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The Benefits of the Circular Economy for Companies' Circular Supply Chains in A French Port Area

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ABSTRACT: *The current situation of depletion and increasing scarcity of renewable and non-renewable natural resources calls for concrete and rapid action by governments, as the planet is currently living on credit. The circular economy can help tackle challenges such as waste gestion, pollution, biodiversity protection and climate change, by reusing production waste and by-products to reduce consumption of resources and safeguard the needs of future generations. The circular economy offers a number of environmental, economic and social benefits. This article presents the benefits of circular supply chains for companies in the Atlantic Port of La Rochelle. We used a qualitative methodology and carried out an in-depth study of 6 companies involved in the port's circular economy project. The results show a number of benefits, including a reduction ordinary industrial waste, financial savings, a reduction in the consumption of virgin resources and a reduction in carbon impact on circular supply chain.*

KEYWORDS: circular economy, circular supply chain, ports, advantages.

INTRODUCTION

In response to climate crises, the increasing scarcity of natural resources, the rising cost of raw materials and the environmental impact of activities, the circular economy is presented as a virtuous and effective solution to remedy the situation, and the covid crisis has more than demonstrated its importance (Ibn et al., 2021). The circular economy optimises the total cycle of materials from raw materials to finished products and the total elimination of waste (Graedel, 1994).

To this end, over the last decade, organisations have systematically implemented production and supply chain systems to extend the life cycle of products, by-products and useful waste (Batista et al., 2019). Supply chain management offers important opportunities for companies to meet the imperatives of the circular economy (Batista et al., 2018) and plays an important role in its integration process (Fulconis, Paché and Reynaud, 2016; De Angelis et al., 2018). The integration of the circular economy into the supply chain is linked to an increase in the rate

of remanufacturing, reuse and recycling (Batista et al., 2018). Universally recognised, the circular economy is full of environmental, economic and social benefits. A study carried out by the Circular Economy Institute in 2015 presents the circular economy as being able to make an effective contribution to the COP21 solutions plan, in terms of reducing greenhouse gases (GHGs), i.e. a reduction of around 35% in a circular system. It would also be a solution in the fight against climate disruption (Aurez et al., 2015). Ports, which are an integral part of the supply chain (Carbone and De Martino, 2003), are considered to be sources of pollution (Junqua and Moine, 2007; Lorek, 2012). To remedy this, French port areas are increasingly incorporating the circular economy into their competitiveness strategies. Ports are increasingly aware of the negative impacts of industrial and logistics activities and are therefore taking a keen interest in the circular economy. French ports have also become aware of this issue and have decided to integrate the circular economy into their development strategy, with the aim of becoming major players in circular supply chains (Mankowska et al., 2020). Indeed, the number of initiatives in port areas has increased fourfold and investment twofold over the period 2015-2019. 90% of these investments are concentrated in the 3 major seaports: Le Havre, Marseille-Fos and Dunkirk (De Lorgeril, 2020).

In this context, where ports are making the circular economy a competitiveness strategy, we ask the following question: what are the advantages of the circular economy for the Atlantic port of La Rochelle? The aim of this research is to highlight the benefits of the circular economy for companies in the Port of La Rochelle and for the port itself. To date, no study has addressed the issues related to the benefits of the circular economy on the PALR. To this end, we studied the benefits of the circular economy in the port area of La Rochelle, using six case studies of companies. Qualitative data was collected through semi-structured interviews and analysed using N'vivo Version 12Plus software. This research shows that (1) ports play an important role in the ecological transition and (2) the ecological, economic and social benefits are clear for companies.

The first section presents the literature review. The second section presents the research methodology. The third section presents the results of the research and the fourth section concludes with a discussion and a conclusion

LITERATURE

Circular economy

Although the concept of the circular economy has been around for a long time, it is difficult to determine its exact origin due to its debates and controversies. Its foundations date back to a time well before industrialisation, when refurbishment and repair had been part of everyday practice for several centuries. However, these practices gradually disappeared with the advent of industrialisation. In 1966, the economist Kenneth E. Boulding revived the idea of a circular economy by comparing the Earth to a spaceship with limited resources. He then proposed setting up a "loop economy" (Le Moigne, 2014 p.39). Subsequently, Reday and Stahel also took up the circular economy concept in 1976 and 1989, particularly after the 1973 oil shock. Faced with the oil price crisis and high unemployment, Stahel and Reday proposed a study on the substitution of energy for labour to the Commission of the European Community in Brussels. The results of this study demonstrated the many advantages of setting up a "loop economy"

such as the sustainable management of resources through their rational use, the creation of regional jobs, the prevention of waste and the dematerialisation of the industrial economy. The term 'circular economy' is used today to refer to this new approach (Aurez et al., 2015; Geissdoerfer et al., 2017). In the same context, Stahel also noted in 1982 that the most appropriate sustainable business model for a loop economy is the sale of use rather than ownership of goods, allowing companies to make a profit while avoiding externalising the costs and risks associated with waste (Geissdoerfer et al., 2017).

