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School of Industrial and Information Engineering

Master of Science in Management Engineering

Exploring Tools and Enablers for Sustainable Supply Chain Management

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Abstract

During the recent past, sustainability in supply chains has gained more attention and raised more concerns, due to the growth of various external factors that put supply chains everywhere under test. Hence, supply chains need to be managed with a sustainable manner, to prevail against these uncertainties and be prepared for upcoming ones. With that in perspective, this research paper attempts to explore the sustainability realm in supply chain management, by evaluating the key enablers to achieve sustainable supply management, the main tools used to activate these enablers, and the effect that these enablers and tools have on the sustainability performance of supply chains. In addition, the paper also highlights the main supply chain processes affected by the sustainability performance, and how sustainability could enhance those processes. The paper also attempts to explore a practical case study, showing the potentialities of these enablers with a real technological solution, aimed at enhancing the sustainability of the supply chain. The main enablers of sustainable supply chain management found in the literature and in the case study were visibility, collaboration, and efficiency. To activate these enablers, modern tools such as emerging technologies and Industry 4.0 technologies are taken advantage of, thereby unlocking further levels of these enablers that were not attainable with traditional tools.

Keywords: Sustainable Supply Chain Management*, *Transportation, Logistics, Resilience, Visibility, Collaboration, ICT, Internet of Things (IOT), Blockchain

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1. Introduction

1.1 Supply chain management

Supply chain management has always been a crucial part to the success of any business. Due to the wide scope of activities, actors, and functions that supply chain management covers, it is possible to find countless definitions for it in the literature. Consequently, a review conducted by (Stock and Boyer, 2009) has gathered over 170 definitions of supply chain management and proposed a consensus definition that comprises all the main components presented by those definitions. They defined supply chain management as : " The management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction"

The definition shows the extremely broad scope which supply chain management covers, hence the great importance of studying it, and exploring its aspects. Supply chains in the past were much simpler and less complex than today's supply chain, mainly because businesses were mostly vertically integrated, were all stages of converting the raw material as well as services to bringing it to the final customer, were managed by the manufacturing company. However, this was a time where demand was stable and homogenous, and capacity was much less than that demand, so firms were competing on capacity and production. As the characteristics of demand began evolving, so did those of the supply chains. Demand became uncertain and dependent on customization, therefore products also evolved into various ranges, with short lifecycle. To cope with this evolution, companies also had to evolve, by focusing on their core competences and specializing in it, acquiring new skills and competences, and eventually resorting to one of the main cornerstones and influencers of modern supply chains, outsourcing. Because every company has core competences in a specific area that grants it competitive advantage, allocating money, effort and resources to other areas was bringing inefficiencies to supply chains, and would reduce the supply chain profitability. Therefore, companies started to outsource those activities to other supply chain partners. This is because companies now are not just competing on capacity; but they are competing on time, cost, flexibility, and reputation. In short, supply chain actors are now striving to be more sustainable, resilient, and innovative.

1.2 Supply chain complexity and threats

Over the past few years, supply chain management has gained an immense amount of attention, due to various externalities and unforeseen events that has exposed them to a lot of threats and showed that supply chains could become very fragile if mismanaged or neglected. These threats could be represented in supply threats, such as the current shortage of semiconductor raw materials and metals, environmental threats such as natural disasters, political threats, like political instability in the country where the supply chain partner is located, or of course global pandemics such as the recent outbreak of the Coronavirus that disrupted whole supply chains around the world. To comprehensively and simply understand the macro externalities that might face a supply chain, the famous PESTEL framework could be referred to, to assess the Political, Economic, Social, Technological, Environmental, Legal aspects that surround a supply chain. The effects of these threats and externalities are amplified more so by the growing complexity and uncertainty of supply chains. Complexity and uncertainty, in turn, are fueled by the increasing number of nodes in the supply chain and supply chain actors, that is mainly motivated by outsourcing and globalization. Lately, globalization has become an essential tool used by many businesses, especially the big ones. Firms could go global either by outsourcing certain activities oversees, which is also known as offshoring, or by expanding globally. Not only has the recent spread of outsourcing created more actors and nodes in supply chains, but it also created whole new markets with various opportunities for competitors to join and provide services at competitive prices. As a result, the lengths and widths of supply chains have become very long and deep. There are now tiers withing supply chains that focal companies or main actors do not even know about, which, is an enormous source of threat for supply chains. With offshoring, the complexity and uncertainty become even stronger, due to the distance between the nodes. Supply chain complexity could be divided into static complexity, dynamic complexity, and decision-making complexity (Serdarasan, 2013). Static complexity relates to the structure of the supply chain and the components involved, while dynamic complexity is more related to the uncertainty of the supply chain operations. On the other hand, decision-making complexity combines both aspects of static and dynamic complexity, and it is represented in the strategic actions taken by the actors in the supply chain (Serdarasan, 2013). Serdarasan then categorized the drivers of supply chain complexity according to their origins; mainly internally externally, or from the supply/demand interface. For instance, an internal driver of static complexity could be the number or variety of product, and external one could be the changing needs of customers, and a supply/demand interface could be the number and variety of suppliers or customers. Therefore, supply chains are thriving to counteract those threats and see through the complexities of the chains through better managing them. One of the ways of efficiently managing supply chains and overcoming complexity and uncertainty is through sustainable supply chain management.

1.3 Importance of sustainability in supply chains

During the recent past, sustainability has gained solid ground as one of the strategic pillars that companies thrive to incorporate into their main objectives and values, to ensure business growth, as well as to sustain a competitive advantage in terms of either costs or product/service differentiation. And since supply chain management is crucial to the success and fulfillment of business objectives and strategy, the field of sustainable supply chain management consequently emerged. One of the most comprehensive definition of sustainable supply chain management found in the literature is that of (Ahi and Searcy, 2013) which states: “The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term.” This definition is significant because it covers all three areas of sustainability, which will be discussed in more depth in the literature review, as well as all types of flows in the supply chain, in addition to all the important stages and processes in the chain. Over the recent past, several themes have emerged in the sustainable supply chain management field, discussing how supply chains become more sustainable, what are the main processes and actors that are affected by sustainability integration, and what are the factors and variables that influence the sustainability performance of supply chains. Among those themes that have emerged, two of the most common attributes of supply chains that were highlighted by the literature review are supply chain collaboration and enhanced visibility. Through the years, research has shown that enhancing those attributes contributes significantly to the overall sustainable performance of supply chains. Consequently, to enhance those attributes, different supply chain practices and tools have been uncovered by the literature, and among the most prevailing practices is information technology. This is because as illustrated previously, modern supply chains are becoming more complex, and the surrounding environment is being more uncertain every day. Therefore, conventional ways to enhancing supply chain sustainability performance should evolve, to cope with the mentioned developments. And with the evolvement of supply chains, information technologies have also evolved into industry 4.0, where the literature also sheds the light on some upcoming technologies, and the potential they have for improving supply chain sustainable performance. Among the various industry 4.0 technologies that have been studied in the literature, Internet of Things and Blockchain were shown to have a great potential to contributing to the enhancement of sustainable supply chain performance. Therefore, it is important to study the aspects of sustainability in supply chains, as well as the how sustainability has evolved in supply chains over the years. It is also worthy to understand in more detail the drivers of adopting sustainable supply chain management, in addition to the obstacles hindering this adoption. And to understand the evolution of sustainability in supply chains, a review of the tools and enablers, such as information technology and some industry 4.0 tools will take place.

1.4 Research questions

Based on the conducted literature review and the case study, this research aims to answer the following two questions:

RQ1: *What are the main enablers of sustainable supply chain management?*

RQ2: *What are the potentialities of emerging technologies in sustainable supply chains?*

1.5 Following Sections

In the following sections, a systematic literature review will first take place. The review starts by giving context to the evolution of sustainability and resilience in supply chains, to understand the different dimensions that makes up the sustainable supply chain management framework. Then there will be a deeper look into how sustainability is enhanced with different supply chain functions, like transportation and marketing. Finally, the literature review will narrow down to how technology aids in the sustainability performance, as well as how key industry 4.0 technologies fit in the sustainable transition of modern supply chains. Following the literature review, the research methodology will be described, then the literature review will be supported by a case study conducted on the supply chain of Whirlpool EMEA, to understand how the topics covered in the literature are addressed on ground. The research will conclude with a discussion of the results attained from the literature review and the case study, to assess the relationship between them and reach an answer to the research questions.

2. Literature Review

2.1 The relationship between Sustainability and Supply chain management

2.1.1 The Evolution of Sustainable Supply Chain Management

To examine the connection between supply chain management, transportation, sustainability, resilience, and marketing, it is important to highlight how the relationship between these factors stands in the literature. The main concept in the literature that integrates supply chain management with sustainability is sustainable supply chain management (SSCM). Originally, the focus was directed towards Reverse logistics and other key concepts, which then evolved to Green Supply Chain Management that tackled the environmental aspects of supply chain activities, and finally the focus expanded to the broader umbrella of SSCM (Fritz, 2019), which is represented by the figure below

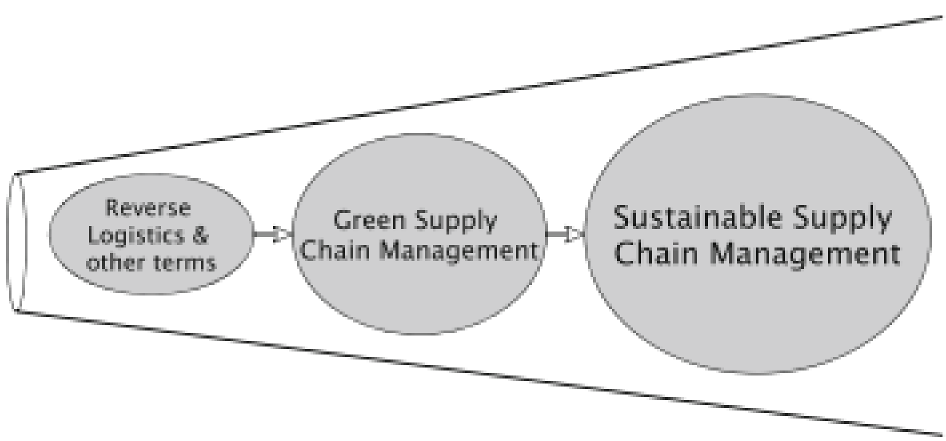

Figure 1 Sustainability funnel (Fritz,2019)

Among the many definitions of SSCM in the literature, a comprehensive one is “the management of material, information, and capital flows as well as cooperation among companies along the supply chain ... while taking goals from all three dimensions of sustainable development, i.e., economic, environmental, and social, into account which are derived from customer and stakeholder requirements.” (Seuring and Müller, 2008). This definition coincides with the framework that was conceptualized by Elkington in 1997, and later developed by Carter and Rogers in 2008, which is the triple bottom line (Carter and Rogers, 2008). The original triple bottom line framework sets the guidelines to describing a supply chain practice as sustainable or not. The main pillars of the framework are Economic, Environmental, and social aspects. For a practice to be considered fully sustainable, it is important that there exist economic, environmental, and social benefits arising from this practice all at once. In addition to these main pillars, four supporting facets aid in effectively achieving sustainability that are: strategy, organizational structure, risk management, and transparency (Carter and Rogers, 2008). The figure below illustrates the interplay between the three main pillars of the framework along with the supporting facets.

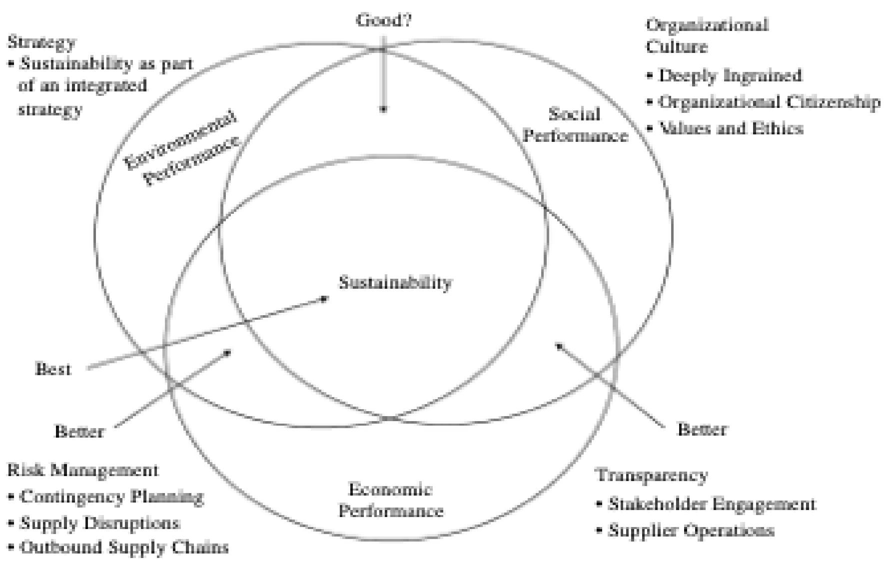

Figure 2 Triple bottom line (Carter &Rogers,2008)

As depicted by Fritz before, under the umbrella of SSCM, lies Green Supply Chain Management (GSCM), which is concerned with the integration of environmental management into supply chain practices. The main concept behind GSCM is transforming all the supply chain phases into environmentally efficient ones. Among these phases are: Green Transport, Green Design, Green Customers, and Green Packaging (Fritz, 2019). In another paper, 8 dimensions of GSCM were discussed among which are Green Distribution, Green Marketing, and green packaging. The paper also illustrates the positive impacts of adopting these practices on the overall sustainable performance from the economic and social sides (Yildiz and Sezen, 2019). Therefore, to achieve high sustainable performances for supply chains, it is important to implement sustainability practices across all phases. Then, under the umbrella of SSCM and GSCM, lies reverse logistics, that is concerned with the reverse flows of materials from the customer back to the seller. It has been shown that reverse logistics has a high contribution in achieving sustainable supply chain goals (Sun,2017). This is mainly due to the reduced waste resulting from reverse flows, in addition to the lower energy and carbon footprint that result from the incineration of these wastes. The degree of reverse logistics implementation has an impact on the circularity of the supply chain, by transforming the supply chain from a linear one, into a closed loop one, and finally into a circular one that aims to achieve zero waste (Farooque, 2019). As a result, the more circular the supply chain is, the more effective it is to achieve SSCM. For instance, a linear supply chain does not reverse any of its flows, thus having a negative impact on the environment. This effect is alleviated by moving to the closed loop supply chain; however, to a limit, because some of these wastes could not be reversed by the supply chain, and this is where the circular supply chain comes in, where these extra flows that are not affordable to reverse, could be transferred to another supply chain that could make use of. Among the other key concepts that were originally studied with reverse logistics are Lifecycle assessment, integrated chain management, and industrial ecology (Seuring 2004; Seuring and Müller 2007).

2.1.2 Drivers and Barriers to Integrating sustainability into the supply chain

Having had a general background of sustainability in supply chains, it is important to understand the motivators and barriers to achieving this connection. Several papers analyze the main drivers and barriers to adopting SSCM in companies. (Khan et.al 2021) and (Koberg and Longoni, 2019) discuss some aspects of the supporting facets that were mentioned before in the triple bottom line, such us organizational culture and strategy, and how these aspects contribute to the adoption or abandonment of SSCM practices. For example, one of the main barriers to SSCM adoption is the hesitation of top management to integrate it into the main business functions (Khan et al., 2020). (Carter and Rogers, 2008) also touch on this note by explaining that managers do not see sustainability as an initiative to improve business performance, but rather as a response to external pressures and to stay competitive in the market. This results in missing an important facet of the triple bottom line, which is an organizational culture that does not have sustainability deeply ingrained in the values and ethics of the company. This view is also supported by (Sajjad et al., 2015) who attributed the barriers to SSCM adoption mainly to lack of top management commitment and high implementation costs. Therefore, managers need to develop and invest in a new set of skills that is sustainably oriented and take advantage of the opportunities presented by sustainable practices in supply chains, through looking beyond the costs and complexity of implementation and realizing the business benefits of these practices (Tyan et al.2019). The opposite is therefore true; having a sustainable organizational culture and top management involvement is one of the main drivers of SSCM implementation (Khan et al., 2020). Other drivers that were illustrated by this research are strategic planning, information sharing, employee empowerment, customer satisfaction, and involving suppliers in sustainability programs. On the other side, some of the barriers that hinder the integration of sustainability into the supply chain include the cost of adoption, lack of knowledge and resources, poor communication, and lack of clear skills and vision. Trivellas et al., 2020, also found that lack of transparency and visibility was a strong barrier to SSCM implementation, where information sharing has the highest impact on the sustainable performances of business, along with transportation and logistical networking. Therefore, to have a clear view of how sustainability is evolving in supply chains, it is important to also study elements related to transportation and information sharing.

Drivers of SSCM are categorized into internal or company drivers and external drivers. Internal drivers include but are not limited to management commitment, organizational culture, and competitive opportunity (Tyan et al., 2019). These drivers also coincide with the supporting facets of the triple bottom line by Carter and Rogers reference in the sustainability part. Then, Tyan et al., 2019, illustrate the external drivers that are divided into supplier/customers and third parties. Suppliers/customers include for instance, green product requirement, reverse logistics requirement, and business social compliance. Third parties include regulatory pressure, reputation, and institutional pressure like that of NGOs. The same view is represented by (Saeed and Kersten 2019), where they classify SSCM drivers into internal and external ones. Internal drivers are related to corporate strategy, organizational culture, organizational resources, and organizational characteristics. External drivers are then elaborated into regulatory pressure, societal pressure, and market pressure. The research then elaborated further on these drivers by classifying them into primary and secondary drivers based on the level of influence on the supply chain performance. For example, primary drivers include those with direct influence on the supply chain performance such as suppliers, employees, shareholders, or customers. On the other hand, secondary drivers are those with indirect influence on the supply chain, such as image and reputation, NGOs, social groups or media.

