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Circular Economy and Supply Chain Change: The Case of Industries in A French Port

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ABSTRACT: *Faced with depleting natural resources, the circular economy offers a solution to achieving sustainable economic development by bringing material, energy, by-products, and waste back into the loop. This article aims to highlight changes in supply chains brought about by circular economy practices. To this end, we followed six companies from various sectors located in a port area that have adopted circular economy practices. Using qualitative case study methodology, we show that transitioning from a linear to a circular economy requires significant transformations and changes at different supply chain levels to achieve a circular supply chain such as changing partners, sourcing locations, increasing the number of suppliers, and upstream waste management.*

KEYWORDS: circular economy, changing, supply chain, port, industrial ecology

INTRODUCTION

The circular economy (CE) seeks to remedy the linear-based economy (Murray et al., 2017). With the goal of making Europe the first carbon-neutral continent by 2050, the European Commission has adopted an action plan in favor of the circular economy (CEAP) for a clean and competitive Europe. France's desire to follow the movement of the European Commission is evident by the anti-waste law for CE, which was promulgated in 2020[1].

According to Yuan et al. (2006), the core of the CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases (reduction, reuse, and recycling). To achieve this, the CE requires the transformation of the supply chains of companies. Martin Christopher (2005, 8) defines the supply chain as: "*a network of connected and mutually interdependent organizations working together in order to control, manage and improve the flow of materials and information from suppliers to end users* ". Supply chains play an important role in the sustainable management of companies (Belin-Munier, 2010) and

[1] https://www.ecologie.gouv.fr/loi-anti-gaspillage-economie-circulaire

undergo profound reorganizations to meet the different economic, social and environmental challenges of CE (Fulconis et al., 2009).

We are witnessing the emergence of several research works on CE. However, De Angelis et al., (2018) pointed out that the literature pays little attention to the implications of supply chains in CE. This observation leads to the following question: how does CE transform the supply chains of companies? It is all about knowing the changes undergone by the supply chains in the operational deployment of CE within companies. This study examines the supply chains of six member companies involved in a circular economy project in a port area. The research contributes to the understanding of the role of logistics and port areas in supply chain sustainability, and identifies the changes occurring upstream and downstream in supply chains as a result of circular economy implementations. The study begins with a literature review followed by a description of the research methodology and six case studies. The results are then presented, followed by a discussion of the findings and a conclusion.

Theoretical underpinning

Circular economy

Research on CE has begun (Korhonen et al., 2018a) and the rapid increase in the number of publications reveals the growing interest in the subject (Homrich et al., 2018). The industrial revolution of the last two centuries has fostered a high consumption of natural resources, marked by mechanized factories, the rapid invention of new technologies, the 'ever-increasing amount of work, people, factories, markets, business, products', the quadrupling of agricultural yields achieved by the mass use of chemicals (McDonough & Braungart, 2011, p.40). CE can be summed up in these main operations of reduction, reuse, repair, remanufacturing and recycling (Ghisselini et al., 2016).

Unanimously recognized as a substitute and an effective way to operationalize sustainable development (Kirchherr et al., 2017), CE is a strategy for a sustainable future. CE is linked to the resource cycle and allows companies to use the waste of ones as resources, in order to slow down cycles of use and waste production (Murray et al., 2017). Its implementation is carried out at different scales. The micro scale which concerns the reduction of the environmental impacts of consumers and companies, meso (eco-industrial parks) and macro (city, region scale) (Ghisellini et al., 2016). CE reduces supply costs, waste treatment and natural resource consumption (Guo et al., 2016).

