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Sustainability in the Automotive tire supply chain: a state of the art

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Introduction

The theme of sustainability is becoming increasingly important in today's industry, and even more in the automotive which is one of the sectors that contributes to a large share of global pollution. It's crucial to discuss the theme of sustainability in a thesis within the current debate, because if adopted, sustainable practices aid in changing society for the better. Being committed to sustainable lifestyle decrease carbon footprint and the quantity of contaminants discharged into the environment, making the entire globe cleaner, living conditions healthier [1]. Given the fact that supply chains normally demand a lot of energy from beginning to the end of the process, and manufacturing and transportation generate a lot of carbon emissions, sustainability in the supply chain is essential for protecting natural resources, business-related resources, and giving customers ethical buying alternatives [2].

This thesis discusses different types of approaches that companies implement to address sustainability issues in the supply chain in the automotive industry, with a particular focus on the tire manufacturing sector. The tire industry is crucial for global economy since it represents the primary requirement producer for transportation in the world, but its importance is directly proportional to its contribution in environmental pollution, and here is where the theme of sustainability intervenes. The methodology used was a literature review and content analysis carried out by relying on the Scopus database as main source of scientific works in April 2023. The selected papers have been published from 2009 until today and treat environmentally friendly supply chain studies belonging to different parts of the world.

In Chapter 1, a general overview of the supply chain domain is presented, followed by the introduction of the main theme of this thesis work, the sustainability issue in the automotive industry with a particular focus on the tire industry. A sustainable supply chain is one that tries to limit, in all its phases, the unfavorable environmental and social impact, including activities as the manufacture of a product and its storage until delivery to the customer.

In Chapter 2, the literature review methodology used is presented, and the papers selected have been summarized one by one highlighting main points and crucial characteristics useful for the contribution to the discussion about sustainability in the automotive industry. In doing so, four micro-topics have been identified, with the strategies adopted by companies to achieve sustainability objectives in the supply chain grouped into four different classes: Closed-Loop Supply Chain approach, Green Supply Chain Management and related practices, new emerging technologies, and sustainable supplier selection and development approach. The aim of the study is to find interconnections between these different approaches, identifying patterns and trends across the industry.

In Chapter 3, results and principles constructed by reasoning based on the data collected through the selected articles are formalized, including the individuation of patterns and trends across the industry. The results show how the efforts to reach sustainability goals across the supply chain in the automotive industry are constantly increasing, even if especially in the case studies related to developing countries is clear that much more must be done. However, that counter-intuitively to what people may think, the adoption of these techniques to reach a desired level sustainability is not feasible for all companies, given the high costs and visible economic results not in a short period of time, but rather in the long period. In addition, the findings reveal that emerging technologies as AI, Additive Manufacturing, Blockchain are being used more consistently in the sector. Focusing on the tire industry, the results display that the Closed-Loop Supply Chain approach is widely embraced with the disposal, retreading and recycling phase of the chain gaining a central role in the strategy of tire manufacturers. Future studies should be done narrowing the perimeter of the research maybe to some minor context focusing on some determinate regions of the world or even countries, or in different sectors. It might be interesting also to investigate more deeply the use of a given technology or a practice across the automotive industry.

Chapter 1

Theoretical framework

The present chapter of this thesis work consists in a general overview of the supply chain domain. The objective is to present the macro topic of the work, the automotive industry and the sustainability approaches related to it, and at the same time to introduce the latter at a micro-level within the tire sector. At the beginning of the chapter, a pair of citations really highlight the deep importance of a supply chain in the industry nowadays, then a simple definition of the term *supply chain*, and the breakdown to pieces of the supply chain process are the first steps that allow the reader to get acquainted with the topic in an easier way. Then, the theme of sustainability applied to the automotive sector, main topic of this thesis work, is introduced.
In the last paragraph, finally, the process of supply chain in use in the tire industry is described and the importance of the issue of sustainability is emphasized as it is one of the sectors that pollutes more in the world economy.

1.1 Introduction to the Supply Chain world

"Competition is becoming less between individual companies, and more between the supply chains they are part of."

Richard Wilding

"Supply chains compete, not companies."

Martin Christopher

The supply chain is of paramount importance in industries for a multitude of reasons. Encompassing the entire process of delivering goods and services from suppliers to consumers, its optimization significantly impacts a company's overall performance and success [3].

Supply chain can be defined as the network of all the people, businesses, resources, activities, and technological advancements involved in the development and selling of a product to a client (Vela, 2023). It involves all the procedures a business does to introduce a good or service to the consumer market. The raw material producers are the first links in the chain, while the truck that delivers the final product to the customer is the last one (Hayes, 2023)

As can be seen in Figure 1, it is a complicated discipline that involves several specialists and activates a number of ecosystem-wide business processes, ranging from the flow of raw materials connected to manufacturing to the logistics of distribution that ensures the delivery of purchased items to the client.

Businesses that understand the value of a strong supply chain are better positioned to succeed in the fast-paced and competitive environment of today's commercial world.

Figure 1: Supply Chain Flow displaying the main actors involved in the process [4]

Here are some key reasons why the supply chain is vital in industries:

- *Efficiency and Cost Reduction*: smooth and efficient running of a supply chain reduces waste, delays, and inefficiencies. This ultimately results in cost reductions throughout the manufacturing and distribution processes, which boosts a business' profitability.
- *Enhanced Collaboration*: involving various stakeholders, including suppliers, manufacturers, distributors, and retailers. Effective coordination and collaboration

among these partners foster better communication, shared goals, and improved decision-making, leading to higher productivity and performance.