Furthermore, Ghisellini et al. (2016) point out that the concept of the circular economy can be traced back to different schools of thought. Environmental economists Pearce and Turner in 1989 introduced the concept of the circular economy based on earlier studies by Kenneth E. Boulding. They describe how natural resources influence the economy by providing inputs for production and consumption and by acting as a sink for outputs in the form of waste. They then examine the linear and open characteristics of today's economic systems. They also explain the shift from the traditional open economic system to the circular economic system, a consequence of the law of thermodynamics that governs the degradation of matter and energy.

From the 1990s onwards, the circular economy gained ground with policymakers and influenced governments and intergovernmental agencies at local, regional, national and even international levels (Geissdoerfer et al., 2017). Since 2013, France has been using the circular economy as a tool in its battle to protect the environment. A law on the circular economy and the fight against waste, enacted in 2020, aims to accelerate manufacturers' production and consumption models through extended producer responsibility, reduce waste by limiting the marketing of plastic packaging, and combat waste by banning the incineration or burial of new non-food unsold products.

The circular economy is defined as a regenerative system in which the input of resources, waste, emissions and energy leakage are minimised by slowing down, closing and shrinking material and energy loops. This can be achieved through sustainable design, maintenance, repair, reuse, remanufacture, renovation and recycling (Geissdoerfer et al., 2017 p.759). Other definitions highlight the cyclical nature of the circular economy and compare it to the natural ecosystem cycle with two important flows: biological flows (biodegradable materials) and technical flows (materials, components and non-organic products) (Ellen MacArthur Fondation, 2014). For Murray et al. (2017), the circular economy is the business supply chain that works for more environmental value.

The implementation of the circular economy takes place at three levels: the micro level (intra-firm), the meso level (eco-industrial parks) and the macro level (circular practices at the scale of a city, a region) (Ghisellini et al., 2016). For the multi-level approach to the circular economy, industrial symbiosis represents a key issue because it is "the activity that engages traditionally separate industries in a collective approach to competitive advantages involving the physical exchange of materials, energy, water and/or by-products" (Chertow, 2000).

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Circular economy's advantages for circular supply chains

Suply chain

From the 1980s onwards, in order to survive the changing environment, companies were forced to reorganise both internally and externally. Internally, all the previously separate purchasing, manufacturing and distribution functions joined forces to manage physical flows. Externally, it is essential for all functions to work together with suppliers and customers to ensure the overall performance of the supply chain (Camman, 2007 p. 40). What emerges is a supply chain management approach that involves both upstream (suppliers) and downstream (customers) relationships. Ganeshan et al. (1998) note that a supply chain is a network of production entities and distribution sites that performs the functions of supplying materials, transforming these materials into intermediate and finished products, and distributing these finished products to customers.

The supply chain is considered to be a source of environmental pollution, accounting for half of all CO2 emissions (Fons and Jan, 2013). Traditional supply chains are based on linear thinking, in which raw materials are extracted, processed, consumed and discarded. This is still a very dominant activity in industry (Dervojeda et al., 2014). Environmental management consists of making the supply chain responsible for reducing the consumption of materials, energy and waste production (Belin-Munier, 2010).

Circular suply chain

Supply chain management offers significant opportunities for companies to meet the sustainability imperatives of the circular economy. The principles of the 6Rs of the circular economy integrated into supply chains consist of increasing the rate of remanufacture, reuse, reemployment, recycling, reduction and repair (Figure 1) (Batista et al., 2018; Batista et al., 2019). The transition to a circular economy is therefore changing supply chains (Larsen et al., 2018), giving rise to the concept of a circular supply chain (De Angelis et al., 2018). According to Dervojeda et al, (2014) "a circular supply chain refers to a production model that is restorative in nature. Essentially, it means that when manufactured products or goods reach the end of their life, they are taken back by a manufacturer and fully reused as raw material for new production". The circular supply chain starts with a broad understanding of business model adoption and further summarises circular product, circular supplier selection and management capability for use, end-of-use and end-of-life phases (Nag et al., 2021).