Contribution of the supply chain to the circular economy

Supply chain is a set of independent companies that exchange materials by participating in the manufacture of a product and its delivery to the end user (Londe & Masters, 1994). This set is marked by a linear sequencing of supply, production and physical distribution activities with a view to making finished products available to consumers. The implementation of CE between industries is to link their different supply chains. Thus, companies develop new supply chains with new partners in the territory and work in collaboration to achieve local sustainability (Zhu & Coté, 2004; Bansal & Mcknight, 2009). This solves, upstream of the supply chain, the

problems of increasing consumption of raw materials and downstream the reduction of more and more waste (Husgafvel et al., 2016). CE expands supply chains so as to include non-traditional partners involved in by-product trading (Chertow et al., 2008) and can affect different components of internal logistics leading to internal process changes (Yuan & Shi, 2009). Faced with questions of sustainability, these different activities are blamed and deemed too polluting. It is necessary to introduce into the management of supply chains, the three pillars of sustainable development - economy, environment and social – and today CE. Consequently, new concepts have appeared. These include:

- Sustainable Supply Chain is the set of strategies that allow companies to reduce their environmental and social impacts at different levels of supply chains (Seuring et Müller, 2008). Sustainable SCM seeks to combine both environmental impacts in different organizations and industries to reduce material flows or to minimize the negative consequences of consumption and production processes (Dong et al., 2016).
- Green Supply Chain an important driver for CE (Cheng et al., 2023) integrates environmental aspects related to production, eco-design, management and waste treatment (Srivastava, 2007).
- Reverse logistics implies the movement of material flow from the consumption point to the original place of production and includes processes for recycling and processing end-of-life products (Kazemi et al., 2019).
- Closed loop supply chain concerns the looping of material flows to maximize product value creation (Guide & Van Wassenhove, 2009). The closed-loop supply chain is the one that has a wider range of circular flows implemented by circular economy business models (Batista et al., 2019).
- Circular Supply Chain is the implication of the principles of the circular economy on the supply chains (De Angelis et al., 2018).

Supply chain management offers significant opportunities to meet the requirements of the CE (Batista et al., 2018). To this effect, 97% of business leaders consider that logistics as important to transitioning to a CE, collaborating with logistic providers will be crucial for companies to implement cost-effective circular strategies (Makarova et al., 2021). Circular models involve networks of businesses that generate new economic value through the exchange of resources facilitated by innovative logistics and supply chain ecosystems (Batista et al., 2018). Companies deploy local cooperation strategies with other companies beyond their supply chains (Ghisellini et al., 2016), with a view to replacing imported resources with local and renewable ones and local waste (Gruner & Power 2017). The contribution of logistics to CE (figure 1) consists in bringing together in "one": sustainable supply chain, reverse logistics, green supply chain and the closed loop supply chain (Liu et al., 2018; Makarova et al., 2021). As Murray et al., (2017) point out, CE is the supply chain of companies that is exercised for greater economic and environmental value.