- *Meeting Customer Demand*: understanding and responding to customer demand is critical for any business. A well-functioning supply chain ensures that products are available when and where they are needed, minimizing stockouts and enhancing customer satisfaction.
- *Adaptability to Market Changes*: industries are subject to constant change due to market trends, technological advancements, and external factors. An agile supply chain enables businesses to adapt quickly to these changes, seize opportunities, and mitigate potential risks.
- *Quality Control*: supply chain plays a crucial role in maintaining product quality. By selecting reliable suppliers, implementing quality control measures, and monitoring the production process, businesses can deliver consistent and high-quality products to their customers.
- *Inventory Management*: companies that practice effective supply chain management are better able to maintain the ideal amounts of inventory while avoiding surplus stock. This reduces the danger of obsolete inventories and carrying expenses.
- *Competitive Advantage*: a well-optimized supply chain can be a significant source of competitive advantage for businesses, allowing firms to differentiate themselves by offering faster deliveries, better customer service, and more innovative solutions.
- *Risk Management*: supply chains are susceptible to various risks, such as supply disruptions, geopolitical uncertainties or natural disasters. Managing the chain with risk assessment and mitigation strategies, reduce the potential impact of unforeseen events (Covid-19 pandemic and the war in Ukraine as concrete examples).
- *Sustainability and Ethics*: in recent years, there has been a growing focus on sustainability and ethical practices within industries. Besides aligning with consumer preferences, an ethical supply chain with environmentally friendly sourcing and fair labor standards also helps to build a brand's reputation.

Efficiency and cost reduction, quality control and inventory management are the areas where the results of a well-managed supply chain can be more visible and in a concrete way. Despite this, all the actions and strategic decision taken to pursue objectives affecting the other areas are likely to have an impact on a longer-term horizon rather than in a short term (Jenkins, 2022). Sustainability is an example, and it will be treated in detail further in the thesis work.

Supply Chain Management (SCM) is, consequently, the discipline consisting in oversighting resources, data and finances as they move in a process from supplier to manufacturer to wholesaler to retailer and then to the consumer [5].
A simple and complete definition of SCM is provided by David Simchi Levi, Professor of Engineering Systems at MIT: "Supply Chain Management is a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses, so that goods are produced in the right quantities, in the right places and times with the focus of minimizing overall costs while meeting the requirements in terms of service level" (Simchi-Levi, 2004).

Three main macro-activities or phases having a crucial role in the supply chain of a firm, on which SCM is involved and can contribute the most are:

- *Selection of Suppliers and Procurement*, that permits to obtain raw materials, goods and services you need to run daily business operations.
- *Production*, that relates to the actual manufacturing and so to how raw materials and parts are turned into finished products. All the components such as technology, tools, machinery, labor and other processing mechanisms are included in this phase.
- *Distribution*, including all the assets and operations that from the warehouses, containing finished products, take place until the delivery to the customer. During this phase is crucial the construction of an efficient distribution network with a solid logic regarding safety and target stock in the relative warehouses.

The role of procurement in supply chain management has become increasingly significant in recent years as a result of how quickly technology has accelerated the rhythm of life.
To improve efficiency throughout this phase of the supply chain, a procurement specialist should routinely check a variety of KPIs, including purchase order cycle time, supplier lead time, supplier defect rate, and fulfilment accuracy. Implementing a successful procurement strategy may result in immediate and evident cost savings since value is generated by reducing operating expenses by buying supplies and materials at the lowest cost.
In order to build a strong portfolio of suppliers that are in line with an organization's overall goals and boost efficiency, a procurement strategy should reduce operational redundancies and foster positive relationships with suppliers [6]. Then, get rid of underperformers by assessing a supplier's potential, goals, level of competition, and financial stability.

In addition, the adoption of strategies for risk mitigation by experts in the field assists in lowering the possible risk that a supplier won't fulfill their obligations under the signed contract.

Coordinating the whole range of operations from the procurement of raw materials to their transformation into finished items is the responsibility of production planning and control. This requires preparation for the shop floor in terms of materials, labor, and energy as well as assuring flexibility in response to variations in demand, changes in the supply of resources, etc. [7]. Powerful AI/ML algorithms that are designed to meet planning objectives like maximum order fulfillment or optimal cost reduction have made production planning automated in recent years.

For what concerns the distribution phase, it’s logical that a modern, rational and efficient distribution network is seen by corporate boards as an indispensable key to success. However, optimizing it means having to face a wide spectrum of issues at a strategic, tactical and operational level as the following: How many warehouses to implement? Where to place them to correctly allocate the stock along the net? How to design these warehouses and how to plan the fastest and most efficient the routes? How much stock to deposit in each of them?
For a correct planning, or reorganization, of the distributive network it’s necessary to start from an accurate and punctual mapping of the current flows identifying functions and role of the logistic nodes and the main sources and destinations of the flows of products and resources. Beside the mapping of the flows must be quantified also the storage costs, handling preparation orders, financial costs and those connected to the possession of the assets, transports and administrative costs.
In order to achieve the lowest Total Landed Cost (TLC) of commodities, the optimization's primary goal is to enhance the whole network, not just its separate parts. The TLC aids in cost mapping and makes it simpler to identify expenditures that may be cut (Jansson and Nordh, 2016). The gathering and analysis of data enables the creation of KPIs, which makes it possible to track the effectiveness of every stage of the supply chain and, therefore, to identify and categorize the "weak links" for further optimization.