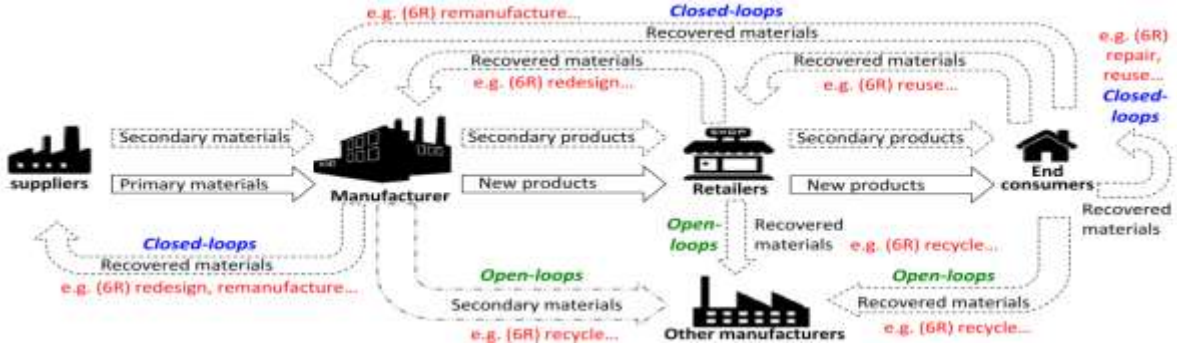

Figure 1: A circular supply chain archetype, Source: Batista et al., 2019 p.7252

Environmental benefits of circular supply chains

Environmental benefits are defined by Dong et al. (2013) as the consumption and/or emissions avoided by the company. Environmental performance is based on the reduction of resource consumption, which refers to the saving of raw materials through the use of reused or recycled materials and the reduction of waste emissions (Guo et al. 2016). Resource scarcity is a key factor for all companies looking to implement circular economy solutions. To improve the use of materials and optimise cycles of valuable resources, valuable materials such as metals can be separated from waste and production leftovers such as ash can be reused. In this way, companies can help to reduce the pressure on natural resources and promote a more sustainable use of materials (Foroozanfar et al. 2022). The example of Kalundborg in Denmark has demonstrated the environmental gains associated with the circular economy. Working together to share water and other by-products has led to a reduction in groundwater use of 3 million cubic meters, a reduction of 275,0000 tons of CO2, SO2 and other greenhouse gases (Jacobsen 2006). In the UK, between 2005 and 2013, the national industrial symbiosis program prevented 47 million tons of industrial waste from being landfilled, reduced CO2 emissions by 42 million tons, reduced raw material consumption by 60 million tons and reduced water use in the industrial system by 73 million tons (Le Moigne, 2018 p.105). In addition, companies in the port of Gdansk in Poland underwent conversion in the face of the economic crisis of the 1970s. A number of measures have been taken to solve this problem, including the circular economy. The port of Gdansk, which was heavily dominated by the metallurgical and petrochemical industries, had many negative effects on the environment. The solution was to encourage other companies to set up in the biotechnology and nanotechnology sectors, which have expertise in the degradation of toxic substances and waste, as well as the recycling of end-of-life products. This was an opportunity for the port's companies to develop their environmental management, in a context where the application of European environmental standards is being imposed on them (Lorek, 2012).

In China, companies that have practised the circular economy have helped to mitigate environmental degradation. Guitang Group's industrial symbiosis, which includes a sugar refinery, has reduced its environmental impact by reusing its by-products. Its by-products are reused as raw materials in the cement plant. This reduces the environmental impact of its effluents (Zhu and Coté, 2004). Morales et al (2019), show that the exchange of flows on the Altamira industrial estate saved 44,820 tons of wastewater, 44,400 tons of carbon dioxide and 26,720 tons of carbon monoxide per year on processes. The company also promoted its image as a green business. Another example of environmental benefit is given by Guo et al (2016): a Shenhua thermal power plant and the Tianshan cement manufacturing industry, which received around 1.63 million and 1.45 million tons of recyclable materials respectively. Furthermore, the automotive industry is a major consumer of resources and is very concerned with resource efficiency, lean manufacturing and materials-aware design. The implementation of CE practices represents a powerful means of transforming or evolving business models in the current linear system towards a resource-efficient, low-carbon and sustainable circular economy (Agyemang et al., 2019). Khan et al. (2022) define resource efficiency as the more economical and rational use of raw materials, energy and other resources.