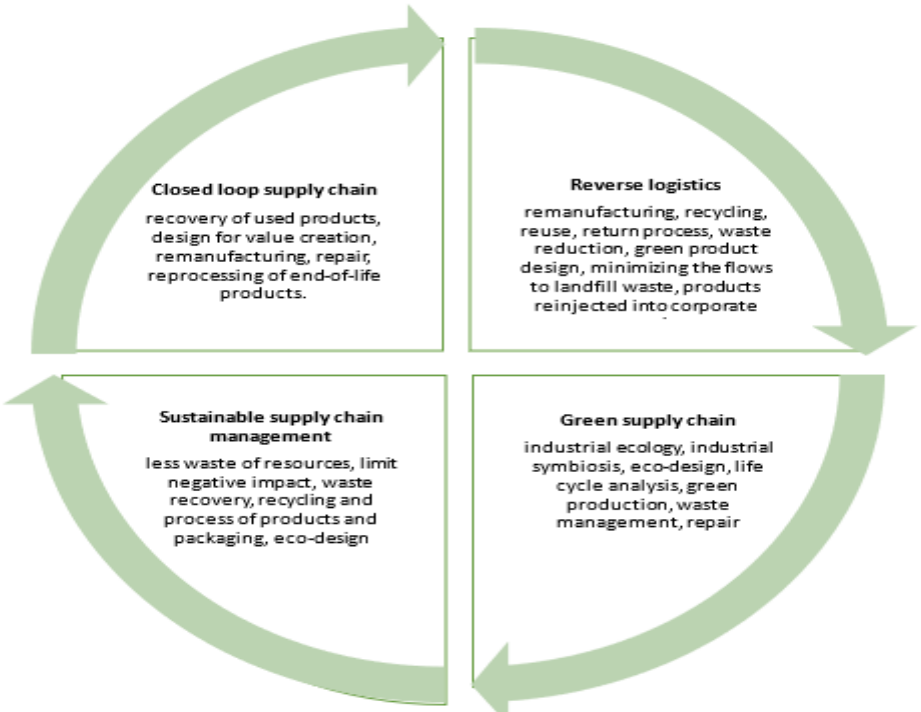

Figure 1: Logistics as a lever for the circular economy. Adapted from Srivastava, 2007; Zhu et al., 2008, Guide and Wassenhove, 2009; Batista et al, 2019; Makarova et al., 2021; Cheng et al., 2023.

Circular economy and logistics from the perspective of organizational change theory

Organizational change theory falls within the broader field of organizational theory and concerns the study of changes in organizations, with its origins traced back to H. Aldrich's work in 1979 (Dumoulin et al., 2010). The concept of change involves comparing two states of working relationships, examining the nature of activities before and after, where the state A is followed by state B (Alter, 2003, p.83). Organizational change is defined as "*a process of introducing new technical or administrative procedures into an organization*" (Denis & Champagne, 1990), which creates observable and relatively lasting changes in a subsystem of the organization (Collerette et al., 2013, p.9). Faced with the impact of economic activities on the environment, it is necessary for companies to change the paradigm and move towards new, more sustainable economic models. In this case, this implies a change in their logistics system (Makarova et al., 2021). Adoue (2007, p. 70) emphasizes that the achievement of pooling and substitution synergies implies organizational arrangements and/or process modifications for players in a given territory. It pushes companies to reorganize, in order to find the appropriate means to secure exchanges stemming from the community and to perpetuate them. This reorganization may possibly affect information and communication systems (Zhu & Côté, 2004). Additionally, companies will need to examine the inner workings of their manufacturing process and supply chains to identify areas for improvement (Makarova et al., 2021). There is potentially a change of CE on supply chains of industries (Fernandes & Kadio, 2018).

The analysis of the literature shows that CE impacts supply chains and causes potential changes. But there is little research on this aspect. It would be interesting to study this subject in a port context.

Context, research methodology and case presentation

The port is an integral part of supply chains insofar as it plays an important role in the management and coordination of physical and information flows (Carbone & De Martino, 2003) and have a capacity to promote the implementation of the circular economy (Cerceau et al., 2014). France has put in place a national port strategy to regain market share at the European level and make French ports essential links in the performance of logistics chains and accelerators of the ecological transition. About the ecological transition, France intends to develop the circular economy and the industrial ecology approach within the port areas[2].

The Atlantic Port of La Rochelle (PALR), located on the Atlantic coast, is one of the largest metropolitan French seaports capable of accommodating large vessels. Its sensitivity to environmental protection has enabled it to obtain ISO 14001 and 26000 certificates. PALR responded to a call for expressions of interest in 2014 entitled "Zero waste territories ". It was selected and carried out this project of CE with the "Union Maritime" (Union of port companies). This project led to the creation of the MER association which brings visibility of circular practices to the PALR (Kadio, 2021).

We adopted a qualitative research methodology by multiple case study (Yin, 2009). We use the multi-case approach to explore changes in supply chains and to predict identical results or contrary results (Yin, 2003). The selection of temporality was to situate ourselves in an approach combining retrospection and contemporaneity (Fabbe-Costes et al., 2013, p.58).