2.1.3 Methods and Practices to Integrating Sustainability into Supply Chains

As mentioned before, it is important to integrate sustainability into all the supply chain process to achieve an effective result. On this note, (Fritz, 2019) illustrates that sustainability needs to be integrated into all the supply chain strategic levels to achieve SSCM. At the highest and first level, sustainability needs to be integrated into the governance mechanisms and top management of a company, were this is an important driver to adoption as mentioned before. This is achieved through involving the stakeholders with sustainability policies and initiatives. These stakeholders include top management, shareholders, and supply chain partners. Therefore, coordination and partnership are of crucial importance for all the stakeholders to be aligned on the path to SSCM. Then at the second level, which is the operational one, sustainability needs to be integrated into all the main functions of a company. Internal integration and alignment are also important to have a coherent and effective approach throughout the whole organization, and to achieve efficient integration, strong information systems must be present. The third level is concerned with integrating sustainability into products and services. At this level, sustainability is integrated into one of the initial phases of the supply chain, which is the design phase. When designing a product or a service, the sustainability impact of this product/ service should be considered through its whole lifecycle. Here, some tools such as environmental lifecycle assessment (E-LCA) and social lifecycle assessment (S-LCA) are used to not only examine the sustainability impact of a product during the usage, but also considers all the processes involved in its realization, in addition to the social impact it has on all stakeholders (Fritz, 2019). Finally, the last level of integration is concerned with transferring sustainability across supply chain partners and monitoring its adoption. As indicated in the drivers for SSCM, involving the supply chain partners in the sustainability journey is one of the motivators to adoption. For this reason, collaboration and partnership is of sheer importance. This is achieved through sustainability programs, supplier training, resource integration, and many other tools that ease the transition of the supply chain partners into adopting SSCM. In addition to this, monitoring of sustainability integration across the supply chain is also as important, to ensure that the process goes as efficiently as possible. This process could be performed either by the focal company itself or using third-party audits. In a similar view, (Tyan et al., 2019) explains that sustainability integration into the supply chain should occur across the whole supply chain tiers. Starting from the focal company, sustainable operations and risk management should be employed to ensure that sustainability is rooted within the company. These include practices such as green product and process design and planning, energy consumption and emissions reduction, green manufacturing, green packaging, product recovery and remanufacturing, and waste management. Moving to the upstream, the focal company should sustainably manage the suppliers, through practices such as supplier sustainability assessment, strategic supplier collaboration, green procurement, and green transportation. Finally, at the downstream of the focal company, pressure and incentive management is important to ensure the extension of sustainability processes to the customers. These include practices such as reverse logistics, product recycling, corporate green image management, and green warehousing and shipping (Tyan et al., 2019). Similarly, (Forslund et al., 2021) illustrate sustainability approaches between the focal company and first and second-tier suppliers where sustainability is empowered through a mix of communication and monitoring; therefore, enforcing the fact that supplier collaboration is crucial to achieving SSCM.

2.1.4 SSCM Performance measures and the impact of SSCM on supply chain performance

For companies to assess their progress towards SSCM, it is important to have an exhaustive performance measurement system put in place, to benchmark their sustainable activities and evaluate how the company is evolving its supply chain to be more sustainable. In fact, one of the drivers of adopting SSCM is the development of these new sustainability-oriented performance measurements that responds to both the internal and external pressure described previously in the drivers to SSCM. Therefore, it is important to evaluate sustainable performance across all stages of the supply chain as well across all three aspects of the triple bottom line. A study taken by (Narimissa et al., 2020) illustrates various supply chain indicators tackling the three pillars of the triple bottom line. For example, some performance measure related to the economic performance include aspects such as quality, cost, flexibility, return of goods, supplier evaluation, and information. These aspects are then refined to specific indicators such as cost of order and cost of supply in the cost aspect, or the amount and accuracy of exchanged information between supply chain partners in the information aspect. Similarly, environmental performance is explained in many aspects that include but is not limited to environmental management and reverse logistics and recycling. Finally, the social pillar of the triple bottom line is represented by aspects such as employee wellbeing, staff training, and occupational health. Not only does SSCM improve the triple bottom line, but it also contributes to achieving a competitive advantage through the acquisition of new skills and competences (Saeed and Kresten, 2019).

2.2 Sustainable supply chain management and transportation

Because Transportation is one of the main phases of supply chain management, most of the sustainability measures addressing transportation in the literature are included under the topic of SSCM. Other papers refine the topic to logistics or distribution such as green logistics. And finally, few papers specifically address the topic of sustainable transport in a stand-alone fashion. For example, in the Fritz 2019 paper, related concepts include reverse logistics and green transport, that was illustrated as a part of GSCM. Although reverse logistics helps improve the sustainability performances of supply chains through reducing waste, it is important that it does not introduce higher costs related with the reverse flows of transportation (Richnák and Gubová 2021). On the other hand, green logistics, which encompasses green transport, is proven to reduce transport costs in terms of fuel consumption, greenhouse gases emissions, and route optimizations leading to fewer trips taken and less traffic (Richnák and Gubová 2021).

Not only is transportation one of the main phases of a supply chain, but it is also one of the main contributors to its sustainable performance. A study conducted by (Trivellas et al., 2020) in the Greek agri-food sector, shows that information sharing, logistical network, and transportation are the main factors that affect that performance of a sustainable supply chain. Transportation has been shown to have a great impact on all dimensions of sustainability, and it is one of the main influencers of achieving SSCM (Andarkhora et al., 2019). This is because when considering logistical activities, transportation accounts for the largest share of emissions (Trivellas et al., 2020).

2.2.1 Sustainable aspects of transportation in supply chains

To address the position of sustainable transport and SSCM in the literature, a review of the main decisions and practices, drivers and barriers to adoption, methods of implementation, and emerging trends and tools will take place. First, the main elements of sustainable transport are related but limited to transportation mode, transportation load, route length, energy efficiency of the vehicles, and other externalities (Mckinnon,2016). Therefore, important decisions that affect the sustainable performance of the supply chain include transportation mode selection, network and route optimization, and transportation emissions reduction practices (Trivellas et al., 2020). In a later study by Farcavcova et al., 2018, 19 decision criteria were demonstrated in affecting green transport. These criteria were categorized according to the time horizon in which they take place in, and the influenceability of these criteria by the actors involved. These criteria are also related to the main elements described by Mckinnon, 2016. The study then applies these criteria on a case of a heavy product that is transported for long distances, and the results confirmed that transportation had the highest impact on emissions amongst all the processes in the supply chain, and that the elements described above have the highest impact on the sustainability performance of transportation. It also shows that sustainability measures in transportation is of high priority, because neglecting them could result in counteracting other sustainability initiatives taken in other phases of the supply chain. Another paper supported these views, where barriers to green transportation are caused by unwillingness of top management to shift to green transportation in addition of fear of risking the invested capital or not getting the desired returns (Saada, 2021), which again puts an emphasis on the importance of top management involvement that was described before. The below figure shows the framework developed by the study conducted by (Trivellas et al., 2020), that illustrates how information sharing and green transport not only affect the economic side of the triple bottom line, but also the social and environmental side of the whole supply chain.

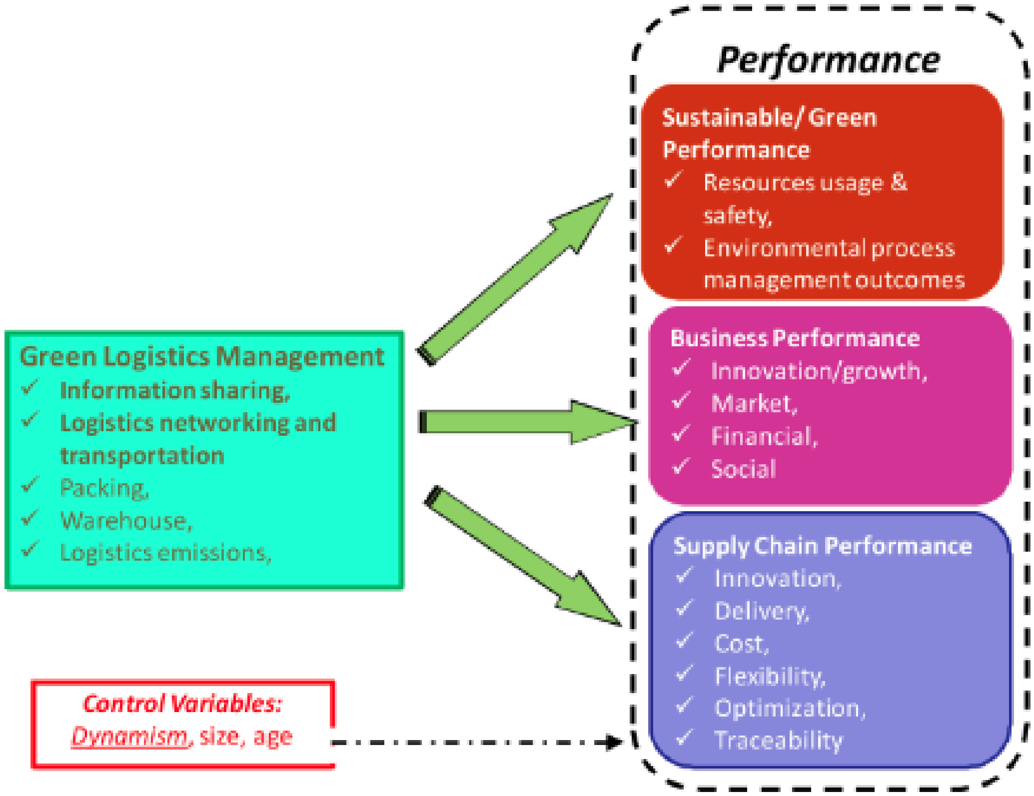

Figure 3 Information sharing and sustainability (Trivellas et al., 2020)

2.2.1 Information technologies as a mediator for SSCM adoption

The importance of information sharing is also illustrated in the Fritz, 2019 paper that was discussed above. The paper showed that efficiently and successfully integrating SSCM in all levels needs to be accompanied by a strong information system that connects all stages and functions and eases the collaboration process between them. Therefore, to ease the implementation of SSCM and sustainable transport, and to overcome the barriers suppressing its adoption, information technology plays a very important role. Digitalization of supply chains or “Supply Chain 4.0” includes digital tools such as artificial intelligence, internet of things (IoT), and blockchain, that are also highlighted through the supply chain control towers (Fritz,2019). Supply chain control towers are a set of tools that increases the visibility of the supply chain in real time and allow for efficient monitoring of resources. In fact, some technology has already started to take place in transportation such as IoT, AI and big data analytics for fleet management, driver and infrastructure monitoring, truck localization, and autonomous vehicles (Hopkins and Hawkings, 2018). Although the implementation of such technologies has commenced in different supply chain areas such as intelligent data processing and robotic process automation in procurement and demand planning, transportation has seen very few applications that are limited to IoT and RFID and autonomous vehicles. Therefore, transportation is one of the supply chain areas that could be disrupted by these technologies, such as blockchain which still has not been implemented in transportation (Queiroz et al., 2020) All this emerging technology could be considered as enablers for the SSCM due to the positive effects that they have on all three dimensions of the triple bottom line (Sarkis et al., 2020).

2.3 Supply chain resilience

According to Fiksel 2006, resilience is “the capacity for an enterprise to survive, adapt, and grow in the face of turbulent change. This could be seen as an extension to the classic risk management approach (Pettit et al., 2019). Another definition of supply chain resilience is “the ability to proactively plan and design the supply chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage.” (Ponis and Koronis, 2012) With the recent pandemic and external turmoil affecting all industries, maintaining absolute control over business processes has proven to be hard. Therefore, resilience is of utmost importance for businesses to survive in a world of everyday variability. It is well known that supply chain is one of the most hard-hit processes by the recent pandemic both through the demand downstream and the supply upstream. According to Pettit et al., 2019, achieving resilience occurs when there is a balance between two factors, which are vulnerabilities and capabilities. Vulnerabilities are all the external factors that drive the disruption or uncertainty, while capability is building the capacity to overcome these disruptions. The research concludes that those two need to be balanced, because excessive vulnerability in relation to capability could increase risk, and the excessive capabilities in relation to vulnerabilities could reduce profitability.

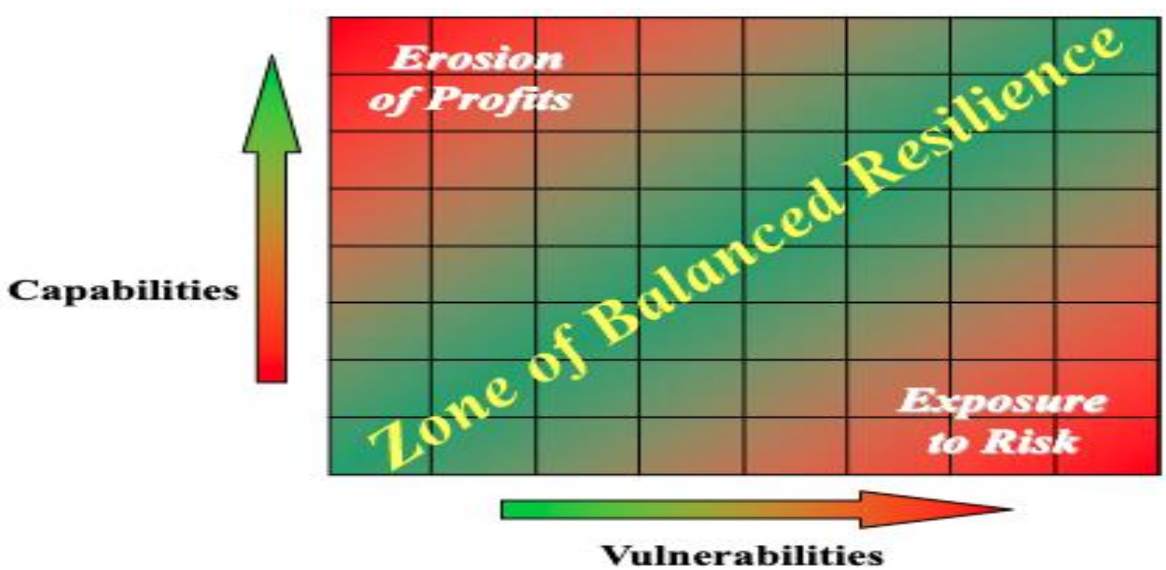

Figure 4 Zone of resilience (Pettit et al., 2019)

2.3.1 The relationship between resilience and sustainability in supply chains

According to Fiksel et al., 2017, sustainability enhances resilience through protecting critical resources and improving the business viability. Collaboration between supply chain partners plays an important role to build a resilient supply chain (Jabbour et al., 2020). Therefore, collaboration is one of the most important aspects to review in a supply chain because not only does it drives its sustainability, but also its resilience. In addition to collaboration, risk management is one of the drivers of a resilient supply chain, which is also one of the 4 supporting facets of Carter and Roger's triple bottom line. The relationship between sustainability and resilience in the supply chain is reciprocal; because as previously mentioned that sustainability enhances resilience, the later also influence the performance of the former (Benitez et al., 2019) For instance, one of the ways to increase the resilience of a supply chain is deploy redundant recourses in place to face any unexpected disruptions. These recourses could include backup suppliers, backup processes, or standard components. However, deploying backup suppliers could affect the social aspect of sustainability through reaching global suppliers and weakening the relationship with local ones (Zahiri et al., 2017) In fact, a famous view that correlates the two topics indicates that resilience is a prerequisite to sustainability. This means that without resilience, the sustainability achieved in the supply chain is fragile (Alcivar et al., 2020). This research also illustrates the various elements of resilience and whether they have an influence on sustainability or not in the literature. Some elements have an influence on the environmental-economical interface of the triple bottom line while other elements influence all dimensions of the triple bottom line. For example, the most common resilience elements in the literature that had an influence on the triple bottom line was redundancy, flexibility, trust, shared information, and innovation (Alcivar et al., 2020). On this note, Alcivar presents a framework that links supply chain resilience, supply chain risks, and supply chain performance management together.

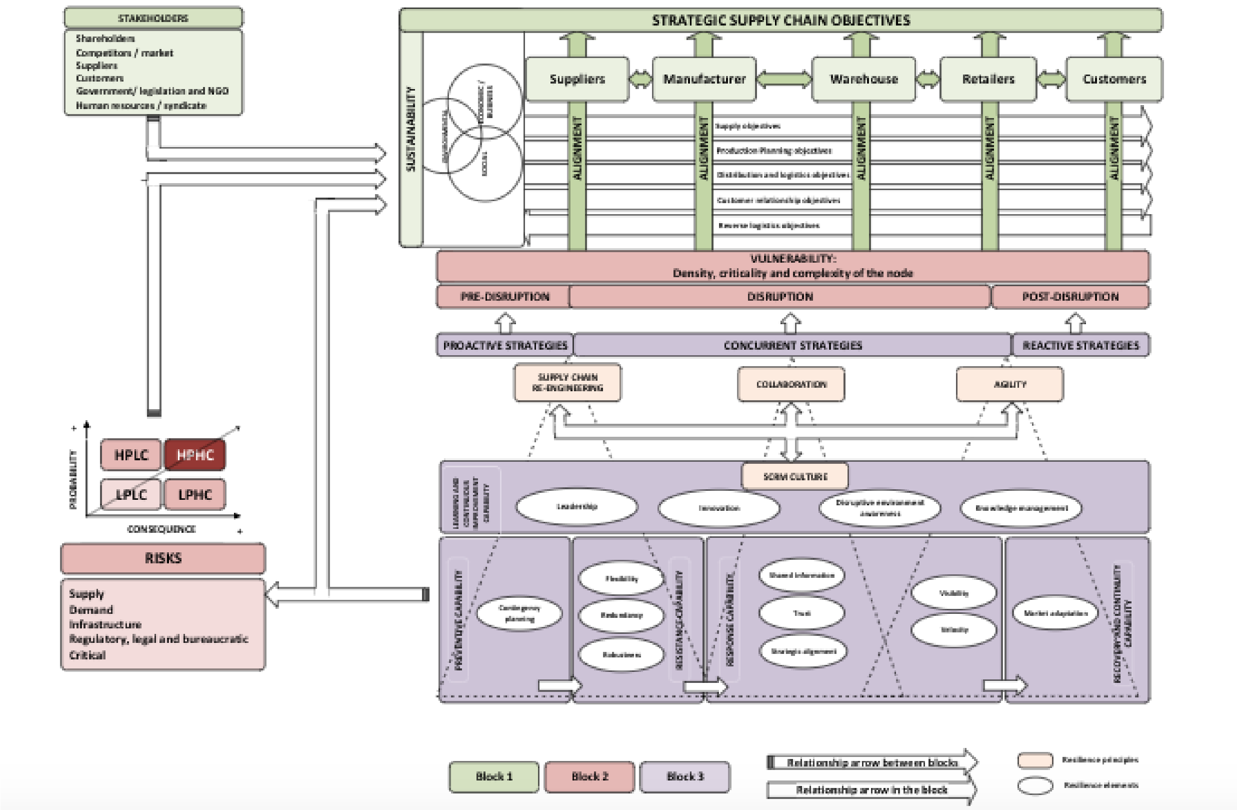

Figure 5 Supply chain resilience, risk, and performance (Alcivar,2020)

This framework is one of the most comprehensive ones found in the literature because it encompasses almost all the topics that are discussed in this research. For example, one of the elements of supply chain performance management is the triple bottom line, which is linked to the strategic supply chain objectives across all tiers of the supply chain, that in turn are supported by processes such as distribution and customer relations objectives. Then, to overcome vulnerability to disruptions, strategies such as collaboration and agility are deployed. Finally, these are supported by SCRM culture that includes shared information, trust, and market adaptation. This further reinforces the view that was found in most reviewed papers, that collaborating and sharing information with supply chain partners is crucial to achieving a better triple bottom line.