Industries that adopt industrial ecology reduce the production of waste, the consumption of renewable and non-renewable raw materials and their ecological footprint, by reusing waste, etc., achieving environmental performance and, in turn, maintaining a green image with the public. In addition, the exchange of water waste and excess heat and steam between industries promotes the optimal use of energy and water in the production system of companies (Beaurain and Brullot, 2011; Foroozanfar et al., 2022).

Economic benefits of circular supply chains

Economic reasons play a major role for industries (Boiral and Kabongo, 2004). They are interested in the circular economy because of the economic performance it triggers, the creation of economic value it brings and the winning opportunities it offers. Adopting circular economy practices is an opportunity for businesses to strengthen their corporate social responsibility and build customer loyalty. Indeed, circular economy initiatives can attract new customers, improve the relationship with existing customers and strengthen their commitment to the company to meet their needs. Good and higher quality circular products ensure that the consumer enjoys the same or even higher satisfaction than the traditional linear product (Agyemang et al., 2019). In this respect, the cost/benefit ratio is decisive for manufacturers who agree to exchange flows. Economic performance involves substituting raw materials with recycled materials. In most cases, reused or recycled materials cost less than virgin materials. Sending waste to other industrial units eliminates the costs associated with its disposal. Some revenues come from the sale of waste to other manufacturers (Dong et al., 2013; Guo et al., 2016; Khan et al., 2022) and from resource sharing (Chertow, 2007). The study by Guo et al (2016) shows that the Huatai chemical industry achieved an economic benefit worth US$24.29 million annually. The same is true for a steel industry in Liuzhou, China, which made economic gains of over $36.55 million, and another in Kawasaki, Japan, which made savings of $54 million (Dong et al., 2013). The example of the Guitang Group factories given by Zhu and Coté (2004) shows the economic gains for the producers, which is the increase in market share despite the large number of other sugar producers in the Guitang region. They also obtained low-priced raw materials from other Guitang Group factories and became competitive on the sugar market in China. The circular economy enables the donor to reduce the costs of processing outgoing flows and receives a fiscal return through sales. Le Moigne (2018 p.105) gives the example of Denso in the UK, an automotive supplier that makes air conditioning systems. The company spends £30,000 on eliminating hazardous production waste (potassium aluminium fluoride). This sum was reduced thanks to the recovery of this waste by another company, Mil-Ver Metals, an aluminium manufacturer. This is a double gain. In turn, the recipient reduces its supply costs (Adoue, 2007 p.68). In the Kalundborg symbiosis, Gyproc, the plasterboard manufacturer, reduces its supply costs by recovering recycled gypsum at a lower price (Le Moigne, 2018 p.105). Moreover, Agyemang et al. (2019) reported on the benefits of implementing CE in the context of the automobile industry in Pakistan. The authors found that economic aspects such as profitability, market share, profits, and cost reduction are the most important drivers for a business. Foroozanfar et al. (2022) point out that implementing circular economy practices can rejuvenate existing businesses and create new service businesses, facilitated by access to more reliable and accurate circular economy-related data and new information management systems. These systems include platforms that improve the visibility of a company's supply chain,

enabling a better understanding of where materials come from, how they are used and recovered at the end of their life, and more informed procurement and waste management decisions. This better understanding of the supply chain can lead to greater efficiency, reduced costs and improved competitiveness for the business.

Social benefits of circular supply chains

The implementation of the circular economy encourages the creation of social links and even the resolution of social conflicts (Beaurain et al., 2017). It enables the creation of links between businesses through interactions that did not initially exist and interactions between businesses and local populations. Moreover, Gabor et al (2018) point out that 4,000 jobs would not have been created without the activities linked to the Kalundborg industrial symbiosis. The same applies to the Valuepark Schkopau industrial symbiosis in Germany, which has created more than 700 jobs (Le Moigne, 2018 p.105). The circular economy benefits all stakeholders in emerging economies. Companies are encouraged to use information exchanges and data to create components that can be recycled and reused in new products, thereby promoting socially responsible manufacturing and stakeholder satisfaction (Foroozanfar et al., 2022).