Collection of the primary data was done through participation in the different steering committees and semi-structured interviews which lasted one hour on average, carried out with companies and stakeholders. The interviews were carried out using a guide addressing the topics of CE, logistics and possible changes. Each interviewee was met twice at yearly intervals outlined in Table 1. Secondary data were collected through access to the process archives on the port's website, press articles and videos relating to the CE. Fourteen interviews were recorded and transcribed into text to enhance data quality and reliability (Yin, 2009). We carried out content analysis on the documents collected and the transcribed interviews (Sheppard, 2020). We conducted an intra-case analysis first, followed by an inter-case analysis, to identify discrepancies and convergences. Data coding was done using NVivo v. 12 Plus software.

[2] https://www.ecologie.gouv.fr/strategie-nationale-portuaire-snp

Table 1: Companies and people interviewed.

Differents cases	Activity	Function of the person interviewed	Duration of interviews
Epsilon	Epsilon, an SJSC[3], resulting from the port reform of 2011 is specialized in the preventive and curative maintenance of the machines of the port. It has a cleaning service that maintains and repairs the tools used for loading and unloading ships Maintenance and cleaning of port quays and hangars after each loading and unloading operation.	Deputy Director and Administrative and Financial Manager Deputy director	1h 27 mins 1h 20 mins
Iota	Iota is the French leader in recycling which has been in existence for more than 25 years and works to treatment and recover waste.	Sales Manager Sales Manager	1 h 27 mins 1 h 05 mins
Kappa	Kappa is a galvanizing, treatment, tinning and sealing company for metal surfaces	Site manager Logistics manager	1h 1h 50 mins
Sigma	Sigma provides project management for the development of infrastructure, roads, docks, medians, buildings maintenance of port infrastructure	Engineering department manager	1h 11 mins 1h
Lambda	Lambda is an industrial and marine electrical installation company. Lambda belongs to the port's shipbuilding sector. Its activity is based on naval and industrial electricity and on the cabling of cabinets and automatist.	Site General Manager Storekeeper	45 mins 1h 15 mins
Omega	Omega is a limited liability company specializing in the recycling and sale of demolition waste.	Manager of plateforme	1h
		Maritime Union Secretary	1 h
		Animator	1h 20 mins 1h 1 h 04 mins

RESULTS

Change of partners and suppliers

Epsilon is part of the logistics and port handling sector. The waste collected was not valued sufficiently by its former service provider and was sent as OIW[4]. Epsilon participates in "biomass synergy," which deals with the recovery of waste such as fertilizers, cakes, wood, cereals, and soy collected from port docks. Implementing circular economy (CE) practices for Epsilon led to the breach of contract with one service provider that lacked expertise for recovering the collected waste and was located far away. Epsilon replaced the provider with a new one that was capable of recovering the waste, which created a new collaboration as a partnership between Epsilon and the new, geographically closer service provider: *"It is true that we were each apart"* (Deputy Director of Epsilon). The new service provider is responsible for collecting the waste from Epsilon and recovering it through reuse, recycling, and energy recovery for urban heating and paper pulp production.

Sigma belongs to the management sector of the port and its infrastructures. It is part of "materials synergy". This synergy concerns the recovery of construction and demolition waste, gypsum, plaster, crushed concrete, rubble. Prior to the CE project, Sigma sourced virgin materials or quarry materials for the construction of its roads, car parks and buildings. As part of the materials synergy initiative, Sigma established a partnership with a company specialized

[3] Simplified Joint-Stock Company
[4] Ordinary Industrial Waste

in the recycling of demolition waste, including the crushing and recycling of waste wood, concrete, and rubble. By collaborating with this local supplier of recycled materials, which is conveniently located only 1.8 km away, Sigma was able to replace its distant supplier, located 150 km away in Le Poitou Charente. Thanks to this new arrangement, Sigma's trucks can now directly access the supply of materials at "La Repentie" and use them for earthworks, instead of making the long round trip to the quarries. As the project leader explains, "Rather than buying materials from distant quarries, our trucks can now help themselves from the local supplier and deliver the materials directly to the site" (leader).

