Resources, Conservation & Recycling*, *104*, 76–93. Doi: 10.1016/j.resconrec.2015.09.005

Masi, D., Day, S., & Godsell, J. (2017). Supply chain configurations in the circular economy: a systematic literature review. *Sustainability*, *9*(9), 1–22. Doi: 10.3390/su9091602

Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production*, *178*, 703–722. Doi: 10.1016/j.jclepro.2017.12.112

Miemczyk, J., Howard, M., & Johnsen, T. E. (2016). Dynamic development and execution of closed-loop supply chains: a natural resource-based view. *Supply Chain Management: An International Journal*, *21*(4), 453–469. Doi: 10.1108/SCM-12-2014-0405

Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context. *Journal of Manufacturing Technology Management*, *30*(3), 607–627. Doi: 10.1108/JMTM-03-2018-0071

Ozkan-Ozen, Y. D., Kazancoglu, Y., & Mangla, S. K. (2020). Synchronized barriers for circular supply chains in Industry 3.5/Industry 4.0 transition for sustainable resource management. *Resources, Conservation & Recycling*, *161*, 1–11. Doi: 10.1016/j.resconrec.2020.104986

Peidro, D., Mula, J., Poler, R., & Lario, F. C. (2009). Quantitative models for supply chain planning under uncertainty: a review. *The International Journal of Advanced Manufacturing Technology*, 43(3–4), 400–420. Doi: 10.1007/s00170-008-1715-y

Peng, H., Shen, N., Liao, H., Xue, H., & Wang, Q. (2020). Uncertainty factors, methods, and solutions of closed-loop supply chain—A review for current situation and future prospects. *Journal of Cleaner Production*, *254*, 1–20. Doi: 10.1016/j.jclepro.2020.120032

Philips Healthcare. (2014). *Philips Circular Economy: Refurbishing Solutions for MRI systems*. Retrieved 08 October 2020, from https://www.philips.com/c-dam/corporate/about-philips/sustainability/sustainable-planet/circular-economy/refurbished-medical-products/case-study-ce-philips-healthcare.pdf

Ponte, B., Naim, M. M., & Syntetos, A. A. (2020). The effect of returns volume uncertainty on the dynamic performance of closed-loop supply chains. *Journal of Remanufacturing*, *10*(1), 1–14. Doi: 10.1007/s13243-019-00070-x

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Ren, H., Zhou, W., Guo, Y., Huang, L., Liu, Y., Yu, Y., ... & Ma, T. (2020). A GIS-based green supply chain model for assessing the effects of carbon price uncertainty on plastic recycling. *International Journal of Production Research*, 58(6), 1705–1723. Doi: 10.1080/00207543.2019.1693656

Ritchie, B., & Brindley, C. (2007). Supply chain risk management and performance: a guiding framework for future development. *International Journal of Operations & Production Management*, *27*(3), 303–322. Doi: 10.1108/01443570710725563

Rizos, V., Bryhn, J., Alessi, M., Campmas, A., & Zarra, A. (2019). *Identifying the impact of the circular economy on the fast-moving consumer goods industry: opportunities and challenges for businesses, workers and consumers – mobile phones as an example*. The European Economic and Social Committee. Doi: 10.2864/775626

Rogetzer, P., Silbermayr, L., & Jammernegg, W. (2019). Sustainable sourcing including capacity reservation for recycled materials: a newsvendor framework with price and demand correlations. *International Journal of Production Economics*, *214*, 206–219. Doi: 10.1016/j.ijpe.2019.03.014

Sandvik, I. M., & Stubbs, W. (2019). Circular fashion supply chain through textile-to-textile recycling. *Journal of Fashion Marketing and Management: An International Journal*, *23*(3), 366–381. Doi: 10.1108/JFMM-04-2018-0058

Sauer, P. C., & Seuring, S. (2018). A three-dimensional framework for multi-tier sustainable supply chain management. *Supply Chain Management: An International Journal*, *23*(6), 560–572. Doi: 10.1108/SCM-06-2018-0233

Schraven, D., Bukvić, U., Di Maio, F., & Hertogh, M. (2019). Circular transition: Changes and responsibilities in the Dutch stony material supply chain. *Resources, Conservation & Recycling*, *150*, 1–10. Doi: 10.1016/j.resconrec.2019.05.035

Sehnem, S., Vazquez-Brust, D., Pereira, S. C. F., & Campos, L. M. (2019). Circular economy: benefits, impacts and overlapping. *Supply Chain Management: An International Journal*, *24*(6), 784–804. Doi: 10.1108/SCM-06-2018-0213