METHODOLOGY

Context: ports, players in the ecological transition

Ports are access points that connect sea and land routes using several modes of transport. Their number increased between 1890 and 2008 in correlation with the increase in the number of ships, due to the development of world trade (Alix and Ducruet, 2015). Ports are part of the supply chain in that they play an important role in the management and coordination of physical and information flows (De Lorgelil, 2020).

Port areas attract many industries because of their proximity to international markets. By locating close to ports, manufacturers can reduce transport costs while benefiting from convenient and easy access to ship loading and unloading. Although some industries located in port areas have less polluting activities, others, such as the heavy industries of oil refineries, steel and coal production, as well as industries specialising in the manufacture of chemical products, pulp and paper mills, and metallurgical industries, have a negative impact on the environment and surrounding populations (Junqua et Moine, 2007; Lorek, 2012; De Lorgelil, 2020). In addition, port areas are places where hazardous waste (liquid or solid) is discharged into the seabed (Cerceau et al., 2015) and where atmospheric pollution occurs. Faced with economic and regulatory pressures, ports have a duty to protect the environment. To promote economic development without impacting the environment and local communities, strategies include diversifying business sectors, welcoming new companies, converting production processes, managing industrial risks and waste on the one hand, and opting for circular economy practices on the other. Indeed, ports are increasingly adopting the circular economy/industrial ecology to become "clean ports" (Rainaud, 2021 p.142).

Port areas are veritable laboratories for implementing the circular economy (Mat et al., 2012), as they offer a unique opportunity to experiment with new ways of managing waste, energy and

materials. Alix and Ducruet (2015) point out that the circular economy introduces a new way of managing, using and recovering these elements. As a result, circular economy approaches are finding as much resonance in industrial estates as they are in port areas.
Mat et al (2012 p. 238) show that the circular economy is perceived by ports as:

- a diagnostic and management tool for responding to environmental issues in port areas,
- a technical and socio-economic solution for competitive advantage,
- a national policy for managing natural resources,
- a local strategy for creating partnership actions to maintain competitiveness.

These different perceptions show the important role played by ports in reducing the environmental impact of the supply chain.

Like many other French ports, the Atlantic Port of La Rochelle (APLR) has decided to commit to circular economy initiatives. APLR is particularly committed to sustainable development and has drawn up a "sustainable development charter" that has been signed by 26 companies. This charter focuses on quality, safety, social responsibility and the environment, and has enabled APLR to renew its Quality, Safety and Environment certifications, notably ISO 9001, 45001 and 14001. APLR has responded to a call for projects aimed at promoting the integration of the circular economy into the practices of port companies. The process began with a technical diagnosis of the flows and a pre-feasibility study. The diagnosis was carried out individually, looking at incoming and outgoing flows, materials consumed, waste produced, water used and discharged, energy consumed and emissions. The diagnostic therefore used maps to represent the various flows into and out of the port. The data collected and analysed from around forty companies was used to set up thematic working groups and exchange synergies. Following the diagnosis, around thirty collective synergies were identified. Only three synergies were rapidly implemented: pallets, materials and biomass. Pallet synergy concerns the exchange of used pallet flows between case 6 and case 4. Biomass synergy concerns port waste between cases 5 and 1. Materials synergy represents the exchange of flows between cases 2 and 3 (figure 2) (Kadio, 2021).

Methodology

The aim of this study is to identify the benefits of the circular economy in the port area of La Rochelle. We chose to adopt a qualitative approach based on the case method (Yin, 2003). The primary data for this study was collected through semi-structured interviews conducted with six companies belonging to different business sectors, the secretary of the union of port companies, as well as the facilitator. Secondary information was gathered from various sources, including the press, steering committee reports, the port's website and videos dedicated to the implementation of the circular economy at APLR. The analysis was carried out using an intra- and inter-case content analysis approach (Bardin, 1993 p.32).

We used a '*purposive*' sample selection for this multiple case study. This method allowed us to apply our own selection criteria based on the principle of "*theoretical replication*". In particular, we chose our cases based more on their involvement in the exchange of flows in the port area rather than on their size, status or sector of activity (Royer and Zarlowski, 2014 p. 236).