1.2 Overview of Supply Chain in the Automotive Industry

The automotive industry is one of the largest and most complex sectors in the global economy. It affects every aspect of daily life and it's an important source of employment with approximately 5 percent of global labor force is directly or indirectly employed in this industry. It includes a wide range of stakeholders, technologies, and processes related to its large supply chain network that spans multiple continents.

From sourcing raw materials to delivering finished vehicles to customers, the automotive supply chain plays a critical role in ensuring the efficient production and distribution of automobiles. In the following pages a comprehensive panoramic view of the supply chain in the automotive industry will be provided, exploring the key stages, stakeholders, challenges, and advancements that shape this dynamic ecosystem.

It is possible to identify at a macro-level five key elements of an automotive supply chain which can be divided further into smaller processes and stages [8]:

a. *Selection of Suppliers and Sourcing Strategies*

   The supply chain in the automotive industry begins with suppliers who provide raw materials, components, and subsystems to the manufacturers. Key considerations include sourcing strategies, supplier selection, risk assessment, and supplier relationship management.

b. *Manufacturing and Assembly*

   This stage involves the assembly of various components and subsystems to create finished vehicles. It comprises process optimization, capacity management, quality assurance, and production planning.

c. *Distribution and Logistics*

   Distribution and logistics are crucial for delivering finished vehicles to dealerships and end customers. Efficient transportation, warehousing, inventory management, and order fulfillment are essential in this phase.

d. *Dealerships and Retail*

The retail segment involves dealerships that bridge the gap between manufacturers and end customers. Topics in this area include inventory management, dealership network optimization, and customer satisfaction.

e. *After-Sales Service and Spare Parts*

A key component in the supply chain for the car industry is after-sales service. Customer loyalty is greatly influenced by efficient spare parts management, service facilities, warranty administration, and customer support.

The just-in-time production and lean supply chain practices in the automotive sector have long been reasons for pride. However, the pandemic brought to light the dangers posed by these lean supply chains and the Original Equipment Manufacturers' (OEM) reliance on a limited number of suppliers and on Chinese manufacturers.

Additionally, in the past several years, flaws in the conventional just-in-time (JIT) supply-chain model have come to light due to geopolitical tensions and digital transformation, which are still transforming manufacturing and assembly processes across many sectors, including the automobile. The JIT technique was developed in Japan and popularized by Toyota in the 1970s. It aims to minimize excess inventory by ordering products and raw materials only when they are really needed in order to save costs and boost production [9].

However, producers of goods, from cars to consumer electronics, are demonstrating with their hands exactly how fragile the JIT model is. Manufacturers of vehicles, electronics, and other tech items for example decreased their orders for semiconductors during the Covid-19 era because they anticipated a decline in sales, and the industry is still feeling the effects of that choice two years later. Indeed, fewer orders for semiconductors led to a global scarcity of the chips that power almost everything, forcing some manufacturers to halt production. In a JIT model to work, if any one of the links in the chain breaks, stalls, or falls out of synchronization, the impact on the supply chains can be felt right away [10].

If the pandemic has highlighted the need to restructure supply chains to be more robust to face disruptions in a more efficient way, the increased ESG monitoring is deterring businesses from relocate their plants and production in developing and under-regulated countries just to pursue lower costs and expenditures. The pressure on corporations related to ESG goals is growing,

due to the fact that lots of activist shareholders persist in demanding increase reporting on ESG goals in many significant corporations, including OEMs.
In contrast to the past, this monitoring nowadays covers both owned and managed assets with the consequence that reporting must investigate all the levels of the supply chain, from the primary suppliers to their own suppliers (sub-supplier), analyzing how the entire supply chain affects the required ESG targets. Upstream in the supply chain, increased ESG goal implementation and tracking at the OEM level will have an impact. OEMs have started performing more in-depth audits of their supply chains, mapping out every component, spare parts and material entering the assembly factories. OEMs like Toyota, Hyundai and Honda with better integrated supply chains will have an advantage over rivals. [11].

Companies are now looking for innovative supply chain management strategies that give more flexibility and transparency. The fact is that transparency in the automotive supply chain is difficult to achieve, since many OEMs and suppliers operate in nations that lack sophisticated record-keeping systems and that do not always adhere to the strict procurement procedures that are used in more industrialized nations.
Some companies including Nissan and Toyota are increasing chip inventory levels, while others including Volkswagen and Tesla are trying to secure their own supplies of rare metals.
The Internet of Things (IoT), 5G, and business applications, however, are also giving businesses new tools to prevent interruption and react to unforeseen events.

The automotive supply chain is changing in a world that is becoming more digital and is plagued by environmental issues. The transformation must face climate change concerns intensifying and governments around the world pressure businesses to adopt more environmentally friendly practices. With an emphasis on electric or hydrogen as energy sources, automotive manufacturers are shifting away from internal combustion engines and large-scale manufacturing to zero-emission, carbon-neutral electric or autonomous vehicles.
Just to have some concrete examples in numbers, the International Energy Agency estimates that global sales of electric vehicles reached 6.6 million in 2021, accounting for 8.6% of all new car sales, more than doubling from 2020 and increasing from just 0.01% in 2010. At the same time, charging stations alone will need to increase from 850,000 in 2021 to nearly 12 million in 2030 [12].
Manufacturers must create a new ecosystem of partners that provides the parts and accessories necessary for the effective production and operations to meet the growing demand for battery-

powered vehicles. This has a big impact on how the procurement phase of the supply chain must be managed.