2.4 The relationship between Green Marketing and Sustainable Supply chain management

2.4.1 Definition of Green Marketing

For all companies, marketing has been one of the main pillars for value creation and achieving a competitive advantage. Following the green direction that companies have been taking recently, it has become utterly important for them to leverage on green marketing philosophies to gain this competitive advantage. According to the literature, numerous definitions were given to the concept of green marketing. Sutduen et al., 2019 defined green marketing as integrating and organizing marketing activities in a manner that could affect the customer's buying preferences and tweaking their choices to more sustainable and environmentally friendly products. It was more thoroughly defined as a set of activities that aim in reducing the environmental impact while aligning with the business goals of being profitable (Nadanyiova, 2018). Hence, it is a critical coalition between the marketing activities, environmental management and supply chain to create value for the company, society and the environment. Further, the differences between traditional marketing activities were highlighted by Nadanyiova; including segmentation, targeting, etc., and the green marketing activities that include the adaption of changes that meet customer's demands, or change customer's preferences to a greener one, while having the least effect possible on the environment, which supports the definition provided by Sutduen et al., 2019 in their research.

2.4.2 Green Marketing benefits for firms, society, and the environment

Different research has shown the benefits that green marketing could cause to both companies and society. Sutduen et al., 2019, also argued that firms don't only incorporate green marketing activities to take an edge in the rigorous competition of the industries but also to improve their long-term organizational performance and most importantly to cement their image and relationship with the communities. By fostering eco-friendly products/services, firms will be gaining more public respect and recognition as saviors of the environment and promoters of sustainability. Nadanyiova supported this argue by stating that following this direction can undoubtedly improve the image of the whole company and eventually attracting new potential customers and generating more profits. Not to mention also the strategic advantages that a company can benefit from like tax relief and costs reduction. According to her, an effective green marketing strategy should be characterized by the following traits; firstly, being an organized long-termed voluntary action taken by the company not an enforced one. Secondly, cross-functional collaboration and engagement with all stakeholders which will be discussed later in the literature review. Thirdly and most importantly, the operation of the firm with respect to the triple bottom line framework of Carter and Rogers that was discussed previously. Finally, the social contribution, awareness and duties of the firms that are focused on improving the quality of life in different dimensions.

2.4.3 Green Marketing Mix

Green Marketing Mix (GMM) was identified as the tools that marketing activities adapt in order to attain a greener approach (Farradia and Bon, 2021). They proposed a conceptual model that defines the GMM main dimensions and integrates them with the stakeholders and the goals of the firm.

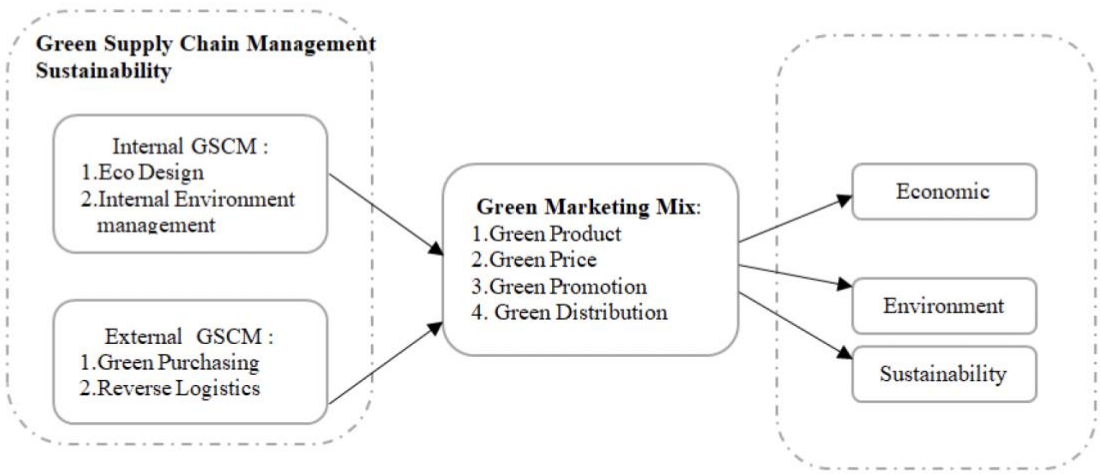

Figure 5 Green Marketing Mix overview (Farradia and Bon, 2021)

It highlights the strong relationship that must take place between the GSCM and the GM in order to for the companies to achieve economic growth, social and environmental well-being. It further divided the GSCM into two folds, internal activities and external ones. The Internal GSCM activities includes providing ecological design for the process and the product as well as environmental management activities to support the GM activities. While the External GSMC are responsible for green purchasing of sustainable and less harmful raw materials and machineries, also fostering reverse logistics that was discussed previously. Those GSCM activities support the implementation of an effective GMM which is divided into Green Product, Green Price, Green Promotion and Green Distribution (Place). Green Product has shown the most significant positive relation, among all the other "Ps", in the perception of a quality of the brand and brand trust. It showed the long-term sustainability development reflected in changing the way consumers approach a product to purchase it (Dangelico and Vocalelli, 2017). The second pillar of the GMM is the Green Price, which demonstrated a negative correlation with brand trust and loyalty. Particularly, if the prices of a product or a service increase the loyalty and trust of the brand will decrease as well as the customers willingness to pay. They further emphasized the importance of selecting the correct price point, especially because environmentally friendly products could cost higher than normal due to materials used or the cost of production. Then comes Green Promotion that also illustrated a positive impact on the perception of the quality of the brand, just like Green Product, as well as the customer's green satisfactions influencing their loyalty to the brand. Dangelico and Vocalelli deliberately explained the importance of using Green Promotion's tools such as green advertising to reshape the consumers' environmental awareness and their "Green Buying Decisions Behaviors" which coincides with Nadanyiova's argument about how building Green Consumers can play a critical role in saving the environment. Green Distribution is also a central pillar in the GMM for any company, since optimizing the distribution and transportation systems in an ecofriendly way contribute the most in minimizing the negative effects that could make the planet suffers. Dangelico and Vocalelli claimed that this could be done leveraging on many tools. Making the green products available in green retail stores as well as a widespread over the internet, has shown a reduced impact of transportation over the environment. Also, upgrading the transportation systems of the firms, such as using green vehicles, delivery robots and distance controlled automated vehicles.

2.4.3 Building Green Consumers

Studies conducted by (Nadanyiova, 2018; Panda et al., 2019) highlighted that green consumers are at the epicenter of the green marketing strategy and their purchasing behaviors were examined. Panda et al., 2019 emphasized the firms’ role in altering the customers buying behavior and altruism. They stressed on two major factors, Social and Environmental sustainability awareness, that could positively affect consumers’ altruistic values and eventually reshaping their purchasing intentions into a much greener one. The Social Sustainability Awareness aims in achieving better lives and well-being within the communities, while the Environmental Sustainability Awareness focuses on protecting scarce resources and preventing pollution. According to them, the companies that can cement their sustainability goals and values in the customers’ heads, are the ones responsible for changing their purchasing behavior to a greener one. This could be achieved not only by providing green products or saving materials but also by showing to the customers that they really care about the well-being of the environment and society. For example, using green vehicles or robots in delivering the consumers' orders shows that the firm is leveraging on innovative solutions to reduce harmful emissions and save the planet, which psychologically affects the customers in a positive way making them feel good about purchasing environmentally friendly products from those green brands. It also nurtures the trust and ultimately may lead to green brand loyalty and evangelism.

2.4.4 Challenges and collaborations between Marketing, Logistics, and SCM departments

Nadanyiova stressed on the importance of establishing a strong collaboration with the environmental management and logistics departments. In fact, establishing a good relationship between the SCM, Marketing departments is not an easy task to do. This kind of integration could be really challenging, especially if the firm is trying to be greener, since the goals of each the different departments are always not aligned which may cause interdepartmental conflicts or communication problems (Abdalrahman and Lehota, 2018). They further elaborated the different roles of the previously mentioned departments, where SCM's role is to maintain low levels of stock to reduce inventory costs as much as they can, on the other side, the Marketing department's main goal is to meet customers' orders as much as they can which means that the stock level needs to be high in that case. Abdalrahman and Lehota then explored the concept of "Collaborative Cross-Functional Integration", which ensures the highest service level that a customer could receive leveraging on interdepartmental collaboration between the SCM, Marketing and Logistics forces of a company. This is based on setting aligned goals, mutual trust and smooth information and resources flow between the departments. Hence, the execution of these goals will be adding value in terms of the firm's image, profitability, sustainability and customer satisfaction. Sutduen et al., 2019 highlighted in their research that for a corporate to achieve green sustainable objectives, a collaboration and strong interdependence must take place between SCM, Marketing and Logistics parties.

2.5 The Role of Emerging Technologies in Sustainable Supply Chain Management

2.5.1 General Overview

Previous literature has investigated the importance of collaboration between the supply chain player in order to achieve sustainability practices. Later, researchers started examining the impacts of adopting early-stage technologies, that emerged back then, such as Information Communication Technologies (ICT), Radio Frequency Identifier systems (RFID), and Control Towers. To achieve a sustainable supply chain, firms have been exploring different types of technologies and their effect on their operations. The main target was to optimize their gains while minimizing the environmental and social risks, Thus, maintaining an exemplar social image and making profits at the same time. Today, in the digitalization era after the introduction of the Industry 4.0 principles, some major digital trends have been rising with some potential benefits that could enhance the supply chain outcomes and reshape how sustainable goals could be achieved. Existing literature is focused on highlighting the role of the newly introduced trends, such as Blockchain technologies, Internet of Things (IoT), Artificial Intelligence (AI), and many more, in SSCM.

2.5.2 Benefits and Challenges of digital technologies

Digital technologies play an assisting role in better improving the relationship with customers, providing real-time transparency, agility, and flexibility, and as a result enhancing companies' performances, efficiencies, and cutting costs and time for delivery, which eventually assure sustainable outcomes (Calatayud et al., 2019). The adoption of such technologies acts as a competitive advantage for firms and offers better value creation in their business models (Onu & Mbhowa, 2018). Despite implementing such technologies could be a risky investment, however, in the long term, it can be beneficial in terms of cutting futile financial expenses and operational efforts in the organizations (Agrawal et al., 2020). Leveraging on those new technological trends shows a memorable increase in the collaboration between the supply chain forces (Kiel et al., 2017).

Onu & Mbhowa arguably discussed the potential drawbacks that could result from implementing such technologies. Having to change the previous procedures and protocols to implement new ones is not considered an easy task to perform. Further, the scaling and sizing of the operations and time for executing activities also arise as a limitation. Finally, they mentioned the risk of deterring the quality of the provided service and the uncertainty of how durable the adopted technology could be.

2.5.3 Information Communication Technology (ICT)

2.5.3.1 ICT for Supply Chain Management

Information Communication Technology (ICT) is defined as the enabler of capturing, storing, managing and sharing data using a variety of sources all working together. These sources are categorized into hardware, software, networks, portable devices, and infrastructures. All of which can facilitate the complex data cycles in firms in no time. Since the early adoption of ICT in companies and its implementation on SCM, companies have been recording lots of economic benefits and overall supply chain development over the years. Singh et al. 2020, profoundly mentioned that the investments in such technologies have not only contributed to increasing the market shares of companies but also to reducing their operational expenses while providing better customer services and retention. They further added that firms became able to expand their supply chain networks geographically, where they have found cost advantages or better resources in the new locations, thanks to the ICT applications that aided in the strong connection between all the companies' supply chain networks across the globe. Additionally, the deployment of Information and communication technologies has shown a major improvement in the agility and efficiency of the supply chain as well as a reduction in cycle & process time and fulfillment of orders. The study conducted by Nair et al. 2019, shows another perspective of the benefits related to the implementation of ICT for enterprises. He divided it into three branches as shown in the below figure:

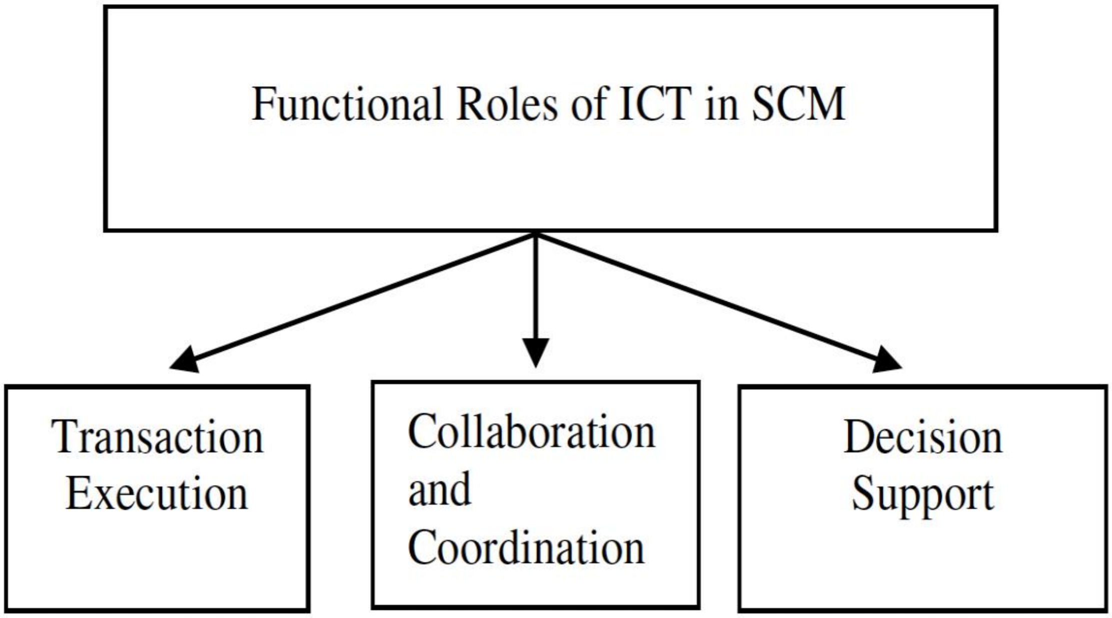

Figure 6 Roles of ICT (Nair et al. 2019)

According to his research, ICT implementation would result in three major benefits for enterprises; Transaction execution is facilitated due to the strong network connection and the robust information sharing methods that are executed in a few seconds. Additionally, The alteration that resulted from the deployment of ICT on physical processes such as inventory and shipping to informational-centered processes within the SC operations has created new ground for co-creation and co-integration between suppliers, supply chain partners, and customers, which eventually increases the performance of the company. Finally, he highlighted the improvements that companies gain in their capacity to respond and react to the dynamics of the industries and market irregularities by making critical decisions backed up by information and support gathered by their ICT systems. The deployment of Information and communication technology systems with their different tools consequently affects all the 4Rs of the SC: Responsiveness, resilience, reliability, and relationships.

2.5.3.2 The impact of ICT on sustainable supply chain performance

In multiple pieces of literature, it has been mentioned the importance of ICT to achieve sustainable supply chain goals. There is no doubt that ICT is a giant tree under which there are many branches as mentioned before and will be discussed more thoroughly in this chapter. It has been proven that information sharing among the SC partners is a key requirement to achieve sustainable supply chain management practices, where capturing, storing, processing, managing, and saving are important (Yao et al., 2022). Nair et al. 2019, supported this by underlining the enhancement that takes place in the visibility and transparency of the information within the different stages of the supply chain due to the smooth and easy access to all the information needed. Similarly, Singh et al., 2020, also stressed on the fact that enterprises that effectively apply ICT tools in logistics areas can strongly leverage on transparency and visibility by monitoring the goods and materials flow, reducing the risk of theft, tracking their process precisely, and mounting their products' security. Therefore, being able to apply more environmentally friendly processes, hitting their sustainability target while gaining an enhanced market share and positive brand reputation. ICT applications in SCM offer transparency along with supply chain activities toward the customer. Nair et al. 2019, later evaluated the effect of deploying Internet-enabled services on communication and collaboration among different supply chain stakeholders. Consequently, this supports supply chain departments moving toward their sustainability goals. The paper conducted by Yao et al., 2022, also investigated the relationship between implementing ICT technologies and sustainable distribution. It outlined that measuring systematically, analyzing, and mitigating the socio-environmental implications that occur from distribution processes must be measured concisely, which could be done by the usage of ICT Technologies like RFID and Transportation Management Systems (TMS). Those tools benefit the firms in preventing any redundant movements in the distribution phase while allowing enhanced visibility all over their transportation activities.

2.5.4 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a non-recent technology that goes back to the second world war when it all began to identify axis' and alias' warplanes. It later became one of the most important technologies in almost all industries due to its various applications, affordable implementation costs, compatibility, and reliability. The main role of RFID is to collect and track data automatically through its three components; the tag that includes a microchip and an antenna; the reader of the radio signals, and the software for informational flow. In the tag, the microchip is responsible for storing information about the product or the object it is linked to, while the antenna allows the microchip to transfer this information to a reader through radio frequency, which is then is received, read, and stored in the company's database management systems. RFID technology has been recognized as a critical enhancement over the standard bar code systems which were riskier to get damaged (Raza, 2021).