Table 1: Presentation of the different cases

Selection criteria	Different cases studied	Activities	People interviewed	Length of interview
Located in the port area Exchange of flows as part of the circular economy approach	Case 1	Tool maintenance and cleaning	Deputy Director and Administrative and Financial Manager Deputy Director	1h 27 mins 1h 20 mins
	Case 2	Port Activities	Engineering Department Manager Engineering Department Manager	1h 11 mins 1h
	Case 3	Building waste recovery	Site manager La Rochelle	1h
	Case 4	Electrical company specialising in industrial and merchant marine installations	General Manager of the La Rochelle site Storekeeper	45 mins 1h 15 mins
	Case 5	Waste collection, recycling, treatment and recovery	Sales manager Sales manager	1 h 27 mins 1 h 05 mins
	Case 6	Metal surface treatment	Manager Site manager Logistics manager	1 h 1h 50 mins
			Project implementation coordinator	1h 20 mins 1 h 1 h 04 mins
			Secretary of the Union of companies in the port of La Rochelle (Maritime Union)	1h

RESULTS

Table 2: Presentation of the different advantages of the cases studied

	Advantages		
Cases studied	**Environmental**	**Economic**	**Social**
Case 1	Reduction of ordinary industrial waste Regulatory compliance Anticipation of environmental legislation Increase in recycling rate	Leader Added value and brand awareness in the port area New identity Modern image Reduction in waste processing costs Profit margins from the sale of port waste	Well-being of local residents New partnership Indirect job creation
Case 2	Regulatory compliance Reduced consumption of natural resources Reducing carbon emissions	Leader Lower supply costs Major benefits Reduced transport costs	Well-being of local residents Consolidation of partnerships

	Use of recycled materials Green image		
Case 3	Reduced carbon impact Reduced use of natural resources Reduced landfill Regulatory compliance	Profit margin Reduced transport costs Visibility	New partnerships
Case 4	Responsible image Good reputation Reduction, reuse, recycling of waste Reduced consumption of natural resources Green image	Competitiveness Lower waste treatment costs Significant profit margins	Partnership consolidation
Case 5	Reduce landfill and/or incineration Reduced carbon impact	Better reputation Increased sales	New partnership
Case 6	Reduction in OIW waste Reduced consumption of new pallets Green image	Better visibility Quality of service Financial savings Competitiveness	Job creation

The results of the research show several exchanges between the companies that participated in the project to implement the circular economy on the APLR. Figure 2 shows several exchanges of pallet waste, construction and deconstruction waste and port waste. According to the needs of the companies and thanks to the mapping of waste flows, the different companies were brought together.

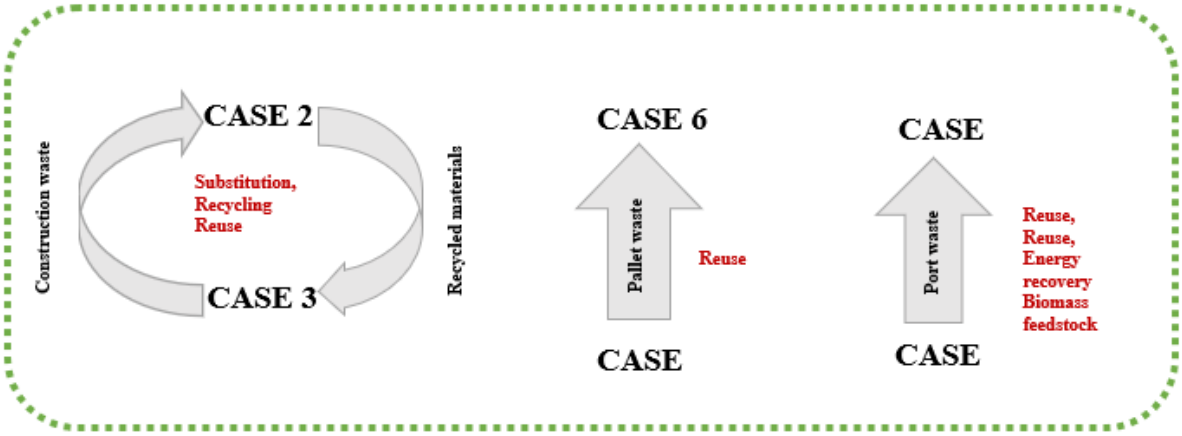

Figure 2: A circular supply chain archetype, at the Atlantic port of La Rochelle.