Meanwhile, everything in the automotive sector, from the automobiles themselves to entire factories, is becoming more connected, with the support of technologies such 5G, blockchain, AI, IoT and robotics. Nissan's "Intelligent Factory", which uses AI, IoT, and robots to produce next-generation automobiles in a zero-emission environment, was unveiled in its facility in the north of Tokyo as a specific example of what mentioned above.

Digital traceability, which enables businesses to track products and items as they travel through the value chain and obtain the exact information about the sources of inputs, supplier sourcing practices, and conversion processes, is another essential component. One of the technological solutions used by manufacturers is business applications, which are software packages designed to support business operations. When combined with cloud services, these can expand access to cutting-edge technology, addressing the need for visibility, analytics, and cybersecurity [13].

As has been said, the development of autonomous and electric vehicles will inject new players into the automotive industry and significantly alter its supply chain practices in the next decade. The automotive supply chain is likely to face some bumps in the road ahead due to factors like globalization, disruptive technology, changing consumer preferences, and adjustments to manufacturing procedures.

Achieving ideal supply chain visibility is essential for increasing manufacturing efficiency and shortening time to market and in addition automakers may need to adapt to new technologies in cloud, AI, data analytics, machine learning, and IoT to ensure that the new ecosystem of their suppliers will be transparent, agile, and resilient to global volatilities.

This seems to be the overview of automotive supply chain in the immediate future and seems to be forced to take a big step forward.

1.3 The concept of Sustainability in the Automotive Supply Chain

In the present paragraph, attention is drawn to the fact that the issue of sustainability is now central to modern industry. Then it is explained how in the automotive sector, sustainability is not only linked to the materials used to build the final product but is mainly linked to all the processes that make up the supply chain.

1.3.1 Sustainability emerging as key factor in Supply Chain Management across industries

Sustainability is a key condition for tomorrow's economic success in all branches of industry. In recent years, customers, employees, investors and governments have put increasing pressure on companies to demonstrate greater environmental stewardship and social responsibility. On the other hand, companies are looking for solutions to reduce the environmental impact of their logistics processes and improve their reputation as responsible actors to consequently bettering off their position on the market.

Therefore, acknowledged that supply chain sustainability has emerged as a key corporate goal, companies have started measuring and keep trace of the environmental and social impact of their goods and services, from the beginning to the end of their life cycles [14].

In the context of the supply chain, the term *sustainability* refers to the effort made by businesses to take into account the effects their products have on both the environment and humans as they move through the chain of production, storage, distribution, and any of the intermediate transit steps [15].

Supply chains have an essential role when it comes to the overall environmental, social, and governance (ESG) activities since they account for 50% to 70% of operational expenses and more than 90% of an organization's greenhouse gas emissions [16].

Organizations are looking for methods to provide long-term value by integrating sustainability into supply chain operations, beyond risk mitigation and compliance. According to Alves and Steinberg's survey, eight out of ten supply chain executives are stepping up their efforts to run sustainable supply chains. They are focusing in particular on resource efficiency, carbon reduction, ethical sourcing, and fair trade (Alves and Steinberg, 2022).

For many businesses, supply chains have come into focus because they use a lot of resources and money and are frequently a source of unnecessary waste: mistake forecasting for example is one of the most typical causes of wastage, because it can potentially result in over-production and over-purchasing of raw materials; it's estimated that between 5% and 7.5% of total annual

waste come from this factor (WRAP, 2017). Inventory mismanagement and unneeded and bad managed transport of goods are amongst the worst causes of wastage.

On the other hand, the goal is to minimize environmental harm from factors like energy usage, water consumption and waste production while having a positive impact on the people and communities in and around their operations.

Cultivating an "agile supply chain", committing to responsiveness, flexibility and quickness in the day-by-day operations and adopting new technologies, will help manufacturers to eliminate activities that don't add any value to the finished product, cutting costs and increasing margins. Optimizing delivery routes to minimize mileage and fuel consumption or aligning production and inventory levels with actual demand signals reducing waste, are just two examples of areas on which the adoption of business management applications and AI can boost, growing in performance and upping the sustainability score of the supply chain (Hafeez, 2023).

Sustainability can be achieved in various modes of supply chain as illustrated below in Figure 2:

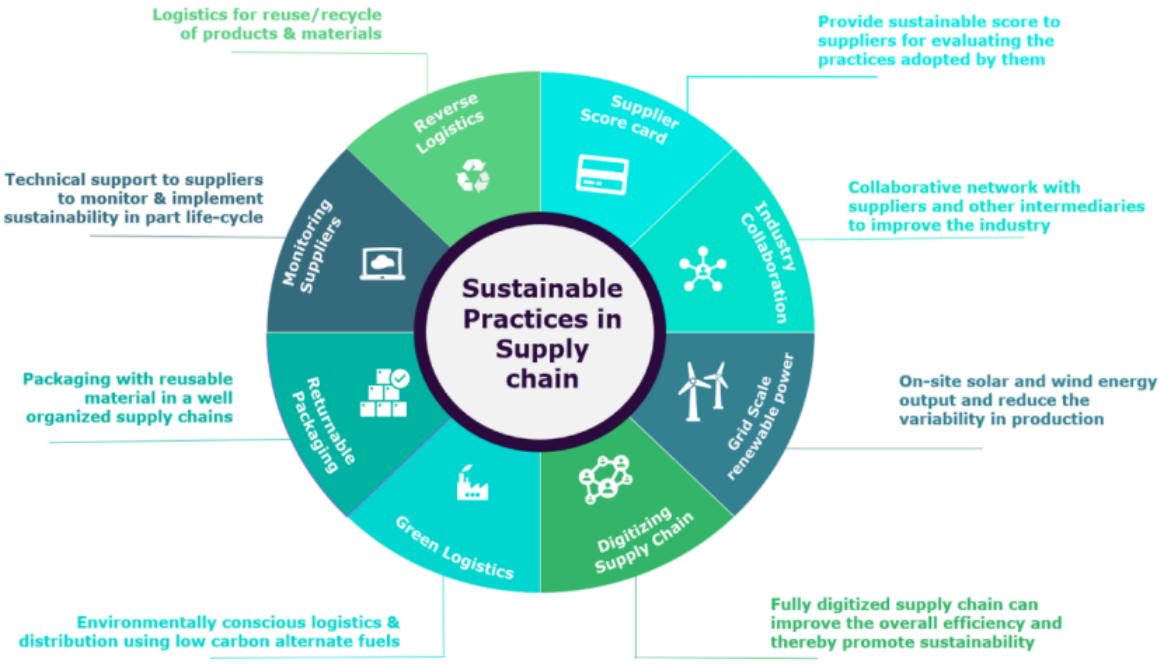

Figure 2: main green practices used in the supply chain domain [17]

The difficulty of tracking and assessing the impact of these activities is one of the major obstacles to developing a compelling economic case for supply chain sustainability.

1.3.2 Sustainability in the Automotive sector: more than the car itself

Setting and achieving climate goals is extremely difficult for the overall transportation sector, but especially for the car industry. The automobile industry, which gives billions of people worldwide mobility and transportation, significantly influences how the modern world is shaped. However, this industry has also made substantial improvements to environmental problems such resource depletion, air pollution, and greenhouse gas emissions. In recent years, the need for sustainability has become more pronounced, leading to a transformation in the automotive industry [14].

The environmental performance of today's cars has gained importance in consumers' mind compared to the past, but they also have concerns about the carbon footprint of production and sustainable supply chains. Firms reacted this change in consumers' behavior and trying to satisfy clients not only serving a high-performance product but also keeping an eye on the sustainability issue, that is a key factor to reach customer satisfaction as mentioned.

The emergence of electrification, the use of lightweight materials, and the decrease of CO2 emissions are crucial factors for the automobile industry's transition to sustainable mobility.

However, disregard the inside of the vehicle isn't an option. Since the inside of a car is where the driver spends the most of their time, it must be both practical and visually pleasing while still being lightweight. Utilizing natural fibers as replacement materials for synthetic ones in the interior has a significant impact and advances sustainability (Wellbrock *et al*, 2020).

Moreover, effective tools for lowering the automobile industry's environmental impact are logistics services. A greener supply chain may be achieved through targeted green practices and astute process management.

Focusing instead on the real objective of this thesis work that is analyze how companies are behaving towards to adoption of a sustainable approach with the supply chain domain, it's possible to identify 4 main areas within which strategies have been developed: responsible sourcing and relative supply selection, closed loop and reverse supply chain, the adoption of new technologies and the Green Supply Chain Management approach with related practices.

Each of them will be deeply discussed in chapter 2.

1.4 Focus on the complex supply chain of the Tire Industry

The market for tires is expected to rise by 2.8% a year between 2022 and 2027, from a volume of 2,268 million units in 2021 to 2,665 million units in 2027 [18]. The flexible cushion that tires provide between the car and the road, absorbing stress, makes them a crucial part of the automotive industry. They are made from a variety of materials, including steel, rayon, carbon black, polyester, natural and synthetic rubber, silica and vulcanization accelerator. These days, a wide variety of tires are available on the global market to satisfy the demands of various vehicle types confronting seasons, combining various technology, or being differentiated by color [19]. The increasing sales of passenger automobiles, particularly in emerging nations, is one of the main factors influencing tire demand all over the world: for example, in South-East Asia in countries as Indonesia, Malaysia and Thailand demand for cars and vehicles are expected to increase around 10 percent annually during this decade, keeping in mind that in these countries secondhand cars account for the majority of cars sold [20].
Along with this, the expansion of infrastructure projects in both the developed and developing countries is expected to fuel the demand for construction vehicles, which in turn will boost the sales of tires. Besides this, the leading companies are engaging in the development of advanced products, such as ecological, flat-run and nitrogen-based tires, that are environment-friendly (Alfina *et al.*, 2006).

The tire industry's supply chain management is becoming increasingly complex today. Many tires are made to order to satisfy the stresses and performance requirements stipulated by the manufacturer of a certain type of vehicle [21]. Nowadays, the physical composition of a tire has become so complex as shown in Figure 3. A single tire consists of more than 100 raw materials and components, and a large group of experts takes part in its design. Years of testing is also involved. Nearly half of the weight of a tire is made from rubber. Passenger car tires comprise nearly 40 distinct rubbers, most synthetic and some natural. Rarely these materials are considered eco-friendly as it’s explained here as follows.
Carbon black for instance is used as a colorant and reinforcing filler in tires. Roughly 1.5 tons of fossil feedstock and vast quantities of water are used to make a ton of carbon black, making it one of the most polluting raw material in the production of tires. Three tons of CO2 may be produced during the complete process of producing one ton of carbon black. Mitsubishi projects that the worldwide market for carbon black would rise at a 6% CAGR to $26 billion by 2025, despite its doubtful eco-friendliness [22].