2.5.4.1 RFID for Supply Chain Management

Multiple studies have investigated the contributions of RFID in supply chain management activities. All have stated that supply chain management and logistics management are on the top of the list when it comes to benefiting from RFID technology. After exploring many works of literature, Raza has recognized that most of the literature focuses on RFID's contributions to inventory, logistics, and transportation areas along with other non-operational activities such as environmental conditions. There were also pieces of evidence related to the RFID's importance in manufacturing and assembly processes. One major role of RFID in supply chain management is tracking and traceability. Raza highlighted the cruciality of collecting information about the product throughout the whole transformation and transportation phases. According to the research conducted by multiple scholars (Onu & Mbhowa, 2018; Varriale et al., 2021), it has been presented that real-time traceability plays a vital role in SCM. Thanks to RFID technologies, companies can effectively and proactively avoid any counterfeit products by checking the information stored in the tags for each product and checking for irregularities. Additionally, when applied to perishable products it has certainly shown a great advantage in tracing and locating a bad product and helping to eliminate it before it affects the rest of the batch. Therefore, assuring the safety and the quality of products entering the markets and following the regulations enforced by the law lately. RFID can control the distortion of information resulting from the bullwhip effect, by the exploitation of real-time communication and information acquisition. Although all the previously mentioned advantages of implementing RFID to assist in supply chain processes, there are still some risks that accompany this (Varriale et al., 2021). They raised some concerns regarding the security of transferring and storing the data. It can be perilous, IT-wise, to transfer these amounts of critical data through Bluetooth or NFC. There is always a possibility for these sensitive data to get interfered with.

2.5.4.2 The impact of RFID on sustainable supply chain performance

The paper "*RFID Technology to Support Environmentally Sustainable Supply Chain Management*" by Dukovska-Popovska et al., 2010, explored how applying RFID Technologies over supply chain phases would impact the companies' sustainability goals. They have alienated the supply chain phases into four main stages to be able to concisely examine the RFID’s benefits for each stage precisely. The four stages are: *Upstream* which includes the procurement phase, *Midstream* linked to the production phase, *Downstream* which relates to the distribution stage, and *Reverse Logistics* stage. They have analysed each party and checked for the benefits and value-added when RFID comes into play. For every stage, each party had to deal with its internal socio-environmental matters and at the same time collaborate with the suppliers and consumers on the cross-border socio-environmental challenges. While exploring every stage, Dukovska-Popovska et al. 2010, have mentioned the added value according to their point of view.

As for the first stage, the Upstream, Dukovska-Popovska et al. 2010, focused on how RFID can be advantageous for the selection of suppliers and sustainability enhancements. RFID connected with sensors can be used to measure the emission rates of a specific product at a specific supplier. It can further measure the energy efficiency of the processing of the raw materials used for this product. These kinds of information become handy when evaluating or comparing different suppliers to choose from depending on their environmental consciousness and impact. Moreover, the information gathered helps in facilitating the purchasing decisions in terms of order frequencies and sizes. In addition, companies can have the ability to decide which suppliers to consider also in terms of distance. The added values here are divided into two folds. First, RFIDs can act as enablers for more environmentally friendly solutions when it comes to managing suppliers for the companies. Not only that but also, it can be, for suppliers, a source of competitive advantage where the suppliers that are able to provide more sustainability information about their products can attract more companies as well as introduce sustainability or greening solutions from the start of the supply chain cycles.

In the second stage, Midstream, RFID can come in handy in tracking and managing the wastes and air emissions produced during the production and assembly processes of a product. Companies, utilizing RFIDs and specific sensors, can precisely measure and store huge amounts of data about the wastes caused by their processes. Eventually, these data are then analysed and worked on in efforts to mitigate hazardous impacts and emission rates on the environment. The value-added behind the incorporation of RFID in the midstream is the ability to automate data collection, storage of large piles of data, and the possibility of identifying the processes that are responsible for the most emissions and wastes.

For the Downstream phase, Dukovska-Popovska et al. 2010, have investigated the benefits brought by the implementation of RFID technologies on transportation and distribution processes. The goal of sustainability-conscious firms is to plan efficiently and effectively all the activities related to distribution and transportation. The choice, evaluation, and redesign of the routes that optimize these processes, as well as the location of the warehouses, are a few examples. Thanks to transparency and traceability, firms can also optimize their transportation activities, by tracking the transportation equipment and getting real-time data regarding the dimensions, volumes, and routes of the containers as well as the number of emissions that are created from a specific transportation activity. According to Dukovska-Popovska et al. 2010, there are multiple added values accompanying this. First such data gathered about the transportation equipment and routing could be provided to the users of these transportation companies so that an optimized utilization could be achieved bringing a better impact on the environment. Secondly, such information could be adequately utilized to support the decisions of choosing the number and locations of the shipping spots, therefore, reducing the negative carbon footprint of retailers. Finally, they proposed that transportation processes would become more cost-efficient since transportation companies could provide reduced prices to their clients in case of utilizing equipment in some specific routes efficiently.

As for the final phase, Reverse Logistics, Dukovska-Popovska et al. 2010, explored the benefits of RFID in enabling the disassembly processes of the returned goods as well as the distribution of these disassembled parts. RFID can document information about the product's parts' materials which can eventually be used in the reverse logistics process by assisting the collection centres and sorting centres of the company to decide what components to go for remanufacturing or refurbishing or even to be landfilled. The real-time sharing of data can support manufacturers reduce their materials costs and at the same time mitigate the environmental risks accompanied by their manufacturing activities. The bottom line is that using RFID can dramatically minimize the complexities of reverse logistics activities, which include the irregularities in material flows and the inventories' uncertain conditions. Thus, RFID supporting an enhanced reversed information flow can lessen the unnecessary consumption of resources and consequently decrease the negative environmental impacts throughout the lifecycle of the product.

2.5.5 Internet of Things (IoT)

Internet of Things (IoT) was first introduced in 1999 by Kevin Ashton and multiple other researchers at MIT. The idea was simply to expand the benefits of the usage of RFID by connecting it with the internet. Purposefully, it was initiated to gather and store information without the urge of having the interactions of humans. IoT then started gaining a wide range of attention as a disruptive technology due to the immensely huge benefits that implementing such technology could offer. Just like how individual computers are connected, IoT connects people, products, and machines altogether through the internet, enabling the optimization of solutions leveraging on sensors, and tools for storing, analyzing data, and decision making (Aryal et al, 2018). It can help businesses gain competitive advantages as well as efficiency and accessibility (Li et al., 2017).

2.5.5.1 IoT for Supply Chain Management

In order to achieve a competitive supply chain for a company, different aspects must be available. First, supply chain agility, that imposed the implementation of flexibility, which is the capacity to rapidly respond and adapt to the dynamic demand of the consumers and the marketplace. Secondly, Versatility where a high level of commitment across design requirements or production lines must take place to fulfill customers' demands almost real-time. In addition, adaptability, which is the company's capacity in terms of variety and volume to rapidly adapt to fluctuations in demand according to demand and market volatility (Badugu, 2020). He emphasized on the importance of ICT and especially IoT in achieving this. Nowadays, the IoT concept facilitates the interconnectedness of different technologies that can potentially transform multiple areas of business, one of which is supply chain management (Bogataj et al, 2017). According to Ben-Daya et al., 2019, the supply chain suffers from many problems regarding delivery efficiencies, nonstop real-time monitoring, and the relationship between the supply chain partners. Implementing IoT technology, which enables physical products to be connected through the internet, allows better and easier continuous observations and recognitions by the supply chain partners. In other words, such technology helps provide transparency and data visibility within the supply chain activities. Furthermore, one other application of IoT is the ability of localizing, monitoring, and tracking products in the supply chain networks (Lee et al, 2017). IoT also has shown a major leap forward in reducing costs and waste (Mathaba et al, 2017). In their research, Kothari et al., 2018, have identified some major benefits for IoT in real-time supply chain management, warehouse and enhanced inventory management, tracking locations, fleet management, transparency in logistics and environment sensing. It was also highlighted that IoT can provide positive impacts on the future economy of companies.

Further, Kothari et al presented a conceptual model below:

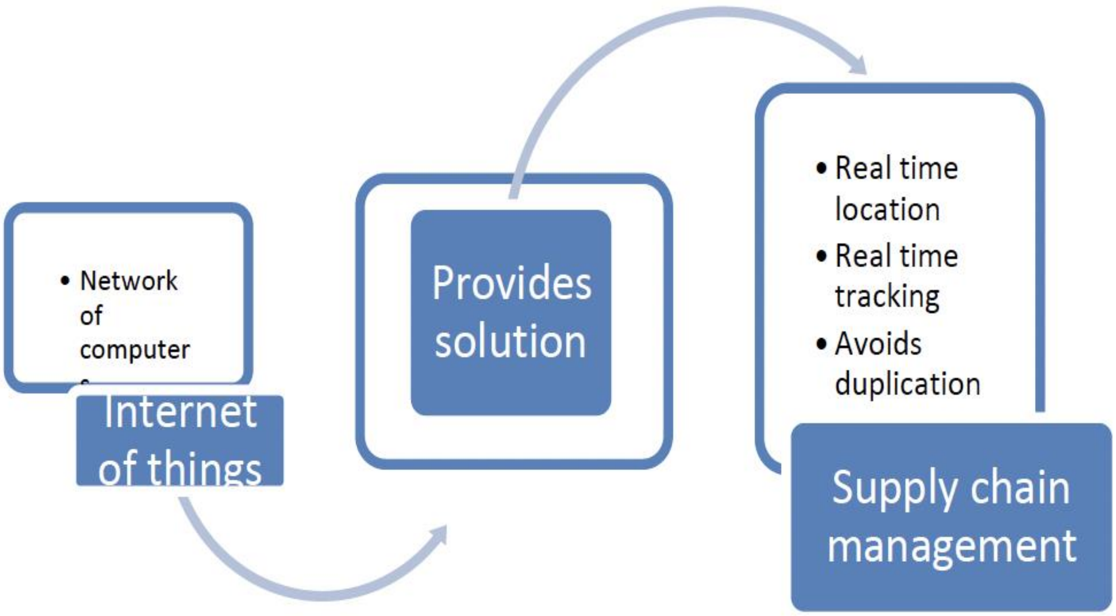

Figure 7 Conceptual model explaining IoT (Kothari et al, 2018)

This model shows how the integration of IoT, leveraging networks of computers, can assist in preventing the limitations that could be present in the supply chain. IoT can offer solutions through real-time location and tracking, and duplication avoidance. Through sensor-based technologies and information sharing through the internet, IoT is able to provide fast and efficient solutions to solve supply chain discrepancies (Manavalan and Jayakrishna, 2018). Tu et al., 2018, have highlighted that IoT improves the manufacturing and transportation systems within the supply chain, where the systems can effectively track the finished product, and anything related to it along the supply chain in no time. Kothari et al concluded that IoT allows real-time visibility and transparency throughout the SCM. This is achievable thanks to the interoperability and connection between different devices through the processes that allow better tracking, monitoring, quality, and quantity measurements.

There is no doubt that the implementation of such technology comes with many challenges. One of which is the complexity to adopt and scale such technology that requires many resources and management. While the most threatening challenge is the risk of cyber-attacks on databases that can cause data leakage or corruption, or theft (Birkel and Hartmann, 2019). Numerous pieces of literature have highlighted the two key players that could alter the process of IoT implementation, which are trust and privacy. Aryal et al further discuss that trust have an impact on both customers and the players tangled in the supply chain cycle, also privacy is utterly important to get concerned about due to the huge amount of sensitive data generated. A critical issue like this requires a strong security system to make it safer and acceptable for companies to implement IoT in their structure (Harwood and Garry, 2017). Recent literature conducted by (Khan and Salah, 2018; Shwarek, 2017) all agree that trust is the key when it comes to data sharing. They further proposed that the usage of blockchain technologies, which will be discussed thoroughly in later chapters, could be a better solution for providing a strong security level and privacy.

2.5.5.2 The impact of IoT on sustainable supply chain performance

For any company seeking to achieve long-term sustainability benefits, implementation of such technology could be crucial IoT can be deployed in worksites. In line with what Manaylan and Jaykrishna proposed in their research, IoT implementation can identify the possible problems that could jeopardize shipments arriving on time, by notifying if there are any disruptions in the shipping routes in terms of road conditions and diversions. Additionally, real-time tracking of vehicles and providing predictive maintenance schemes for these vehicles and transportation facilities. They further discussed the potentiality of automating repetitive operations in the supply chain, which plays an important role in achieving sustainability in the SC as shown in the figure below, as one of the major applications of IoT adoption.

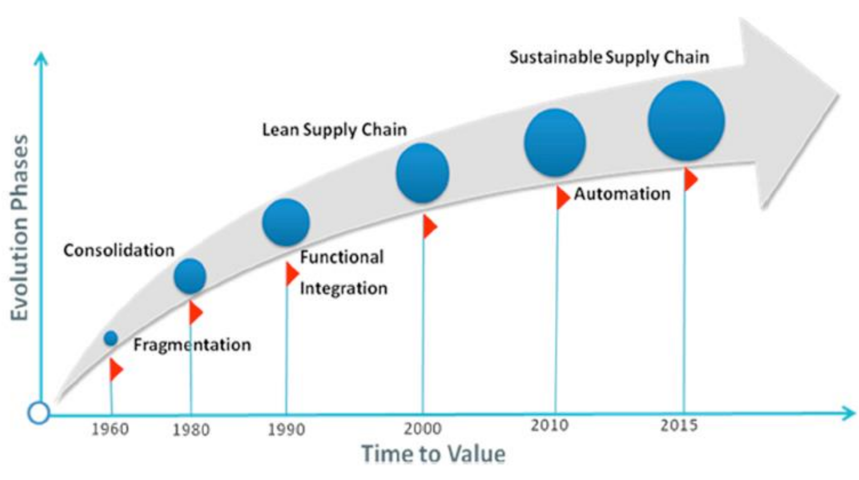

Figure 8 Supply Chain evolution (Manayalan and Jayakrishna, 2018)

Manayalan and Jayakrishna also presented the futuristic vision of Industry 4.0, leveraging IoT, in pursuing sustainability in the supply chain departments and the entire business. As shown in Figure 10 of the “Factory of Future”, it is believed that connecting the whole business together digitally reduces the carbon footprint on the environment and helps decision makers to take critical decisions based on real-time data thanks to IoT. Further, IoT not only enables connecting machines, devices, and operators with the enterprise but also is able to connect multiple levels and manufacturing sites digitally together via Cloud and the Internet. They finally added that implementation of such technology promotes the usage of sustainable energy sources.

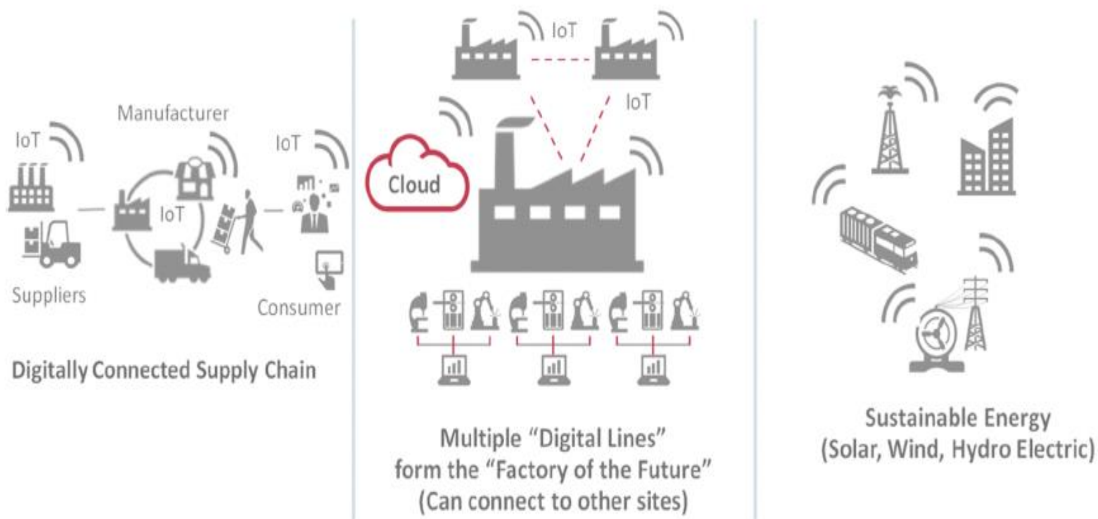

Figure 9 Factory of Future (Manayalan and Jayakrishna, 2018)

Badugu proposed an integrational framework between fuzzy logic and IoT that can promote a sustainable supply chain for organizations. Fuzzy Based Decision Making (FBDM) is used to endorse circular supply chains, as shown in Figure 11.