Senthil, S., Murugananthan, K., & Ramesh, A. (2018). Analysis and prioritisation of risks in a reverse logistics network using hybrid multi-criteria decision making methods. *Journal of Cleaner Production*, *179*, 716–730. Doi: 10.1016/j.jclepro.2017.12.095

Silva, F. C., Shibao, F. Y., Kruglianskas, I., Barbieri, J. C., & Sinisgalli, P. A. A. (2019). Circular economy: analysis of the implementation of practices in the Brazilian network. *REGE*, *26*(1), 39–60. Doi: 10.1108/REGE-03-2018-0044

Simangunsong, E., Hendry, L. C., & Stevenson, M. (2012). Supply-chain uncertainty: a review and theoretical foundation for future research. *International Journal of Production Research*, *50*(16), 4493–4523. Doi: 10.1080/00207543.2011.613864

Souza, V., Bloemhof-Ruwaard, J., & Borsato, M. (2019). Towards regenerative supply networks: a design framework proposal. *Journal of Cleaner Production*, *221*, 145–156. Doi: 10.1016/j.jclepro.2019.02.178

Stella McCartney. (2020). *Sustainability: Recycled Nylon and Polyester*. Retrieved 08 October 2020, from https://www.stellamccartney.com/experience/en/sustainability/themes/materials-and-innovation/recycled-nylon-polyester/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Strukton. (2020). *Mobile Plant for 100% Circular Concrete*. Retrieved 08 October 2020, from https://strukton.com/en/civiel/circuton

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), 207–222. Doi: 10.1111/1467-8551.00375

Tsiliyannis, C. A. (2016). A fundamental law relating stock and end-of-life flow in cyclic manufacturing. *Journal of Cleaner Production*, *127*, 461–474. Doi: 10.1016/j.jclepro.2016.03.054

Tsiliyannis, C. A. (2018). Markov chain modeling and forecasting of product returns in remanufacturing based on stock mean-age. *European Journal of Operational Research*, *271*(2), 474–489. Doi: 10.1016/j.ejor.2018.05.026.

Van de Ven, A. H. (1989). Nothing is quite so practical as a good theory. *Academy of Management Review*, *14*(4), 486–489. Doi: 10.5465/amr.1989.4308370

Turken, N., Cannataro, V., Geda, A., & Dixit, A. (2020). Nature inspired supply chain solutions: definitions, analogies, and future research directions. *International Journal of Production Research*, *58*(15), 4689–4715. Doi: 10.1080/00207543.2020.1778206

Van der Vorst, J. G., & Beulens, A. J. (2002). Identifying sources of uncertainty to generate supply chain redesign strategies. *International Journal of Physical Distribution & Logistics Management*, *32*(6), 409–430. Doi: 10.1108/09600030210437951

Van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. *Journal of Cleaner Production*, *113*, 743–754. Doi: 10.1016/j.jclepro.2015.11.065

Velenturf, A. P., & Jopson, J. S. (2019). Making the business case for resource recovery. *Science of the Total Environment*, *648*, 1031–1041. Doi: 10.1016/j.scitotenv.2018.08.224

Veleva, V., & Bodkin, G. (2018). Corporate-entrepreneur collaborations to advance a circular economy. *Journal of Cleaner Production*, *188*, 20–37. Doi: 10.1016/j.jclepro.2018.03.196

Vilko, J., Ritala, P., & Edelmann, J. (2014). On uncertainty in supply chain risk management. The *International Journal of Logistics Management*, *25*(1), 3–19. Doi: 10.1108/IJLM-10-2012-0126

Wang, Y., & Hazen, B. T. (2016). Consumer product knowledge and intention to purchase remanufactured products. *International Journal of Production Economics*, *181*, 460–469. Doi: 10.1016/j.ijpe.2015.08.031

World Economic Forum. 2020. *The global risks report 2020* (15th ed.).

Yawar, S. A., & Seuring, S. (2017). Management of social issues in supply chains: a literature review exploring social issues, actions and performance outcomes. *Journal of Business Ethics*, *141*(3), 621–643. Doi: 10.1007/s10551-015-2719-9

Yazdani, M., Gonzalez, E. D., & Chatterjee, P. (2019). A multi-criteria decision-making framework for agriculture supply chain risk management under a circular economy context. *Management Decision*. Doi: 10.1108/MD-10-2018-1088

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie European Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Zhen, L., Huang, L., & Wang, W. (2019). Green and sustainable closed-loop supply chain network design under uncertainty. *Journal of Cleaner Production*, *227*, 1195–1209. Doi: 10.1016/j.jclepro.2019.04.098

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