Lambda is part of "pallets synergy" and relies on pallets for receiving its raw materials. However, once the materials are unpacked and installed, Lambda ends up with a large amount of pallet waste: "*We receive our raw materials on pallets and once installed, in fact, we end up with large volumes of pallet waste and up to now we didn't know what to do with it"* (Director General). Previously, the solution was to dispose of the pallets in a dumpster and pay a service provider to manage the waste. Thanks to the CE project, Lambda was able to terminate its contract with the service provider and seek new opportunities to reuse the waste pallets. As the Director General explains, "*the CE initiative allowed us to form new partnerships with other companies and reuse our pallet waste, instead of paying for its disposal*".

Increase in the number of suppliers

Iota specializes in the collection, sorting, and recovery of various types of waste materials such as paper, cardboard, wood, and plastic. As part of the "Biomass synergy," Iota receives waste streams for the purpose of recycling or repurposing in building mechanization. With the CE project, Iota has signed a contract with a new waste supplier located at the port, which has increased the number of its suppliers and expanded its opportunities.

Kappa is involved in the galvanization of metal surfaces for its customers and is part of the "pallet synergy" initiative. Kappa receives used pallets from a company, which it reuses for logistics operations related to the delivery of galvanized materials. With the CE project, Kappa has also increased the number of its suppliers since it did not have any prior relationship with its current supplier before the project. Overall, the CE project has brought positive change to both Iota and Kappa by offering them new partnerships and opportunities that were previously unavailable.

Change of Supply location

Sigma, Iota and Kappa which belong to different synergies have seen their supply sources changed to short-circuit supply to minimize the distance traveled by their supplies. Previously, Sigma obtained its materials from quarries in the Vendée region, which meant a round trip of approximately 300 km: However, Sigma now sources recycled materials in La Rochelle territory to reduce its carbon footprint. As one of its engineers stated, *"La Rochelle is an area with a shortage of quarries. Today, for quarry materials, you have to go get them in the Vendée" but with the CE project, Sigma has found a more convenient source of materials.*

Similarly, Iota has found a new source of waste supply located close to its operation, thereby reducing its carbon impact. As they explain, "*In the carbon balance, we are only 1 km from the*

rotation of the dumpster." Kappa had previously obtained pallets from Deux-Sèvres and Aytré but with CE, it has developed new partnerships and sourced pallets locally in La Rochelle territory.

Overall, the CE project has enabled these three companies to move from the long-circuit supply to short-circuit supply, leading to reduced transportation distances and emissions as well as more sustainable sourcing strategies.

Self-sourcing

Sigma owns a significant number of old buildings in the port area, including blockhouses, and is committed to sourcing recycled materials for its needs. In order to achieve this goal, Sigma has decided to recycle its demolition waste instead of simply disposing of it. As one of its engineers explains, "*Rather than crushing the materials and not backfilling them on our sites, Sigma plans to integrate this recycling strategy in its calls for tenders. By demolishing a building, for example, Sigma will obtain recycled rubble and become the owner of the resulting stock of materials. Then, Sigma will ask third-party companies X or Y to implement this stock for its various needs*."With this approach, Sigma can reduce its reliance on virgin materials and promote the use of recycled materials in its operations. By taking control of the recycled materials supply chain, Sigma can ensure the quality and sustainability of the materials it uses, while supporting the local circular economy.

Change in the management of waste streams

Epsilon used to manage its waste streams in two stages: collection, picking up, and sending it as OIW. This waste management policy caused significant ecological losses. As the Deputy Director stated, "*You should know that previously, all this waste used to be put into the same dumpster, which means we didn't bother to sort or separate them. We took all the piles and sent them as OIW*."