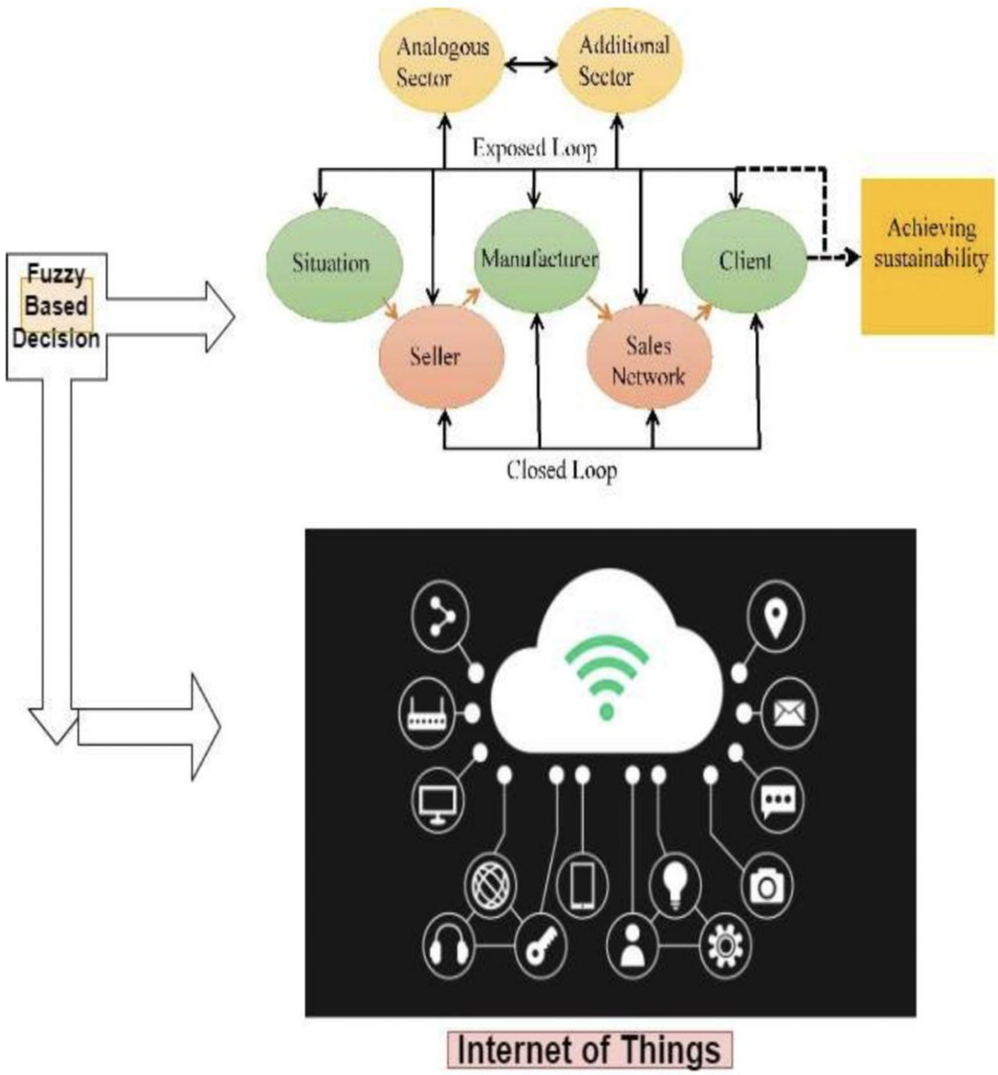

Figure 10 Framework of FBDM and IoT (Badugu, 2020)

In the exposed supply chain loop, environmental assets are extracted and it is urged to get rid of some goods, materials from packaging, and wastes from different levels of the supply chain. Mostly, these undesired objects are stored with limited usage.

Regarding the closed-loop supply chain, its aim is to increase sustainability by recurring the suppliers' demands for products and materials from packaging, however, retrieving the cost in such loop is limited due to the limited activities of the SC producer and the involvement of additional parties. In contrast, a closed-loop supply chain also yields a significant amount of waste, since reusing or recycling of discarded objects is hard in terms of feasibility. Badugu claims that by partnering with analogous and additional sectors supply chain could gain extra profit from these wastes. It is understood that by reinstating the market for commodities and materials for packaging, the closed-loop SC enhances the protection of the environment. Relying on Cloud systems can offer broadness of accessibility and resource management in the IoT network for the supply chain, which allow companies to syndicate product services to optimally deal with consumers' demands and precisely respond.

2.5.5 Supply Chain Control Towers (SCCT)

In his research "*Control towers in supply chain management – past and future*" (Trzuskawska-Grzesińska, 2017) summarized the history of Control Towers, mentioning that they date back to the 1990s when logistics managers were in need of precise visibility over the shipments and operations. It was implemented then by the least means of technologies available back then, telephones and printouts. Basic operations, like shipment delays, and route changes had to be done manually by operators, which was not so optimum for the supply chain processes. Later, the concept of Control Towers started getting more updates and incorporating new emerging technologies at that time.

GPS tracking systems and data storage systems were leveraged to facilitate more the tracking and visibility required for operation, logistics, and transportation activities. Although this was an advancement, however, many issues, like information overload and lack of infrastructure and accuracy, raised some concerns to the supply chain management departments. This is when the third generation of supply chain control towers came into play adopting the latest technological tools such as remote sensors, IoT, and efficient data analytics tools. The third generation, which was commonly used before the fourth industrial revolution, allowed for better real-time visibility, integration, insights, and handling of activities and products. Currently, with all the disruptive technologies that came along with Industry 4.0, Control Towers have changed from being reactive to predictive. In other words, Control Towers are now able, autonomously, to predict and anticipate any kind of disruption that could occur before it even happens.

2.5.5.1 Control Towers for Supply Chain Management

In the modern world, having a supply chain control tower is a one of the five critical steps for supply chain management. It can provide companies with a whole panoramic visibility over the demand, supply, transportation and trading operations all at one centralized place. In other words, one of the vital roles of the control towers is enhancing the short-term and long-term decision-making strategies, based on not only the wide visibility that it offers, but also the predictive execution that could be performed. Consequently, lessening the time needed to resolve possible problems and improving risk management. SCCT are able to deal with multiple sorts of problems that could actually take place during the supply chain cycles such as real demand realization, demand swings, and distribution issues (Trzuskawska-Grzesińska, 2017). Patsavellas et al., 2021, probed that SCCT leveraging the fourth industrial revolution can act as a “single access point of truth” that serves all the stakeholders, decision-makers and the cross-functional partners of the supply chain. Such platform has the ability to collect, analyze and distribute data, detect crisis before happening, and allow monitoring, measuring and managing over the whole SC cycle. SCCT could bring to companies in enhancing the supply chain resilience and supply chain agility, where companies can spot problems ahead, be alert, and can respond quickly in case of any unprecedented events (SYAHCHARI et al., 2022). The collaboration and coordination between the supply chain partners have seen a massive enhancement after the introduction of supply chain control towers (Patsavellas et al, 2021). As mentioned in previous chapters, supply chain collaboration can mitigate the high distortion of information (bullwhip effect) and reduce the operational and administrative expenses for the entire chain. Moreover, it allows suppliers to build good relationships, loyalty, and reducing their costs via information sharing. Patsavellas et al have proposed a matrix that divide the functionalities and benefits of supply chain control towers in three categories: See, Plan, Act. Under the See category, there are six major benefits stated: B2B Integration, End-to-End Mapping, Real-Time Monitoring, Granular Visibility, Data Management, and Alert Generation. B2B Integration represents what was mentioned before in increasing the communication between SC partners and reducing bullwhip effect, while End-to-End Mapping denotes the wide visibility provided over the whole supply chain network and the autonomous decision-making development. Real-Time monitoring aims to improve the service levels leveraging the tracking and recording of the demand-supply performances in real time manner. Granular Visibility offers a precise work medium for pulling high levels of details over multiple variables. Data Management and Alert Generation both focus on storing and structuring data, optimizing the autonomous decision-making phases, and providing information and alerts to stakeholders prior any anticipated disruption or crisis. Secondly, is the Plan category, where information is being analyzed and used to improve the profitability/revenue models of businesses, market share expansion, ROI to the stakeholders, and effective decision making. Finally, the Act category, that presents three more functionalities: Process Automation, Human-Machine Collaboration, and Exception-Based Decision making. Thanks to supply chain control towers, automatic the execution of different plans and schedules can take place without any human interaction, where visibility comes into play in facilitating the execution and the performance measuring. It is true that SCCT allows fewer human interactions in most of the cases, but it also features Human-Machine Collaboration, where it provides the means to cross-functionally collaborate between individuals and machines across the organization, orchestrating effectively responses to some events and providing trusted algorithms to facilitate the different processes. Finally, Exception-based decision making, which as mentioned before is the key for mitigating possible risks and preventing crisis prior happening. After analyzing all the previous categories, it is easy to say that SCCT can be advantageous in cost reductions, enhancing efficiency, and providing better customer experience.

Trzuskawska-Grzesińska has conducted a study over three companies to test which key business capabilities of SCCT could bring the highest benefits, according to the needs of each company the responses were collected and visually represented. The below graph represents the results:

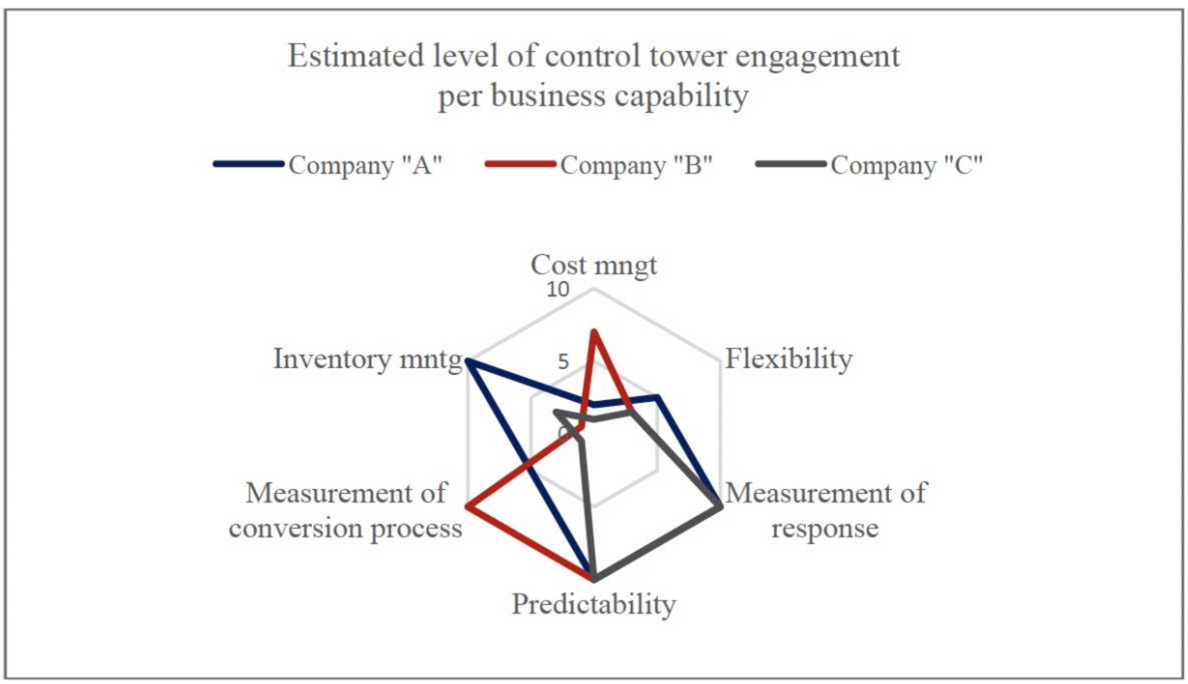

Figure 11 Companies analysis; SCCT example (Trzuskawska-Grzesińska, 2017)

All three companies have agreed on the importance of predictability and response measurement capabilities for their businesses. Company B highlighted the benefits that could result in terms of conversion process measurements and cost management. While Company A's responses were highly moving towards Inventory management and flexibility. Like any other technology, supply chain control towers could come up with some limitations or challenges. According to Patsavellas et al, some companies might be having some difficulties accepting collaboration with partners, since it could be hard for them to be fully transparent, disclose data, and provide access to the partners to check their schedules and sensitive data. Further, there is always risks for hindering accuracy due to human interventions. Although the data is collected autonomously, there is still a human interaction to update data through various input sources which might cause discrepancies. Additionally, many challenges could rise during the integration process of SCCT in terms of finances, time and skill resources needed, since such integration to be done it requires working with all the SC partners all along who could have different levels of technology competencies, schedules and resources. Finally, the adoption of a supply chain control tower necessitates a huge financial investment as well as investing in the operators to acquire the skills needed to effectively operate.

2.5.6 Blockchain

2.5.6.1 Blockchain for supply chain management

Blockchain is a disruptive technology that emerged in the recent past and enabled the rise of the famous Bitcoin. The first application of the blockchain was in the finance industry, specifically in cryptocurrencies. This was due to the inefficiencies and costs required to maintain the processes of the finance sector. Due to the immense amount of transactions and actors involved, tracing those transactions and their owners was difficult, which required the appointment of intermediaries, that in turn cost a lot of time and money. Blockchain technology came into play here, where it eliminated the inefficiencies related to time and money wasted, through tracing and validating transactions efficiently and effectively over the blockchain networks (Nofer et al., 2017). The basic idea behind this technology in a nutshell, is that it is a distributed ledger that involves blocks of transaction data connected to each other through a hash value and a timestamp, to form a chain of blocks or a ledger of data. Through these hash values, the chains could be traced back to the first or “genesis block”, and any change in these hash values would consequently cause a change in the hash value of the genesis block, thereby ensuring the integrity of the whole chain. This is achieved through a consensus mechanism that is agreed upon by all nodes in the network, which adds a block to the chain only after it has been validated by most nodes through the consensus mechanism (Yaga et al., 2018). After the information is stored in the block for a certain amount of time, it is then permanently added to the ledger, where it cannot be altered or tampered with. (Nofer et al., 2017). This is done to achieve trust ability and traceability of any transaction occurring over the network. The second most famous tool empowered by the blockchain is smart contracts. Smart contracts are a way to execute contracts automatically through transferring assets when certain conditions are met, relying on the decentralization of intermediaries through the features mentioned before (Al-Saqaf and Seidler, 2017). Basically, smart contracts take the normal contracts clauses, and transform it into code on the distributed ledger, where these codes are executed automatically when the clauses are put into action. Due to these benefits, the applications of the blockchain have been extending into industries beyond the finance one and applications beyond cryptocurrencies, that mainly aim to enhance the trust ability and traceability of processes (Scott et al., 2017). Various applications of blockchain could be implemented and prove effective in the supply chain management context. Among those applications, smart contracts are the most widely used (Queiroz et al 2018). Because smart contracts do not involve intermediaries and are executed automatically (transfer of money and/or goods) once certain conditions are met, transactions are usually faster, trust is strengthened between the supply chain partners, and transaction costs are reduced (Queiroz et al 2018). Consequently, smart contracts could help reduce supply chain lead times significantly, improve responsiveness, and enforce security and trust through the supply chain.

2.5.6.2 The influencing sustainable factors for adopting blockchain in supply chains

In the research conducted by (Chang and Chen, 2020), it has been shown that the three main supply chain performance areas that could be influenced by blockchain are traceability and transparency, stakeholder involvement and collaboration, and supply chain integration and digitalization. Similarly, (Park et al., 2021) summarize the four main characteristics of a blockchain-based supply chain into: Traceability, reliability and security, synchronized transaction processes, and cost efficiency. As described before, these are some of the main areas that have a significant influence over all aspects of the triple bottom line, which in turn improves the sustainable performance and resilience of the supply chain. Firstly, transparency and traceability are of key importance to the success of the supply chain, due to the large amount of supply chain partners and the information exchanged between them. With the implementation of the blockchain, each supply chain partner would have a duplicate of their transactions on the ledger, thereby having more visibility over those transactions, and reducing the need for centralized organizations monitoring them (Amofa et al., 2018). Not only are these transactions distributed, but they are also immutable as previously described. This feature could reduce disputes between the supply chain partners in addition to reducing the need for alignment between different functions and partners in the supply chain (Chang and Chen, 2020). In addition, employing smart contracts could also improve the monitoring of transactions and physical goods through the supply chain with the help of Internet of Things (IoT), thereby improving the overall traceability of the supply chain (Hasan et al., 2019). As illustrated previously, collaboration is one of the main influencers and indicators of the sustainable performance of a supply chain. According to (Chang and Chen, 2020), the influence of blockchain on collaboration between the supply chain partners depends on the willingness of the managers to implement the technology, especially during its current early stages. There needs to be an alignment between the supply chain actors, which could be hindered by the different levels of readiness across the partners in terms of management commitment, migration from legacy databases, and interoperability between the different functions and stages. In addition, blockchain could facilitate supply chain integration through the enhanced visibility and disintermediation provided by the ledger. As a result of the enhanced visibility and control, sustainability across the supply chain as well as resilience are also empowered.

2.5.6.3 The impact of blockchain on sustainable supply chain performance

The following research by (Rejeb and Regeb, 2020) and (Park et al., 2021) categorizes the previously described supply chain features of the blockchain into according to the triple bottom line elements. Starting with economic sustainability, these features are represented in market disintermediation, operational efficiencies, cost efficiencies, and value creation opportunities. A very important feature of the blockchain is the elimination of supply chain intermediaries, which reduces the supply chain complexity, and hence, facilitates the collaboration between the supply chain partners, as well as improve the visibility over the whole chain. In fact, disintermediation is the most associated feature of blockchain in supply chain performance. Then, operational efficiency is embodied in the enhanced visibility and traceability that are granted through the real time monitoring of goods and information across the chain (Treiblmaier, 2018).

Through the enhanced visibility of course, companies could have a more complete and clearer picture of where the status of their products across the chain. For example, by getting accurate information on their inventory levels, demand data, and the logistical status of these products. A consequence of Disintermediation is also cost efficiencies, which are mainly overhead costs related to monitoring and control, and transaction costs. In fact, (Ko et al., 2018) shows that through the implementation of blockchain, companies could reduce their networking costs. Finally, value creation opportunities are made available thanks to the sharing models and visibility granted by the blockchain. Through these models, companies could improve collaboration through utilizing and sharing available recourses, such as trucks, containers, or warehouses for instance (Meyer et al., 2019). Moving, to the social element of the TBL, it has been shown that trust is the most prevailing factor that supply chain partners consider when implementing blockchain technology (Wang et al., 2019). And as described before, trust is one of the main elements that empower supply chain sustainability and resilience. According to (Veuger, 2018), the transparency and completeness of information granted by the blockchain is a solid foundation upon which supply chain trust could be nurtured and strengthened. Finally, environmental sustainability is also improved by the blockchain, again through monitoring and control. Greenhouse emissions and carbon footprint could be significantly narrowed down through the constant monitoring that the blockchain offers. For instance, through facilitating the tracking of production parameters such as emissions, energy consumptions and raw material usage. On this note, (Saberi et al., 2019) illustrates that blockchain could help companies identify products materials that consume a lot of energy and emits a lot of greenhouse gases, and in turn helps identify more environmentally and economically efficient alternatives to them. Resource sharing plays a role here again, where supply chain partners are encouraged to collaborate to achieve better environmental performance, through the utilization of shared assets and equipment in real time. Through logistical collaboration, supply chain partners can reduce the overall number of trips taken, and improve products tracking, thereby reducing environmental emission associated with transportation and reducing waste and improving the circular economy through product traceability. To sum up, the main features of the blockchain, that have the biggest impact on supply chain sustainable performance are disintermediation, immutability, traceability, and autonomy through smart contracts. The effects of these features are resonant through all aspects of the TBL and are comprehended in traceability, visibility, resource sharing, trust, efficiency, and collaboration. The results are summarized in the following table.