DISCUSSIONS

Environmental benefits

Depending on the company's sector of activity and/or its position as a giver or receiver, the environmental benefits vary. Guo et al (2016) note that the performance of the circular economy lies in reducing the consumption of natural resources. In general, Cases 6, 4, 2 and 3 show that reducing the use of natural resources is the first environmental benefit observed. This is followed by a desire to comply with environmental regulations. For Cases 1, 2 and 3, this compliance represents a desire to become players in the ecological transition by playing a specific role at their level. Case 1 differs from the other cases in its accommodating (CSR) and proactive (anticipating future environmental regulations) strategy towards environmental laws. This finding is in line with Gabor et al (2018), who note that companies adopt the circular economy under the constraint of environmental regulations. It is clear that the reduction in carbon footprint is significant for cases 5, 2 and 3. As mentioned above, Case 2 reduces its carbon footprint by trading with Case 3. Case 3 helps its customers to reduce their carbon footprint by sourcing locally in La Rochelle. Case 5 manages to reduce its carbon impact by making short-haul rotations, covering only a few kilometers. This reduction in carbon footprint is seen as a mechanism of industrial symbiosis, as highlighted by Leight et al. (2015). Cases 1, 6 and 4, on the other hand, manage to reduce their OIW waste through the circular economy. Case 1 manages to increase the recycling and recovery rate of port waste by 80% by reducing OIW waste, thus avoiding landfilling thousands of tons of waste. Case 4, because of its great sensitivity to environmental issues, reuses pallets both internally and externally.

The implementation of the circular economy at the Atlantic Port of La Rochelle has enabled some companies to obtain a green image and a good reputation, as demonstrated by Morales et al. (2019). Case 2 has differentiated itself by using recycled materials for its constructions, which has helped to improve its image. Other companies, such as Case 6 and Case 3, are considered models in terms of green practices, which has helped them gain greater visibility. Cases 5 and 3 have managed to avoid landfill thanks to the circular economy. This is a plus for both cases, as landfill regulations are becoming increasingly strict and fines are rising. So avoiding landfill is a competitive advantage for both cases.

In fact, reducing OIW, increasing the recycling rate, reducing landfill and reducing carbon impact are all actions associated with circular supply chain. The reduction in carbon impact can be seen in the transport of secondary raw materials or in the collection of waste. In addition, as part of the circular economy, supplies are sourced from suppliers located in the same area.

Economic benefits

The economic benefits of circular economy practices are numerous for the companies studied. They can gain increased recognition, added value, a renewed identity, even a modern image like Case 1, or a leading image like Case 2. Case 1 enjoys a high profile and an excellent reputation for waste recycling, and can even offer advice to other companies in the same sector. What's more, it sets an example in the port area as a successful player in port waste management.

As for Case 2, by agreeing to carry out experiments on the use of recycled materials, it is reinforcing its status as a territorial leader.

Case 5 has acquired a better reputation thanks to its collaboration with Case 1. Working with a company located in the port area is an asset in terms of image. Cases 6 and 4 have strengthened their competitiveness thanks to the circular economy, while Case 3 has increased its commercial visibility in the La Rochelle area. According to Tudor et al (2007), companies that become involved in the development of the circular economy increase their competitive advantage. By adopting circular economy practices, some companies at the Atlantic Port of La Rochelle have managed to reduce their waste treatment costs, such as Cas 1 and Cas 4. For example, Cas 1 has managed to reduce its costs by recovering its waste. As for Cas 4, which was charged for pallet skips, it is now making higher profit margins. It is interesting to note that, according to Guo et al (2016), sending waste to other industrial units for reuse or recycling costs less than sending it to landfill for final disposal. This model can therefore be advantageous for companies looking to reduce their costs while adopting a more sustainable approach. Some companies have succeeded in reducing their procurement costs by replacing natural raw materials with secondary raw materials, which has enabled them to make significant profits. The examples of Cases 6 and 2 illustrate this. Case 2 saved €19,000 by replacing quarry materials with recycled materials, and Case 6 saved €3,000 by using pallet waste.

In addition, transport costs for Case 2 have fallen, as it now sources its raw materials from the La Rochelle area rather than from the Vendée. Case 5 has also seen an increase in its turnover thanks to the adoption of circular economy practices. These economic benefits are undeniable for companies in the Atlantic Port of La Rochelle seeking to improve their competitiveness while reducing their environmental impact. It is true that when companies adopt circular economy practices, whether they are donors or receivers, gains are made at all levels of trade. In fact, the economic benefits obtained can be seen in the circular supply chains in terms of procurement, transport and waste management. Companies can also benefit from reduced production costs, improved profitability and competitiveness, and more effective management of raw material risks. In short, the circular economy offers significant economic benefits for businesses looking to improve their performance and sustainability for their suppl chain.