With the implementation of the CE project, Epsilon is now managing its port waste streams differently. To ensure better waste recovery, Epsilon is integrating new stages in the waste management process, such as identifying the waste type, collecting, storing, and finally transporting it to the treatment center.

The new waste management process has impacted the dock cleaning process significantly. Previously, the cleaning of port docks was a single-step process. However, with the implementation of the CE project, the process is now dock by dock to ensure better sorting of waste and to avoid the risk of mixing. Mixing waste would make the treatment process difficult, as stated by an employee: *"The cleaning of docks has changed. When we clean a dock, for example, on fertilizer, there is now a whole procedure that we have to follow before proceeding to the next dock, such as that of cakes. We have a sweeper that comes to clean and suck up all the waste, which we will empty into the dumpster. The state of the waste determines the cleaning process; if it sticks, we have to return to the workshop, wash the sweeper's dumpster, and then return to the dock to collect the fertilizer waste"*.

Overall, the new dock cleaning process ensures that waste is sorted and treated appropriately, in line with the principles of a circular economy.

Use of secondary raw materials instead of virgin raw materials

Sigma has also achieved a "substitution synergy" by replacing quarry materials with recycled materials. These recycled materials include rubble, marly limestone, and crushed bricks, which come from a supplier Sigma met through the CE project. This innovative approach is a great example of how circular economy principles can create value for companies by promoting the use of sustainable materials and reducing waste.

Increase in the volume of supplies

Omega is a specialized company that recycles demolition waste through recycling, crushing, and recovery of waste wood, concrete, and rubble. Like many other companies in the port area, Omega is also involved in "materials synergy". It has identified new suppliers who provide significant demolition waste such as waste wood and rubble. This has allowed Omega to increase its supply volumes and secure its business. Similarly, Iota has increased its waste volumes through waste streams generated by its new port partner. The CE project has enabled companies to establish new partnerships and catalyze circular economy practices that increase access to sustainable raw materials while also reducing waste and emissions.

Change in the means of communication

The means of information and communication are not spared by CE. The communication system for pick-up requests had to adapt to reduce the waiting time for pick-ups for Epsilon: *"Previously, it used to be a fax system. It was a person from the cleaning service who had to send a fax to the company so as to integrate into the schedule. Now, with our new partner, we set up a new system where we have dematerialized the request; the logistics of the new partner is necessarily equipped with a computer tool; we also created a framework of dumpster exchange orders, where, in the same way, in a spirit of simplicity for everyone, we tried to make it as intuitive as possible, that is to say, a date that allows the requester to know who made the order and check boxes"* (Epsilon Deputy Director).

DISCUSSION

In view of this research, eight main results emanate. The changes are seen at several levels: upstream regarding relations with suppliers and downstream regarding partnership/customer relations. Internally, the changes concern the waste management processes and the means of communication.

Theoretical contributions

The use of the theory of organizational change for the analysis of the types of logistical changes that arise from the operational phase of CE is new and constitutes one of the main contributions of this article. A comparison of before and after CE implementation (Alter, 2003 p.83), this research focuses on the impact of CE on supply chains.

Firstly, the pillars of CE identified at the PALR are: industrial ecology, re-use of packaging, recycling and recovery of waste, reduction of consumption of natural resources through substitution, sustainable supply and short circuit supply. These pillars have driven change and created lasting value in supply chains.

Secondly, the cases studied show that all sectors of activity are concerned by CE. The case of the PALR, despite the diversity of activities, has been a favorable ground for CE. Consequently, ports can play their role as privileged actors for accelerating the ecological transition and improving their economic, social and environmental competitiveness (Cerceau et al., 2014).
Thirdly, we highlight the changes to supply chains. To this end, we have identified 8 main changes. The practice of "4Rs" (reduce, reuse, recycle, recover) and sustainable sourcing impact supply chains both upstream and downstream. These changes are affecting suppliers, partners and supply methods. In addition, recycling, recovery, and reuse practices increase the volumes of supplies, the number of suppliers and transform supply methods from long circuits to short circuits. Furthermore, the reduction in the consumption of natural resources materialized by substitution creates self-supply. The logistical management of waste with a view to recycling and recovering has created a new logistical management process that integrates the activities of identifying, sorting, storing and transporting waste.