Tire cord made of polyamide is one component that is essential to most tires. Each bias-ply tire, which has plies that cross over one another in a crisscross pattern, contains around 5% of durable, high-tenacity filament made of polyester, polyamide, or rayon. Previously created with raw petrochemicals, recyclable options are beginning to be made available. However, the majority of the reinforcement in radial tires is made of steel. Always paying attention to sustainability, the Japanese manufacturer Teijin introduced in 2008 what is widely regarded as the first tire cord fabric to use chemically recycled polyester fiber [22].

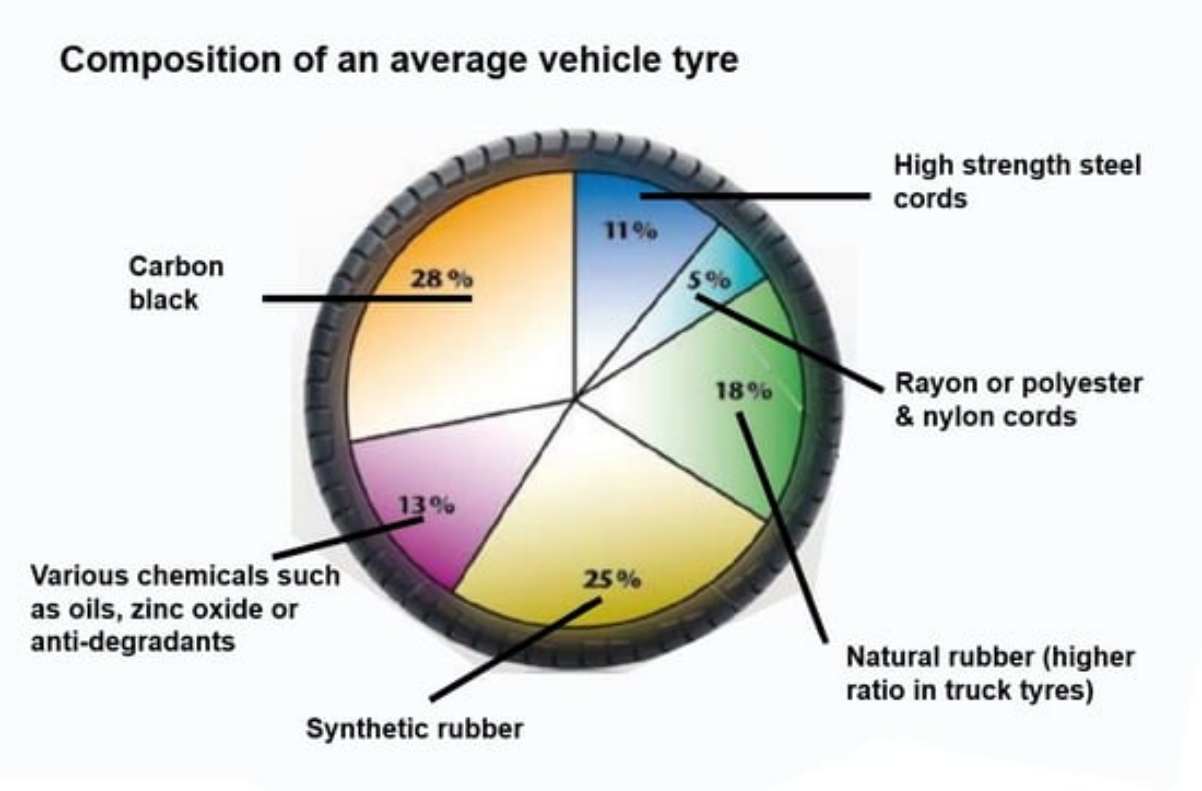

Figure 3: material composition of a passenger tire [22]

Bridgestone, Michelin, and Continental all made the commitment to get rid of oil-based products from their supply chains by the year 2050 in 2021. Pirelli and Hankook want to replace some fossil-based elements in their products before 2050. Meanwhile Goodyear most recently stated in December 2021 that it will achieve carbon neutrality by 2050 but did not make a commitment to eliminate petroleum-based materials [23]. Bridgestone Americas is looking at guayule, a drought-resistant desert plant, as a potential new local source of natural rubber for tire manufacture. To promote the concept, Bridgestone was awarded a research funding by the American Department of Energy. Meanwhile, Goodyear Tire & Rubber Company said that it will completely replace petroleum-derived oils in its products by the year 2040 and replaced

some of the petroleum-based components in certain of its city bus tires with biobased soybean oil compounds [22].

The tire industry's supply chain faces several challenges, and addressing these challenges is crucial for the industry's sustainability and success. Firstly, the tire industry is working to address the environmental impact of tire manufacturing and disposal, including issues related to waste and resource consumption. Particularly important for this industry is the recycling phase positioned at the end of the chain. Indeed, sustainability is going to have a key role also regarding the tire industry for the coming years. The idea of a circular economy for tires, a new model that is expressly mentioned in some OEM company objectives for the coming decade, ties in with the trend of more localized supply and more sustainable material sourcing. Price volatility is another unique problem for this business since, given the vast volumes produced, changes in raw material prices, particularly for natural rubber and petroleum derivatives, may have a significant influence on production costs. Butadiene, a crucial component of the synthetic rubber used in modern tires, was previously provided by petrochemical refineries as a waste product from the production of ethylene. However, ethylene producers switched to lighter feedstocks, which increased price volatility for butadiene throughout the world.