Table 1 Features of Blockchain and their Impacts on Sustainability factors

	Collaboration	**Visibility**	**Resource sharing**	**Traceability**	**Efficiency**	**Trust**
Disintermediation	X	X			X	
Immutability					X	X
Traceability	X	X	X	X	X	X
Autonomy					X	X

2.5.6.4 The impact of blockchain on sustainable transport and logistics

One of the most influenced fields by blockchain is transportation and distribution. In the research performed by (Chang and Chen, 2020), the most prevailing sector found was physical distribution and logistics. And as described before, transportation is one of the most phases of the supply chain affecting the overall sustainable performance of the supply chain. The previously described impacts of the blockchain on supply chain sustainability is again playing an important role in achieving a more sustainable transportation performance. Traceability and smart contracts are the main enablers here, granting the transportation phase of the supply chain several benefits. This is illustrated in better tracking and control of goods and information as they move through the nodes of the chain. Administrative documents could be tracked more accurately and timely, such as orders, receipts, payments, and invoices. In addition, sharing information becomes more effective, where supply chain partners could have a clearer idea about the delivery of goods, inventory levels, and status of vehicles (Litke et al., 2019). Resource sharing is also a potential benefit, as mentioned before. Through having a clear visibility over the loading status of containers and vehicles, companies can share these resources, thereby reducing transportation costs, and sharing the risk (Meyer et al., 2019). Immutability here is an important driver as well because it provides security to the chain, by protecting the important transport information and documents such as the shipping notice or the bill of lading that are exchanged between the supply chain partners from theft and counterfeit (Tijan et al. , 2019). This is achieved through the digital token feature of the blockchain, which is associated to the physical good being transported. The most technologically advanced and emerging link between the blockchain and sustainable transport is the application of internet of things. As described previously, blockchain is a great enabler to the wide use of IoT in supply chains, and especially in the transportation and logistics phase. According to (Tijan et al., 2019), logistics and transportation is one of the most prominent fields of blockchain and IoT integration due to the huge potential that these technologies offer when put together. This is because the logistics and transportation sector are starting to rely on smart connected assets, like containers, shipments, and goods to improve the overall performance. The empowerment of IoT by the blockchain could even reach the potential, where IoT devices being transported could interact with other actors in the supply chain through smart contracts, thereby enabling them to pay custom fees and duties autonomously using cryptocurrencies (Wagner et al., 2018). These benefits are also summarized in the paper by (Hackius and Petersen, 2017), where they describe them as: facilitating paperwork processing, identify counterfeit products, facilitate origin tracking, and operate the internet of things.

2.5.6.4 Blockchain applications in transportation and logistics

One of the main application areas of the blockchain in transport and logistics is shipment tracking. Due to the increasing trend in outsourcing transport and logistics to third party providers, traditional fleet management systems have evolved into more holistic transport management systems, with the purpose of reducing the complexity and uncertainty associated with the widespread of outsourcing. However, according to (Wu et al., 2019), these systems are not completely effective, because the information provided by them, such as shipment level tracking is often not validated, in addition to its being still controlled by the carrier and disclosed to the stakeholders ad-hoc. Therefore, trust and transparency are of sheer importance here. This is where the previously described benefits of blockchain come into play in the supply chain. The article by (Li et al., 2017) proposes a framework over the blockchain that integrates with companies' current ERP tools and provides validation and transparency through real time online shipment tracking shared with the supply chain partners in the transportation phase. The framework is composed of multiple private ledgers, and a single public ledger. Through the multiple private ledgers, it is possible to store the so-called custody events, that are events related to the ownership of the transported asset, which could stay with the original owner, or transported from a party to another. Then, for immutability, the hash value of this event is stored and validated on the public ledger, which also stores monitoring events, that are related to the geographical location of the asset and are posted to the ledger through physical monitors (Wu et al., 2019). The following figure illustrates the functions of the framework.

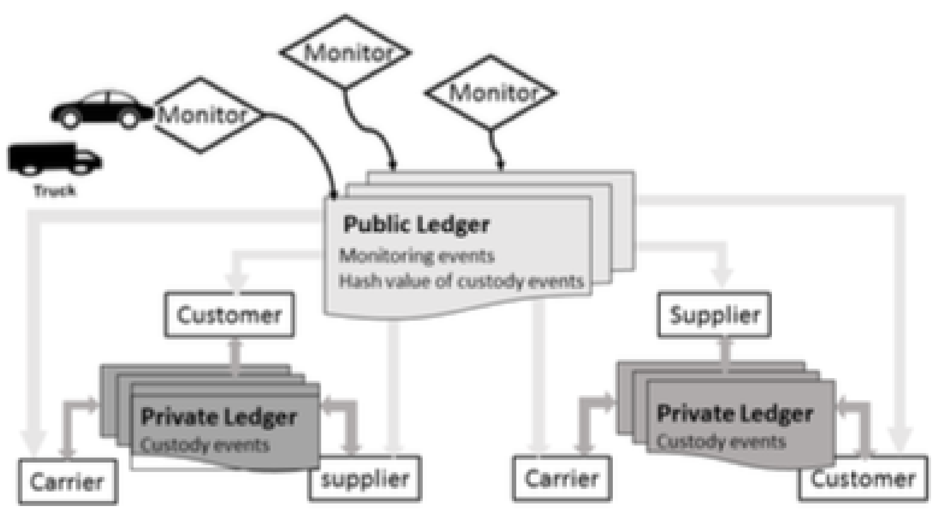

Figure 12 Blockchain framework (Wu et al., 2019)

In a similar study, (Hasan et al., 2019) have also proposed a model to track shipments using blockchain technology, and more specifically, smart contracts. With the help of IoT equipped containers, smart contracts can gather information from the IoT sensors, such as temperature, geographical location, sudden drop in a good, or high pressure. Based on the gathered information, the smart contracts autonomously initiate actions, such as payments, refunds, certifying the receiver, and managing the shipment conditions. Similarly, (Meyer et al., 2019) proposed a conceptual framework, to help route containers efficiently, with the help of blockchain and the physical internet. The latter is based on IoT technology, and it aims to connect all physical assets in the logistics and transportation field. The proposed framework provides a solution to sustainably allocating, tracking, and routing IoT containers, with the help of blockchain and smart contracts. One of the most famous cases of blockchain application in the transportation field is, the collaboration of Maersk and IBM to use IBM's blockchain cloud solution to track containers transparently and efficiently in real-time, as well as trace every step of the transported goods back to its origin (Queiroz et al., 2020; Tijan et al., 2019; Park et al., 2021)

2.5.6.4 Challenges to blockchain implementation in supply chains

Despite all the mentioned benefits and capabilities of blockchain technology for a more sustainable supply chain management, there are still some technical, as well as managerial challenges to adopting it. The most common technical difficulty with adopting blockchain technology is its performance and scalability of it (Tijan et al., 2019). Since all nodes across the chain process the information stored on the ledger, global and complex supply chains could face difficulties in expanding the potentialities of the technology across the chains. In addition, the technology is power intensive, which is counterintuitive when applying it to improve the sustainability of a supply chain, since it consumes a vast amount of energy and negatively affect the environmental and economic sustainability of the chain. Although the decentralization feature of the technology has a lot of benefits, it could pose a threat to the privacy of the supply chain actors due to the absence of a central authority monitoring the information that is spread across the whole chain. This brings us to managerial challenge, where the absence of regulations and the immaturity of the technology makes managers reluctant to adopt it, because they fear the current methods may be overwritten in the future, or even deemed illegal (Gatteschi et al., 2018). This view was also supported by (Hackius and Petersen, 2017), who found that the most common reason that managers are reluctant to adopt blockchain in the logistics field, is regulatory uncertainty. In addition, managers do not fully understand the impact of blockchain on their supply chain, and they do not have a clear vision of whether their chain needs it and how to implement it (Aich et al., 2019)

3. Research Methodology

The starting point for the creation of this thesis work was the process of desk research that provided an extended understanding of different aspects of Sustainable Supply Chain Management (SSCM), and the relationship and roles of different means of technologies to achieve SSCM. This was achieved mainly using two approaches: conducting a traditional literature review over the current research and exploring the findings of the literature review on a practical case study of a company in the home appliances or white goods industry.

3.1 Literature review

To understand the overall picture and current developments in the sustainable supply chain management field, and to try to formulate and answer the research questions, a traditional literature review was conducted. The review was conducted by mainly collecting information from the google scholar and the Scopus database, with the help of both previously established and emerged keywords. The keywords that were mostly used in the search phase were: Sustainability, supply chain management, resilience, transportation, logistics, technology, marketing, supply chain processes, visibility, collaboration, Internet of Things, Blockchain. After collecting the information, the data gathered was filtered first by date of publishing, were most information considered was published in 2017 or later, unless it is a crucial piece of information that important for describing the fundamentals of the topic under study. Then the abstract introduction and results of the research found was read in order to identify the relevancy and filtered again.

Finally, after having all the relevant research and information, the data collected was compared to each other, then categorized into mutual topics, which was used to guide the body of the literature.

3.2 Case study

To explore the finding of the literature review on ground, a case study was conducted over Whirlpool, one of the biggest companies in the home appliances sector. The type of case study used was a single holistic case study with embedded units because the unit under analysis is Whirlpool, which is the min actor involved in the study, and the focal node in the supply chain. Other embedded units are also represented, such as the functions and process withing the company, the suppliers, and service providers. This is due to the relational nature of these units to the focal company, and their vitality in operating the supply chain. The case study design is mainly of exploratory nature, since the aim of the case study with the literature review, is to explore the information gathered and assess its viability, which is also represented through the research questions of the study. The data collected for the case study was mainly through meetings with the supply chain and logistics managers in the company, the company's annual and sustainability reports, and market analysis websites such as Statista. After collecting the data, it was also refined according to the topics' relevancy and the themes occurring in this research study. To interpret and analyze the data, some established models and frameworks were used, such as the Supply Chain Operations Reference (SCOR) model, and the triple bottom line framework, because they provide a comprehensive overview of all supply chain processes as well as link them with the sustainability pillars and practices. This also helped in providing a structured representation of the findings, to be able to contextualize the theoretical background into the case study. The structure of the case study commenced with some background information about the company, in order to provide the setting of the company's size and scope. Following the company background, a more in-depth description of the company's supply chain description was presented. Then, the current sustainability practices that the company has undergone was also explored, to set the tone for the topics and themes of this research. Information gathered for the case study was through meetings and files shared, which will be elaborated further in the appendix .

4. Whirlpool Case Study

4.1 Company background

Whirlpool Corporation is one of the biggest and oldest home appliances companies in the world. It has a global presence with 54 manufacturing and technology centers, operated mainly through 4 regions: North America, Latin America, Europe Middle East and Africa, and Asia. (Annual report,2021). The company is involved in the production and selling of a wide range of big and small appliances that include laundry and washing appliances, cooking, and refrigeration appliances. Those appliances are presented through a large brand portfolio that includes several brand names such as Whirlpool, Hotpoint, Kitchenaid, and Indesit. Aside from the direct global presence in the mentioned regions, the company also sells its products all around the world through its dispersed central and regional distribution centers, in addition to its trade customers. In 2022, the company achieved an all-time high sales figure, coming in third worldwide with 22 billion US dollars, and a 5-6 percent of organic sales growth, preceded by Hair Smart Home, and LG Electronics, with 36 and 22.7 billion US dollars of sales respectively. (Statista, 2022). The company's main driving market is North America, with 57 percent of its sales accounted for this region, and the main selling categories are refrigeration and laundry with 30 and 28 percent of the total sales respectively (Annual report, 2021). Operationally, the company was more efficient than its main competitors in converting these sales into profit. In 2021, Whirlpool's EBIT margin came to a company's all time high of 10.8 percent, which is almost the double of the 5.2 and 5.17 percent achieved by Haier Smart Home and LG electronics respectively (Annual reports, 2021).

4.2 Supply chain background

Whirlpool Europe Middle East and Africa has two main channels of realizing and delivering its products. The first one is its own producing factories, with 9 production facilities in Europe, and the headquarters located in Milan, Italy. The other channel is through finished product sourcing (FPS), where the final product is produced by global suppliers, located mainly in China and Turkey. Below is a holistic map of Whirlpool's supply chain, representing the main nodes, material flow, information flow, and financial flow.