Social benefits

It is important to emphasise that the circular economy also brings significant social benefits. Implementing circular economy practices encourages social links between businesses in the same area. This can take the form of the creation of partnerships between businesses that did not know each other before, as in the case of the Case 1-Case 5 pairing, or to strengthen existing relationships, as in the Case 6-Case 4 and Case 2-Case 3 pairings. Companies can also benefit from indirect job creation, as in Case 1, or direct job creation, as in Case 5. As an example, the Kalundborg industrial symbiosis model, as described by Gabor et al. (2018), has created around 4,000 jobs through the implementation of circular economy activities. The social benefits offered by the circular economy are therefore numerous for companies in the Atlantic Port for La Rochelle, which can establish new partnerships for the supply and recovery of waste, and thus strengthen social ties and local economic dynamics.

Implication to Research and Practice

Theoretical contributions

Several studies have been carried out on ports and sustainability to present them as players in the ecological transition and the benefits that arise from the implementation of the circular economy for the companies involved (Cerceau et al., 2014; Mankowska et al., 2020; Foroozanfar et al., 2022). Our research work is in the same vein contributing to current, knowledge on the benefits of the circular economy, namely reduction in waste processing costs, reduction consumption of natural resources, new opportunities, etc. This research into the benefits of the circular economy in a port supports the literature that highlights the many benefits of the circular economy. As integrators of multiple activities, ports are ideal places to accelerate the ecological transition of territories by developing circular economy and industrial ecology models. By developing circular economy and industrial ecology models, energy transition projects for industrial port areas, and the routing of goods by rail and river. The study also has theoretical implications. First, there is the generalisation benefits of the circular economy. Most of the benefits of the circular economy have been found in the literature, and their relevance and application in PALR.

The Atlantic Port of La Rochelle is further confirmation of the role that ports can play in the move towards ecological transition. As state institutions, ports are leaders that can rally a group of companies behind them to protect the environment. To this end, the objectives are to increase the attractiveness of industrial port areas, in particular for companies focused on the ecological transition, and to improve the competitiveness of ports.

Managerial contributions

Firstly, the circular economy offers many economic, environmental and social benefits to businesses and local communities. It is therefore important for businesses to consider the benefits of this approach in order to seize the opportunities that arise. Indeed, the results can help managers integrate circular economy strategies into their strategic planning, by identifying opportunities to reduce costs and natural resource consumption, reuse materials and reduce the ecological footprint of their business or sector.

Secondly, we are also encouraging public authorities to finance circular economy projects in ports, as was the case for the Atlantic Port of La Rochelle to adapt sustainable practices. The French port ecosystem has the opportunity to play a decisive role in decarbonising transport chains by 2050. To this end, we are providing them with a concrete example of circular economy projects implemented in a port with other companies from different business sectors.

Thirdly, many port players are seeking to make their supply chains as virtuous as possible in order to meet the demands of distributors and end consumers. For French ports and economic players, the deployment of the circular economy can improve the performance of supply chains towards circular supply chains and contribute to competitive advantages. Indeed, the benefits of the circular economy highlighted can help managers to make more informed decisions and develop more sustainable practices, which can have positive effects on the economic and environmental performance of their business.

Finally, the results of this research can also serve as an incentive for port companies and port management bodies that are still reluctant to value circular supply chains. It is therefore important to encourage further circular economy projects in ports that have not yet seen investment.

CONCLUSION

Our research has highlighted the various benefits arising from circular economy practices in a French port area, in particular the Atlantic Port of La Rochelle. Environmental, economic and social gains were identified in the circular supply chains in the various cases. A number of benefits have been identified, from upstream to downstream and internally. Firstly, there is a reduction in the cost of raw materials, waste treatment and transport. Secondly, reduced environmental impact, which means less waste going to landfill, reduced consumption of raw materials and energy, which helps the company to reduce its carbon footprint and comply with environmental regulations. Then there is the improvement in reputation with stakeholders such as customers, investors and regulators, which is beneficial for the image and loyalty of customers, and thus helps to improve the company's profitability and competitiveness. Finally, implementing circular economy practices can encourage collaboration between businesses, which is beneficial for knowledge exchange, cost reduction, performance improvement and job creation.

Future Research

As far as our research is concerned, our results are limited to the APLR's fieldwork, the cases of 6 companies belonging to 4 sectors of activity and the 15 interviews carried out. It would be interesting to enrich and broaden the cases studied and the field of study in order to further refine the results.

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