To conclude, the tire industry's supply chain is continually adapting to meet the demands of an ever-changing market and environmental landscape. By embracing sustainable practices, enhancing logistics and distribution, and focusing on innovation and quality, the tire industry can forge a path towards a greener, more resilient, and customer-centric future. As consumers and regulatory bodies place increasing emphasis on environmental responsibility, the tire industry's ability to navigate these challenges and embrace sustainability will be pivotal to its long-term success and contribution to a cleaner and more sustainable world.

Chapter 2

Literature review

In the vast landscape of academic study, this literature review serves as a guiding beacon, discussing the key theories, developments, trends, and crucial discoveries that have shaped our perception of sustainability in the context of supply chains.

In the present chapter, firstly it will be briefly presented the methodology that has been used, while secondly the identification of classes, based on which the articles selected have been clustered, will be analyzed and explained. Finally, each article is summarized with the aim of highlighting the main points and characteristics that prove why it has been selected as a significant source for this research domain.

2.1 Material and methodology

In this chapter, the methodology utilized to conduct the research is presented, along with a breakdown of the methodical steps taken to carry out the study's goals. The methodology serves as the backbone of any academic research, providing a clear framework for data collection, analysis, and interpretation.

By detailing the research design, data sources, data collection techniques, and analytical tools, this chapter offers insights into the rigor and reliability of the process implemented to write the work.

A literature analysis has been done about topics pertaining to sustainable and environmentally friendly supply chains in the automobile industry. The analysis was carried out by relying on the Scopus database as main source of scientific works in April 2023.

Scopus is one of the largest databases in several scientific fields, frequently used to look up literature (Schotten *et al*., 2017). An indicator of academic and organizational performance known as *bibliometric* is one that considers a multitude of factors, such as the volume of publications and citations, patterns in research findings, collaborative networks with the aim to unpack and examine the prevalent elements in a certain domain of study (Donthu *et al*., 2021).

Bibliometric studies are crucial in order to create syntheses on a broad and varied spectrum of authors, contexts, and perspectives that, collectively, constitute findings from research through the combination of data from many sources (Reynaud & Todescat, 2017).

Keywords connected to the various designations about the main topic have been used. The following lists contains the main keywords used in the research of the most suitable articles: *automotive supply chain sustainability*, *tyres supply chain sustainability*, *automotive supply chain sustainability practises*, *TBL automotive components*, *just-in-time material sustainable automotive*, *sustainability automotive logistics*.

2.2 Identification of Classes

To study the sustainable supply chain in the automotive industry, a content analysis method which involves the analysis of the papers, the identification of the trends and the derivation of conclusions inferred based on the findings (Hassan, 2023), has been applied initially. Based on the collected information, four main classes have been identified accordingly with the main macro-topic treated in the papers. The following clusters have been chosen:

Closed-Loop Supply Chain

The closed-loop supply chain (CLSC) has drawn attention in the sustainability debate since it is considered one of the most important configurations of the circular economy (CE). The circular economy attempts to close the supply chain loop by reducing the need for virgin materials via the reuse or recycling of existing materials (Scur *et al*., 2022).

In contrast to Reverse Logistics, CLSC involves not only the movement of commodities and raw materials from suppliers to producers, who subsequently sell them to final customers, but at same time permits the reverse flows of materials and goods from end-users to manufacturers or facilities, such as collection and recovery centers or disposal sites.

The governments are trying to push the adoption of it through the reward-penalty mechanism (RPM) that encourage the return process and cut the operating expenses, being a crucial issue in the CLSC with the ultimate goal of maximizing the social welfare (Wang et al., 2022). The process of returning a product is complicated and frequently includes numerous parties, which leads to both incentives (financial gains, promotions) and penalties (fines, reductions, and reduced subsidies).

GSCM and Green Practices

The green supply chain management (GSCM) strategy drives value creation for both the economic and the environmental performance through the integration of environmental management practices into organizational activities within the specific firm and at the same time with its external supply chain partners (Golicic and Smith, 2013).

Green supply chain management is not only regarded as a way to protect the environment but also as a useful and potential approach to progress, acquire a competitive advantage, and boost an organization's performance. In the articles related to these topic various practices will be examinate in details as reverse supply chain, reverse logistics, Lean-Green manufacturing and plenty others.

New Technologies to reach Sustainability

Here are included all the technologies from the relatively new like IoT, cloud-based software, ERPs, to the latest as blockchain, additive manufacturing and many others. New technologies for recycling, retreading and the usage of lightweight and less polluting materials will be discussed too.

Sustainable Supplier Selection

Supplier evaluation and selection must be executed with care to provide the best outcomes, since suppliers constitute an essential and crucial gear in the supply chain structure that can guarantee to the company economic success. This procedure is regarded as the beginning of the partnership between the supplier and the buyer (Rosa, 2004).

The subject of evaluating suppliers and supply chains in terms of sustainability assigning a score, ranking them, or at least keeping track of how responsibly each of them takes into account sustainability within their operations has been covered in quite a few articles. Anyway, clear suggestions on how gathering supplier sustainability data and integrating it into business operations are still uncommon.

2.3 Closed-Loop Supply Chain

In this paragraph the papers clustered within this class will be summarized one by one, putting the focus on the distinctive features of each article related to the theme of sustainability linked in this case to the Closed Loop Supply Chain topic.