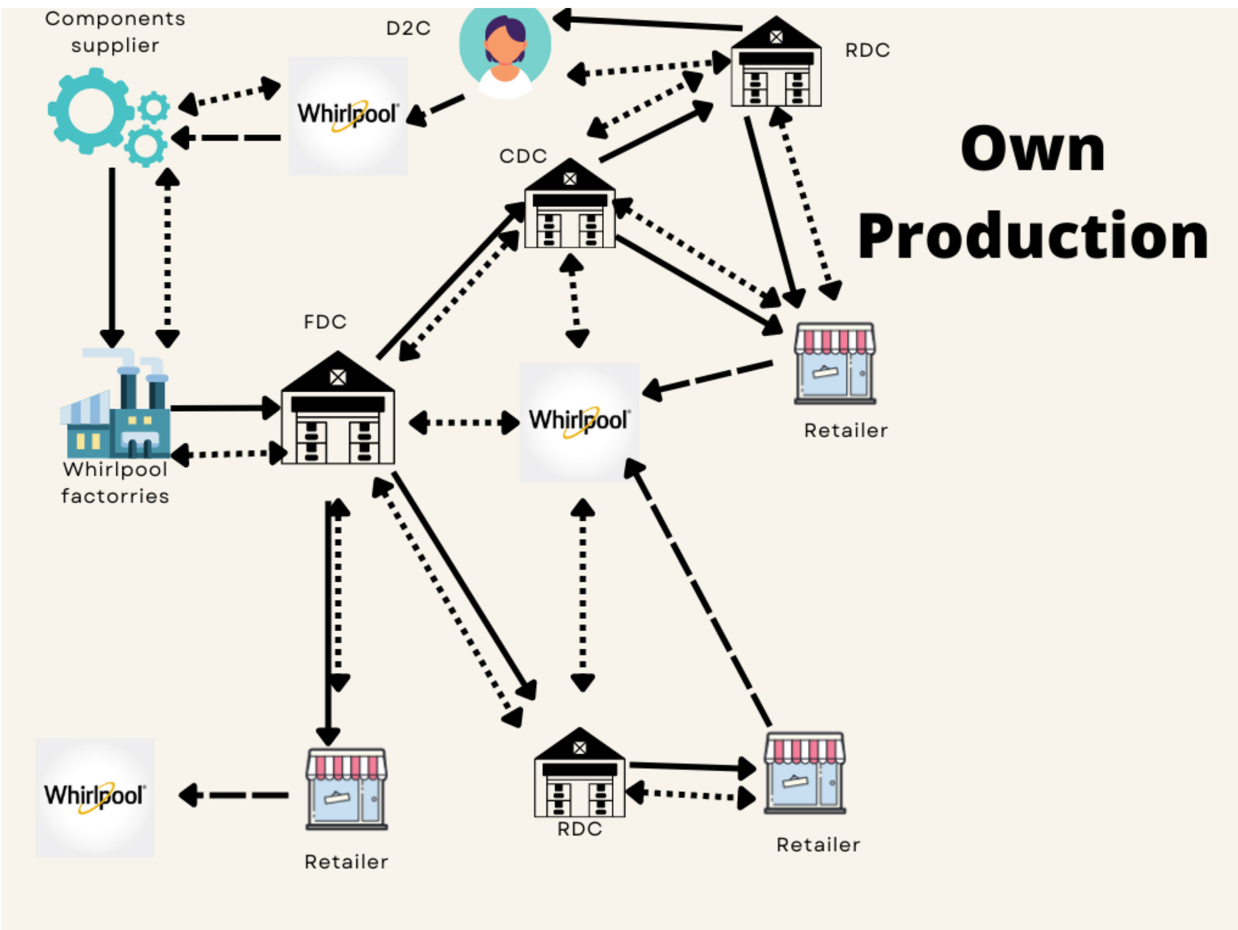

Figure 13 Whirlpool Supply chain map

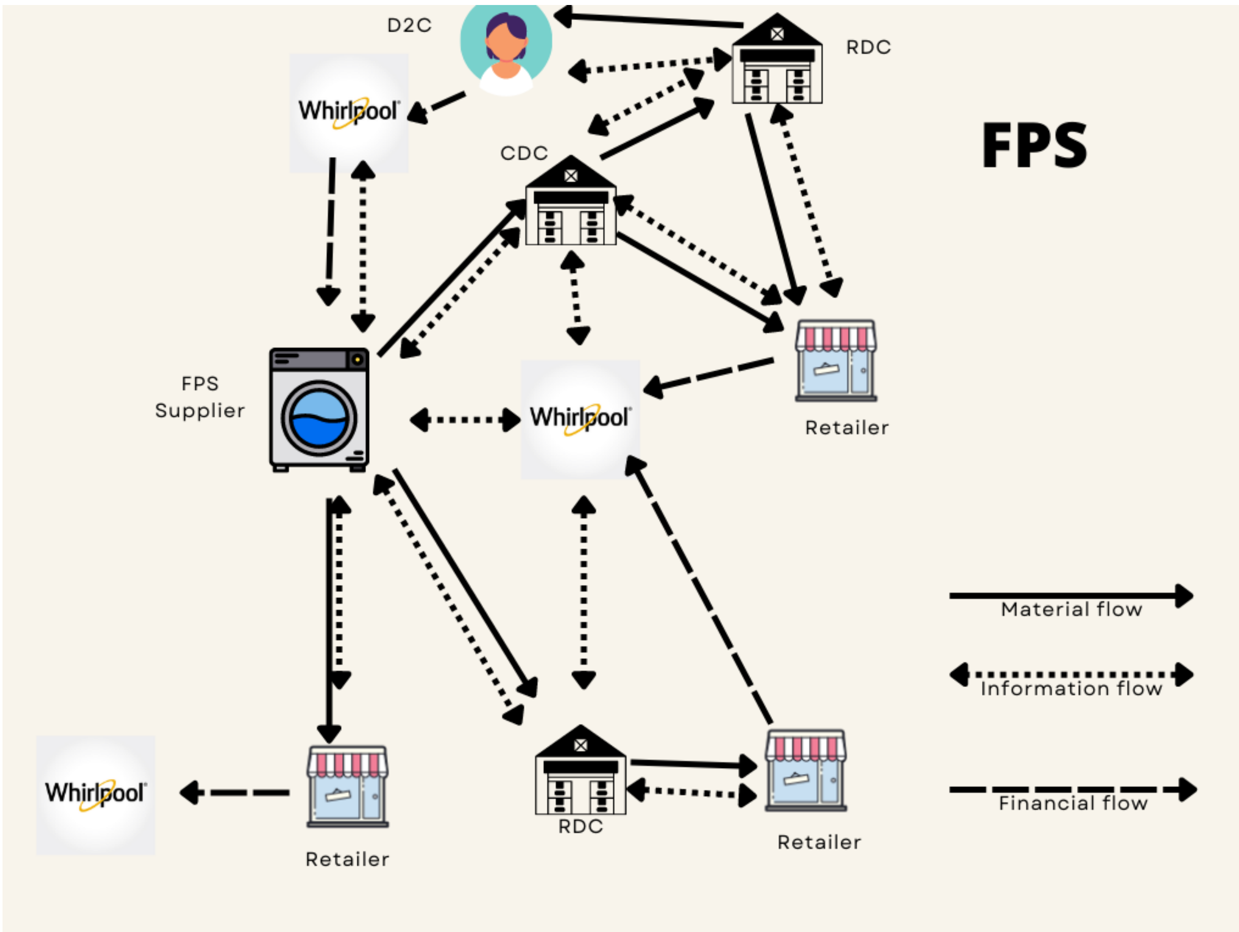

Figure 14 Whirlpool Supply chain map 2

The above maps represent the flows through the Whirlpool EMEA's supply chain along the two streams of production; the Whirlpool manufacturing facilities, and the finished product souring (FPS), which are mostly similar with the exception of the starting nodes. In the first map, the component supplier receives the requirements needed from the supply chain team, then sends them to the factory in need of those components. After the factory produces the final product, it is stored in the factory distribution center (FDC), which then can go to a Central distribution center, followed by a regional distribution center (RDC), and from the RDC to the retailer, or directly to the final customer (D2C) through online channels. The FDC could also send the good directly to the RDC or even directly to the retailers through build to orders (BTO). For the FPS flow, the finished goods supplier receives the production plan from whirlpool's supply chain team, and the rest of the flow is similar to the previous one, starting from the FDC. As for the information flow, various kinds of information flows through the nodes like orders, production plans, invoices, delivery requests, and so on. And finally, the financial flow is usually from whirlpool to its suppliers, and from the customers and retailers to Whirlpool. To describe the supply chain of Whirlpool, the Supply Chain Operations Reference (SCOR) model will be used, because it encompasses the whole supply chain processes, and links them to practices, performance, and people. The below chart shows the structure of the SCOR model.

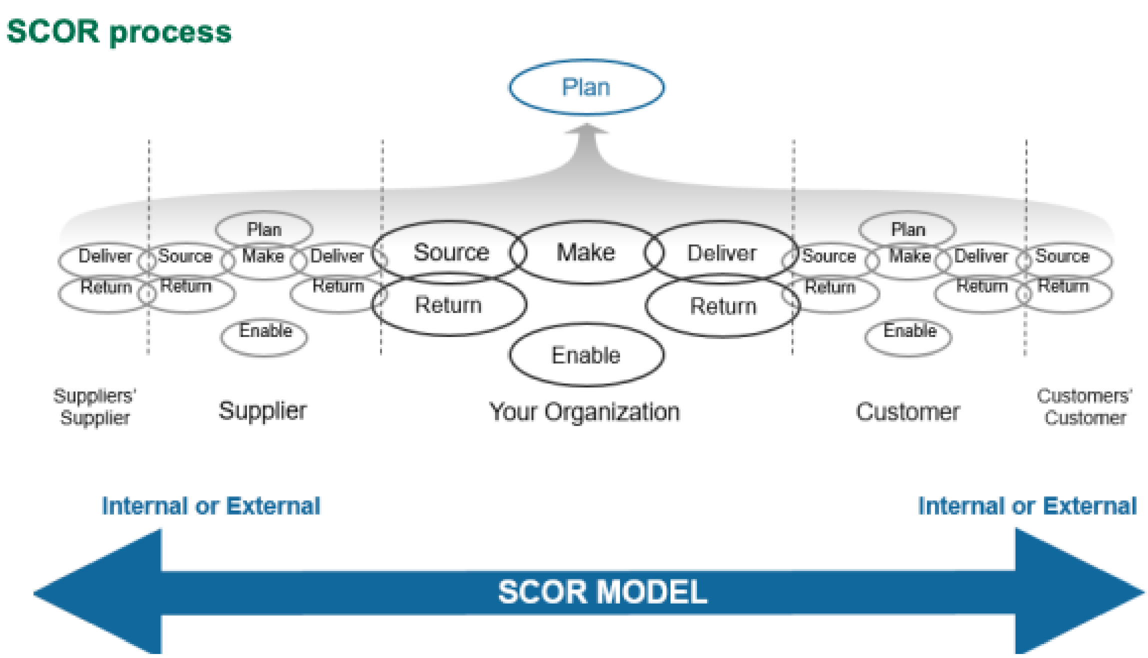

Figure 15 SCOR model (ASCM,2020)

The first main level of the SCOR model describes the six main processes that are: Plan, Source, Make, Deliver, Return, and Enable. Inside each process there are more in-depth levels. For instance, for the source process, there could be source stocked product, source make to order (MTO) product, or source engineer-to-order (ETO) product. Then under each of these, there is another level of sub-processes, metrics, and practices (ASCM,2020). For the purpose of this study, the focus will be on the plan, source, deliver, and enable processes of the FPS flow of Whirlpool.

4.2.1 Plan

The planning process is the main one that links all the other processes together, through identifying, prioritizing, and aggregating the supply chain requirements and resources, balancing them together, and communicating the plans through the supply chain (ASCM,2020). The planning process of Whirlpool's FPS function consists of analyzing the demand forecast coming from the final markets, aggregating the demand based on the market or final destination and the stock keeping unit (SKU). The demand forecast is usually provided at the SKU level, and could be aggregated to the product category level, up until the whole market or sales area level. The time horizon for the forecasts are 12 months, detailed into monthly and up to weekly forecasts, and are updated every month. After that, the plan consists of assigning the requirement needed for each market based on different constraints, like capacity limitations, lead times, minimum order quantities (MOQ) and shipping container sizes. Then, the conducted plan is communicated to the supplier, which in turn verifies the plan and confirms it back.

4.2.2 Source

After having communicated the plan with the supplier, the source stage comes into effect, where this stage is concerned with ordering, delivering, and transferring the products (ASCM,2020). The products being sourced could be either stocked products that are based on demand aggregations and stock levels at the warehouses, or it could be based on BTOs, where the order comes directly from the final customer or retailer, and the customer order is shared with the supplier, where the order is delivered directly to the final customer without staying at the Whirlpool warehouses. The sourcing strategy of the FPS flow is usually of a divisional type, where each planner is responsible for a final category of products, such as washing or refrigeration.

4.2.3 Deliver

The deliver stage is an essential part that completes the previous two stages, because it is where the transportation and receipt of the products that has been sourced and planned takes place. The delivery process is initiated with the creation of a delivery request by the supply chain team, which is a request that contains the quantity planned, and usually corresponds to the shipment of one container. This delivery request is then automatically sent to the fourth party logistics provider and the supplier, where the management of these shipments are outsourced to the fourth party logistics provider. The logistics provider manages the delivery request right after it has been loaded into the container at the supplier's warehouse, up until it reaches the port of destination, where another local carrier manages the shipment till it reaches the final warehouse or customer, at which the unloading occurs. Due to the distance of the suppliers, the transportation mode of most shipments coming from the suppliers are through sea, with some shipments from Turkey coming through road, depending on the proximity of the target warehouse.

4.2.4 Enable

The enable process is mainly concerned with managing and monitoring the previous processes, the supply chain network overall, the information and technology in the supply chain, the supply chain contracts, and the supply chain performance (ASCM,2020). One of the key enablers in the Whirlpool supply chain is the constant monitoring and balancing of the supply chain requirements and the supply chain resources. This is achieved by identifying possible variations in demand and aligning the resources with it, which requires high levels of visibility and collaboration, both internally and on the supplier level. For example, when a potential gap is identified between supply and demand, suppliers are immediately involved through the anticipation of additional production, or when extra production is not possible, coordination with the markets occur to identify opportunities of redirections from a saturated market to the affected market. The suppliers' performance is also constantly assessed and monitored to identify areas of improvements, such as percentage monthly backlogs of current orders. As mentioned before, collaboration is of sheer importance to the success of the supply chain; therefore, the company is always connected to the suppliers and the markets through constant meetings, shared files that all parties work on, online portals, and the enterprise resource planning (ERP) system. For example, crucial information is constantly exchanged between all parties, such as the annual demand forecast that is updated periodically and shared with the suppliers to have a better capacity plan, which in turn is also shared with the company. The company's ERP system is also connected to the online portals, which is also connected to supplier's system. For example, when a production run is planned by the whirlpool supply chain team, it is automatically uploaded on the Supplier collaboration portal, which then mirrors in the supplier's system, where the supplier could check the production plan and confirm it. Through the online portals, shipments could also be managed and tracked starting from its confirmation, up until it is unloaded at the final warehouse. As soon as the supplier loads the goods, they create a shipping notification through the portal that could also be viewed in the whirlpool system, where this notification number could also be used to track the shipment.

5. Findings and Discussion

The first part of this section is going to focus on analyzing the Literature Review. Starting with the broader look at the founded resources, moving to the useful insights and knowledge we found, then further exploring profoundly what was discovered from the literature which raised our research questions stated before in section 1.4. This takes us to the second part of this section, the Case Study that we conducted with Whirlpool Corporation, in efforts to correlate the knowledge that we have acquired from the secondary research with practical real-life industries. In this section we will be recounting and elaborate all the findings that we have got trying to answer to our research questions.

5.1 Literature review

The first phase of the literature review started by searching for documents, which included the activities of collecting material belonging to the academic universe. Extensive research was done on both Google Scholar and Scopus in the areas of: *Sustainable Supply Chain management, Green Logistics, Green Transportation, Supply Chain Resilience and Green Marketing.* After investigating all the literature related to the mentioned topics, we have identified the most important factors that are responsible for achieving a sustainable supply chain. Then we started to be more curious to know about the roles of different types of emerging technologies in achieving sustainability in supply chains and how can companies leverage these technologies to fulfill their sustainability goals. That’s when we decided to dive head-first into further exploring this topic in depth.

We started gathering publications related to different types of technology and its usage in supply chains generally and in sustainable supply chain specifically.

To construct the literature review 89 publications have been used, some of which have covered more than one topic of interest. The below visuals represent the number of papers associated with the topics of interest:

Table 2 Topics explored in publications

% of topics found in Publications	
Sustainability	67%
Technologies	56%
Logistics	28%
Marketing	25%
Transportation	25%
Resilience	10%

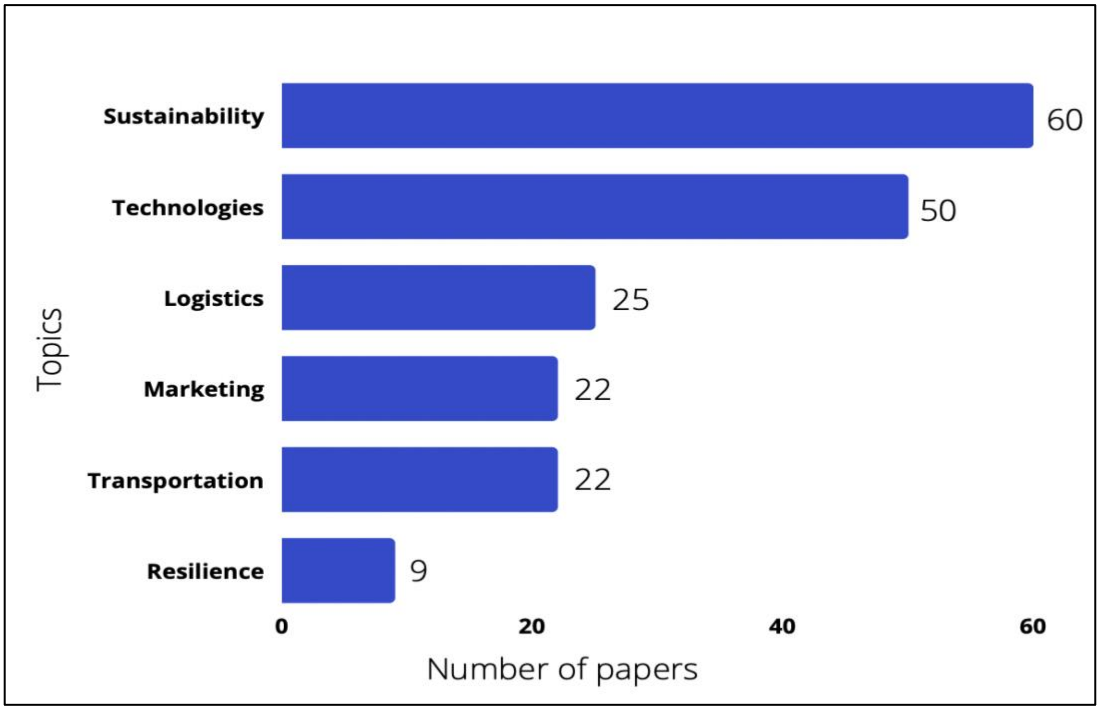

Figure 16 Number of publications for each topic

As shown in Table 2, 67% of the publications that we found were focused on sustainability in supply chain which was branched into many sub-topics like sustainable logistics, transportation, marketing and SC resilience. Then comes the technologies related papers which provided us with the information needed to conclude the literature review and prepare for the construction of the case study. Analyzing the technology papers that we found, we were able to identify different technology enablers that, according to literature, could facilitate the fulfilment of the sustainability goals for companies' supply chains. The stripping of the technologies categories is shown in the below figure:

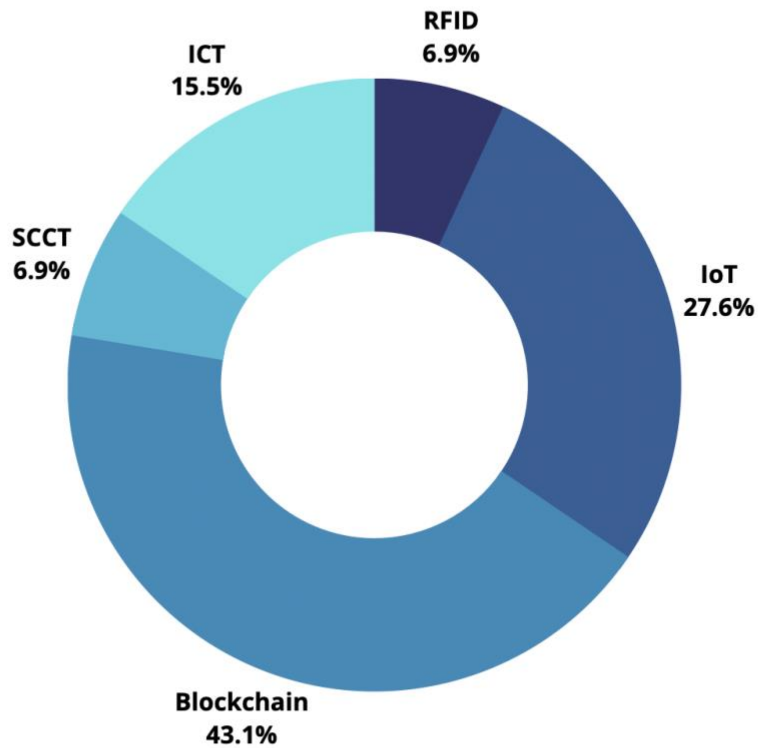

Figure 17 Technologies explored in publications

Where Blockchain and Internet of Things related papers were covered by the majority of papers we found, followed by Information Communication Technologies and then Radio Frequency Identifiers and Supply Chain Control towers come in last. Although we can say that they are still in the early adoption phase, Blockchain and IoT, are widely explored by recent scholars. This is because of the great potentialities that they could offer in enhancing the supply chains of organizations. It is also important to note that not all of the countless technology enablers were explored by us, only the most important ones were explored in this paper.

From the literature, we were able to identify the crucial factors when it comes to sustainability in supply chains. The following figure presents those factors:

Figure 18 Factors affecting sustainability

The first and most highlighted in publications is *Visibility*. We have understood that visibility is a major cornerstone for sustainability, because of what it offers in terms of benefits to the whole supply chain. *Supply Chain Collaboration* between partners was the second highly spotlighted factor in the literature. The vast majority of scholars have stressed on the importance of these specific two factors and the benefits they could bring to pursue sustainability in the supply chains. Then *Trust, Traceability, Efficiency,* and *Resource Sharing* have acquired relatively equal attention in the publications. The below table summarizes the mentioned factors and the most important benefits that they could bring according to theory.