Fourthly, communication and information systems have been affected and modified by CE. The implementation of CE required the dematerialization of communication systems in order to make easy the exchange of information between the different actors involved in the synergy. Various works have already highlighted the importance of information sharing for the success of CE (Zhu & Coté 2004; Morales et al., 2019).

Fifthly, several advantages flow from these logistical changes. First, an environmental impact materialized by the reduction of the consumption natural resources, reduction of carbon impact and waste. Then, the economic level is marked by the reduction of supply, waste treatment and transport costs (Chertow, 2007).

Sixthly, we identify activities related to the closed loop supply chain (the looping of material flows), sustainable logistics (reduction of environmental impact), green logistics (waste management and treatment) and reverse logistics (return of used products to the circuit). The interweaving of these concepts, within the framework of CE, leads to circular supply chains (De Angelis et al., 2018).

Seventhly, our research identifies the important, although modified, role of supply chains in the operational deployment of CE. Indeed, the implementation of CE requires acting on transport, sources of supply, partnership relations and consumption of raw materials (Fulconis et al., 2016).

Managerial contributions

At the managerial level, our research raises companies' awareness of the possible logistical changes triggered by CE. These changes occur in waste management processes, partnership

relations, supplies, means of communication and information and transport. Depending on the pillar and/or the synergy put in place, there is a change.

Moreover, CE offers companies the possibility of guaranteeing and securing their activities thanks to new woven local supply chains and the use of local waste transformed into secondary raw materials (Gruner & Power, 2017). Thus, we encourage companies to deploy CE, some of the benefits of which, once again, are demonstrated in this research. Through the different environmental gains obtained by companies, we emphasize that CE practices do indeed converge towards the sustainability of supply chains. In addition, it is important that ports that are still lagging behind in the deployment of the circular economy get on board because these changes are made with the aim of making ports sustainable.

CONCLUSION

This paper focuses on the supply chain transformations resulting from the implementation of CE in a port context, which is an area that has received little attention in CE literature. Our findings suggest the need to adopt multiple perspectives when considering CE. Globally, we have identified eight significant changes in supply chains related to industrial ecology, recycling, reuse, recovery, and sustainable consumption resulting from the implementation of CE within companies. As a result of these changes, companies are developing new supply chains through enhanced collaborations generating new streams, which require the active involvement of the logistics function. The logistics function is a crucial aspect of CE implementation, and it is impossible to separate the two terms. Port areas, with their diverse activities, play an essential role in promoting sustainable supply chains through CE practices. These initiatives and collaborations will lead the way for sustainable development by transitioning from a linear economy to a CE, which can improve the sustainability performance of the territory. CE can bring performance in terms of sustainability, which is necessary for the growth and development of any area. Overall, our study highlights the importance of considering the logistics function and port areas in promoting the transformation towards a circular economy for sustainability and growth.

Future research

The limitations of our research primarily involve the small sample size of six companies, which may limit the generalizability of our results. Future research should aim to expand the sample size and explore other port areas to identify other variables that can impact the supply chains of companies. Additionally, the full potential of CE has not been fully revealed in this study, and it would be relevant to investigate with other companies the benefits of CE on supply chains. Further research can explore how specific CE practices contribute to improved supply chain sustainability, efficiency, and overall business performance. Furthermore, future research could examine the challenges and barriers to implementing CE in a port context, the role of public policies, and stakeholder collaboration. Overall, this study provides a foundation for future research to explore the transformative potential of CE for sustainable supply chains in port areas.

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