Table 3 Factors affecting sustainability

Factor	Benefit
Visibility	• Reducing Disruptions • Promoting Agility • Increasing Speed • Meeting Customers' Demands • Data-Driven Results • Mitigating Wastes
Collaboration	• Improving Resilience and Agility • Enhancing Responsiveness to Customers' Demands • Efficient Forecasting and Operations • Refining Communication
Trust	• Maintaining Strong Partnerships • Assuring Partners satisfaction

Factor	Benefit
Traceability	• Enhancing Responsiveness • Reducing Wastes • Promoting Efficiency
Efficiency	• Reducing Environmental Impact • Protecting Social Reputation • Allowing Better Resource Allocations
Resource Sharing	• Reducing Inventories • Facilitating Production • Lessening wastes • Mitigating Environmental Impact

After identifying the vital factors for sustainability, we were able to classify which of the emerging technologies that we explored can be responsible for improving such factors. The below table illustrates what each technology can offer to achieve sustainability in supply chains:

Table 4 Technologies roles in Sustainability

	Visibility	Collaboration	Trust	Resource Sharing	Traceability	Efficiency
Blockchain	☑	☑	☑	☑	☑	☑
IoT	☑	☑			☑	☑
SCCT	☑	☑			☑	☑
RFID	☑	☑			☑	
ICT	☑	☑		☑		☑

One of the major findings that we deduced from the previous table is that the two mostly common factors, according to literature, that are responsible for fulfilling sustainability goals for the companies are Visibility and Collaboration. Then we were able to validate this finding when we conducted the case study with Whirlpool, which will be discussed thoroughly in the next section. Further, we recognized that Blockchain technology has shown a memorable ability to check all boxes for all the factors related to sustainability, Visibility, Collaboration, Trust, Resource Sharing, Traceability, and Efficiency.

5.2 Whirlpool case study

5.2.1 Current sustainability practices

Whirlpool corporation has undergone several sustainability initiatives and practices through the years, and across different regions in which it operates in. In the EMEA region, the company is widely adopting sustainable packaging, by aiming to replace all the expanded polystyrene (EPS) used in the packaging material as well as other disposable materials with other options that are more environmentally friendly. The company was able to reduce the weight of the EPS packaging of one of its brands by 25% and is working on an initiative to transform the packaging of one of its product categories, into fully paper-based packaging, which aims to reduce waste during disposal, as well as keep the product protected during transportation (Sustainability report.2021). The reduction of waste and the protection of the transported product in turn helps both improving the environmental impact as well as reduce costs related to packaging material and product damage. From the sourcing side, the company implements supplier code of conduct with all of its suppliers, where the suppliers are obliged to adhere to several standards and measures, including sustainability measure and environmental targets. This is achieved through evaluating potential suppliers' performance in these areas for possible qualification, as well as monitoring the performance of existing supplier, both directly and through third party audits (Sustainability report.2021). However, although the company provides trainings for all suppliers over the supplier code of conduct as well as encouraging them to extend these practices to their whole supply chains, these constant monitoring and audits only occur for the first-tier suppliers.

5.2.2 Enhancing visibility and collaboration through technology

Whirlpool EMEA is currently working with a third-party service provider to develop a tool that aims at enhancing visibility and collaboration through the supply chain. The tool is currently in it is pilot phase and is to be rolled out by the beginning of 2023. The solution is embodied in an online portal that works as a supply chain control tower in managing shipments from the start of the booking to reaching the warehouse, and even after it departs from the warehouse and reaches the customer. This portal acts as a layer that connects Whirlpool with the carriers and freight forwarders and provide real time connectivity between both parties and the shipments to be transported. The solution uses emerging technologies such as Internet of Things (IoT) and machine learning, to provide real time end-to-end visibility of shipments, slot booking management at the warehouses, and warehouse yard management. Not only are these technologies able to provide a real time situation and estimated time of arrival (ETA) of a shipment, but they can also perform predictive analytics, based on location, external factors in these locations such as weather or strikes, and historical information of this route, to provide a real time predicted ETA and information on possible disruptions such as shipments at risk, detention, and routing alerts, as well as notifying the concerned actors with such disruptions. This allows the management of shipments to be more efficient and resilient, by reducing time and costs associated with delays and inefficiencies, as well as foreseeing possible disruptions and taking the necessary actions to avoid them or mitigate them. The visibility is not enhanced while a shipment is being transported, but also after it has reached the warehouse. This occurs through real time tracking of the unloading progress, where it is possible to identify the any delays in unloading, the time taken for the unloading process, the quantity and status of the goods being unloaded. The unloading process occurs through the slot time booking feature of the solution, which connects the carrier to the warehouse, and allows the carrier to autonomously book free slots for unloading based on the dynamic availabilities in the warehouse. To drive sustainability even further and illustrate the key sustainability aspects of the process, the solution also provides a sustainability dashboard, which incorporates important sustainability measures associated with the shipments, such as average emission per shipment, average emission by transportation mode, and distance traveled. The solution also enhances the visibility of Whirlpool through tracking and illustrating the carrier’s performance through time, by showing key metrics such as throughput time, on time and late deliveries, average delay and so on.

5.2.3 Case discussion

Comparing the findings of the literature review with the case study and the solution Whirlpool is perusing to optimize the supply chain, several relations could be inferred regarding the enhancement of sustainability in the supply chain. As described before, visibility and collaboration are two of the key enablers of sustainable supply chain management. The main aim of the solution that the company is implementing is to provide end to end visibility over the logistics operations associated with shipments. This will provide the company with more control over the variables that might cause disruptions in the operations, and ultimately enhance the resilience of the supply chain, since having great visibility over the operations will allow the company to foresee those disruptions and initiate a course of action to avoid or minimize it. Secondly, enhanced collaboration is also one of the outcomes of this solution, since it allows real time connectivity between the company, the supplier, and the logistics carrier. As a result, high quality information is constantly shred between the actors, which allows for consistent alignment between them, and eventually a more effective problem resolution and smooth operations. In addition to visibility and collaboration, traceability was also found to be one of the enablers of sustainable supply chain management. Ultimately, traceability and visibility go hand in hand, where being able to trace products across the supply chain would in turn also contribute to enhancing visibility. Through having precise and real time locations as well as history information of the products' being shipped, the company could efficiently track and trace every single SKU, which helps in effectively identifying products at risk of delay for instance. As a result of, the company would be able to reduce the operational costs associated with transporting the goods, have a faster and streamlined process in meeting the demand on time, and be more flexible in counter acting uncertainty in the transportation process, which all in all would improve the overall efficiency of the supply chain and drive towards better sustainability. Resource sharing is also one of the main benefits of this solution, since the platform shared by the company and the supplier, which enhances collaboration even further and provides an aligned method to operating the supply chain. It is worth to mention that this level of effectiveness of the solution would not be enabled without the utilization of the accompanied emerging technologies. Through Internet of Things, the solution is able to accurately track and trace the goods in transit with the help of the connected equipment being transported. In addition, artificial intelligence is necessary to the provision of high-quality predictive analytics, since traditional tools and models, could not process the immense amount of information related to today's complex and uncertain supply chains, with the same efficiency and effective output.

5.2.3.1 Overall sustainability picture

To assess how the practices adopted by the company fit into the sustainability pillars, the triple bottom line of sustainability has been used together with the processes of the SCOR model, identifying which sustainability pillar could be enhanced through every process, as a result of the implemented practices. The following diagram shows the interplay between those two aspects.

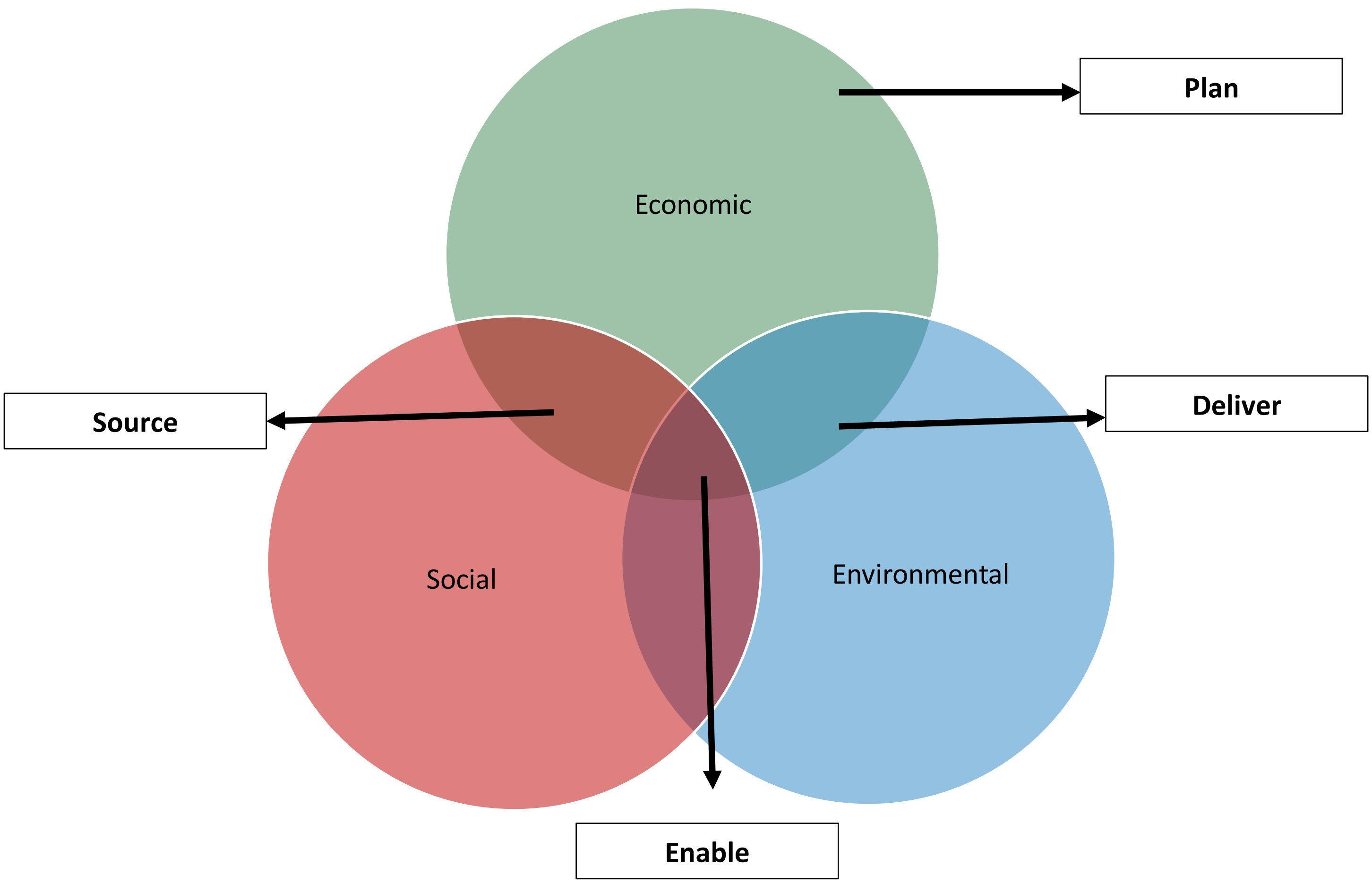

Figure 19 Triple bottom line +SCOR

Starting with the plan process, it is shown that the sustainability practices being adopted by the company only enhances the economic side of the triple bottom line. This is because of the better visibility brought forward by the new solution, which gives a clearer picture of the stock arriving to the warehouses, and thereby allowing for better alignment between the demand, the stock, and the production to be planned. As a result, associated costs misalignment between demand and supply, such as overproduction, would eventually decrease. Secondly, through the sourcing process would also be enhanced through the economic and social aspects. This is mainly due to the visibility provided by the solution as well as the collaboration benefits associated. For example, being able to have a real time tracking of shipments would improve the communication between Whirlpool and the shipment carrier, as well as free the sourcing employees from several manual activities related to shipments inquiries, which will give them more time to focus on more strategic activities. This would reduce costs related to non-value adding activities, in addition to giving the employees more motivation. Then moving to the deliver phase, the economic and environmental pillars are targeted by the practices the company is adopting. Through the tracking and predictive analytics, several costs related to inefficiencies could be reduced, such as costs related to delays, distance traveled, and potential risks and disruptions. This will also lead to less environmental emissions, especially with the sustainability feature that is solely dedicated to analyzing this area. In addition to this solution, the previously mentioned reduction in EPS packaging would also help reduce waste and reduce costs related to product damage. Of course, reducing environmental impact would also mean reducing costs related to environmental taxes and fines, therefore also improving the economic sustainability. Finally, the enable process is one that combines all three aspects of the triple bottom line. Through the supplier code of conduct, the company makes sure that the sustainability goals are also extended to its suppliers, thereby enhancing the performance of the supply chain as a whole and helping the supplier to also reap the benefits of sustainability. The carriers are also encouraged to be more sustainable since their sustainable performance is constantly being tracked through the platform. Not only would this enhance the social and environmental sustainability of the supply chain, but it would also reduce transactions costs associated with miscommunication and poor visibility through the chain, thereby enhancing the overall environmental aspect of the triple bottom line.

6. Concluding Remarks

As it was shown in this research paper, sustainability is a crucial aspect for the prosperity of supply chains, especially during these uncertain times. Therefore, it is of sheer importance for supply chains to continue to pursue sustainability and find innovative and effective ways to achieve it to be able to thrive against unforeseen events and disruptions. And as we have seen through the research, to have a great sustainable performance, some key enablers need to be present, such as visibility, collaboration, efficiency, and resource sharing. Companies could put these into enablers into action through different ways. One of the most efficient ways to promote these enablers is through the use of emerging technologies and ICT solutions. This is because with the development and evolution of modern supply chains, achieving sustainability with the highest effectiveness could not be achieved anymore with traditional methods. This is where evolving technologies come into play to facilitate the transition into a more sustainable supply chain. Therefore, ingraining technology orientation deeply into the organizational cultures through top management support and awareness, is crucial to identification of possible technological opportunities and solutions that would not only help companies optimize and sustain their supply chains, but also achieve their top business objectives and strategies with ease. To develop this line of research further, it is suggested to explore further into the practical effects and benefits of emerging technologies on sustainable supply chains through real implemented cases, especially for blockchain, since it is one of the fewest implemented technologies for sustainability, mainly due to its technological maturity.

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Appendix A

Table 5 Author and Topics explored

Topics / Authors	Sustainability	Transportation	Logistics	Resilience	Marketing	Technologies
Fritz, 2019	X	X	X	X		
Carter & Rogers, 2008	X	X	X		X	
Yildiz & Sezen, 2019	X	X	X		X	
Sun,2017	X	X	X		X	
Farooque, 2019	X	X	X	X	X	
Seuring 2004	X				X	
Seuring & Müller 2007	X		X		X	
Saeed & Kresten, 2019	X		X		X	
Khan et.al 2021	X		X			
Koberg & Longoni 2019	X					
Tyan et al. 2019	X	X	X		X	
Richnák & Gubová 2021	X	X	X		X	
Trivellas et al. 2020	X	X	X		X	
Andarkhora et al. 2019	X	X	X			
Mckinnon,2016	X	X	X		X	
Farcavcova et al. 2018	X	X	X			
Sajjad et al. 2015	X					
Saada, 2021	X	X	X		X	
Hopkins & Hawkings, 2018		X	X		X	

Topics Authors	Sustainability	Transportation	Logistics	Resilience	Marketing	Technologies
Queiroz et al. 2020	X	X	X	X		
Sarkis et al. 2020	X	X	X		X	
Fiksel 2006	X			X		
Pettit et al. 2019	X			X		
Fiksel et al. 2017	X	X		X		
Jabbour et al. 2020	X	X	X	X		
Abdalrahman & Lehota 2018			X		X	
Sutduean et al. 2019	X				X	
Farradia & Bon 2019	X				X	
Nadanyiova 2018		X			X	
Serdarasan 2013						
Ahy & Searcy, 2013	X					
Forsland et al. 2021	X	X				
Narimissa et al. 2020	X					
Zahiri et al. 2017	X			X		
Alcivar et al. 2020	X			X		
Farradia & Bon, 2021	X				X	
Dangelico & Vocalelli, 2017	X				X	
Panda et al. 2019					X	
Abdalrahman & Lehota, 2018	X		X		X	
Agrawal et al., 2020	X					X
Onu & Mbhowa 2018	X					X
Calatayud et al, 2019	X					X
Kiel et al., 2017	X					X

Topics / Authors	Sustainability	Transportation	Logistics	Resilience	Marketing	Technologies
Nair et al. 2019						X
Yao et al. 2022						X
Singh et al. 2020						X
Raza, 2021						X
Varriale et al. 2021	X					X
Dukovska-Popovska et al. 2010	X					X
Aryal et al, 2018						X
Li & Li, 2017						X
Badugu, 2020	X					X
Bogataj et al, 2017	X					X
Ben-Daya et al. 2019	X					X
Lee et al, 2018						X
Mathaba et al, 2017			X			X
Kothari et al. 2018						X
Manavalan & Jayakrishna, 2018	X					X
Tu et al. 2018						X
Birkel & Hartmann, 2019						X
Harwood & Garry, 2017						X
Khan & Salah, 2018						X
Shwarek, 2017						X
Trzuskawska-Grzesińska, 2017						X
Patsavellas et al. 2021						X
SYAHCHARI et al. 2022	X					X

Topics / Authors	Sustainability	Transportation	Logistics	Resilience	Marketing	Technologies
Nofer et al., 2017						X
Yaga et al., 2018						X
Al-Saqaf & Seidler, 2017						X
Scott et al 2017						X
Chang & Chen, 2020						X
Park & Li, 2022						X
Sifah et al,2018						X
Hasan et al., 2019	X	X	X			X
Rejeb & Regeb, 2020	X					X
Park & li, 2021	X					X
Treiblmaier, 2018	X					X
Ko et al 2018	X					X
Veuger, 2018	X					X
Wang et al., 2019	X					X
Meyer et al., 2019	X	X	X			X
Kouhizadi et al., 2019	X					X
Litke et al., 2019	X					X
Tijan, 2019	X					X
Hackius & Petersen, 2017	X					X
Dubrovnik et al., 2018	X					X
Wu et al., 2017	X	X	X			X
Gatteschi et al., 2018						X
Aich et al., 2019						X

Appendix B

Table 6 Case Study Resources

Contact person	Role	Sources	Contact
Mariarosaria Cecco	Operations/Production manager	Meeting	mariarosaria_cecco@whirlpool.com
Paolo Cervini	Supply/logistics manager	• Meeting • Presentations • Files • Videos shared	Paolo_cervini@whirlpool.com

Whirlpool annual and sustainability reports:

- https://investors.whirlpoolcorp.com/financial-information/annual-reports-and-proxy-statements/default.aspx
- https://whirlpoolcorp.com/2021SustainabilityReport/

Statista report:

- https://www.statista.com/topics/2309/whirlpool/#topicHeader__wrapper