2.3.1 Barriers to circular supply chain: the case of unorganized tire retreading in India (Bhattacharya and Kalakbandi, 2022)

This study emphasizes the importance of further investigating the potential role of the retreading unorganized sector in fostering the transition to a CE in emerging economies. Based on the gaps identified in the literature, this paper examines the obstacles to CE adoption in India's unorganized tire retreading business, an industry which is extremely fragmented, with small and medium-sized enterprises controlling most of it. In Figure 4 the life cycle of a tire is displayed.

Retreading tires is a long-standing tire industry technique. However, governments across the world have only recently recognized the worth of it in terms of what it adds to the notion of the circular economy.

The information was gathered by conducting semi-structured interviews with 23 tire retreaders in 15 Indian cities and 8 Indian states. It's important to keep in mind that if in European countries, laws and regulations governing tire re-treading procedures have already been put into place, in India the situation is different, given the fact that these laws are still under development. In addition, in the Indian case they must face multiple barriers that prevent the full growth and progress of this activity.

Unorganized retreaders, the central actors in this study, have a significant impact on extending the life of natural resources (natural rubber, carbon black, and steel), lowering greenhouse gas emissions and resource waste, creating job opportunities, and giving customers financial advantages by lowering the entire cost of owning their tires.

Ten significant obstacles to the expansion of the retreader industry has been identified, divided in 4 categories:

- Retreader-oriented barriers as lack of skilled labor, lack of effective promotional methods and lack of awareness of funding schemes.

- Customer-oriented barriers as lack of knowledge, wrong perception about retreading.
- Policy-oriented barriers as poor implementation of standards and lack of incentives.
- Supply chain-oriented barriers as demand uncertainty and volatility in material prices.

Poor standard implementation was cited as the most significant obstacle in this survey by nine respondents, followed by consumers' concern about pricing (*price-conscious behavior*) and respondents' *lack of knowledge* about retreading techniques. The most significant obstacle to the CE, according to the literature, is the *inadequate implementation of standards*. Furthermore, the theoretical framework in the study illustrates how barriers interact with one another, offering detailed implications and helpful recommendations for policymakers and original tire manufacturers (OTMs).

Figure 4 : Life cycle of a tire [24]

2.3.2 A stochastic multi-objective location-allocation-routing problem for tire supply chain considering sustainability aspects and quantity discounts (Ebrahimi, 2018)

The model's major and secondary goals are to reduce the overall costs and environmental impact of a closed-loop supply chain network while taking sustainability considerations and quantity reductions under uncertainty into account. The third goal aims to make the integrated network as responsive as possible.

Correspondingly, in this research a stochastic multi-objective optimization MILP model will be formulated to optimize the choice of which supplier to integrate as member of the chain and to achieve the best solution in terms of location-allocation-routing problem.

An Iranian case study is presented, in which a maximum of six suppliers must be chosen from a group of eight contenders in order to provide five different types of raw materials to three factories The tire producers try to produce four distinct tire types, and these goods are sent to a maximum of five distribution centers (DCs) out of seven potential DCs using one candidate route out of two possible ones. Then, DCs send these stored products to ten final customers. DCs then ship these stored goods to 10 ultimate clients. Out of the four existing facilities which collect obsolete products, customers only can return some of these unusable tires to three of them. Finally, some of these recoverable returned products are sent to manufacturers, while the remainder is transported to two recycling facilities for decomposition.

An actual case study is used to validate the model, with the help of an augmented ε-constraint method, a solution from the derived Pareto solutions is chosen as the best approach for the case scenario based on the opinions of experts and managers.

This study was selected due to its ability to give answers simultaneously on a mix of crucial problems that the logistic and the supply chain department have to face in the day by day. Indeed, it constructs a closed-loop supply chain network while taking different quantity discounts and sustainability factors into account and concurrently it address, thanks to the MILP model, the problems of location, allocation, routing, and supplier selection, summarizing them in just a single model.

According to the results obtained, it’s clear that the modeling that considers quantity discount and the routing problem performs the best in terms of the first and second objective functions, cited at the beginning of this paragraph. The final objective, however, cannot be fully achieved. Anyway, supply chain planners can make decisions under a variety of circumstances using this model.

2.3.3 Lead Acid Batteries (LABs) Closed-Loop Supply Chain: The Brazilian Case (Scur *et al*., 2022)

A closed-loop supply chain is necessary in the circular economy to ensure the logistics of raw materials to the appropriate destination of the end-of-life (EOL) product.

Through an exploratory research, Brazilian lead-based automotive battery chain is evaluated by investigating two main manufacturers, two recycling companies, and eight distributors / retailers. The study's objectives are to examine the interactions between key players in the lead

acid battery supply chain, identify the mechanism that induce recycling initiatives, and develop an explanatory framework.

The analysis of the literature revealed an upsurge in research into RL procedures and the recovery of EOL goods, particularly those like LABs that have hazardous and potential high polluting components and the same time high economic value. Luckily, a LAB is one of that chemistries which present an high rate of recycling and reusing for its main components, unlike other types of batteries. Indeed a new LAB can be likely to include up to 80% recycled materials.

Environmental laws encourage the impact of advances in green technology in polluting businesses. Indeed, lead battery producers innovate and design new batteries, but they also establish cooperative agreements with competitors to design batteries for recycling and resource efficiency. This proves the vision that these companies have towards the future and show how also in this battery *micro-sector* of a bigger one that is the automotive, the CLSC approach would continue to be adopted in the next years, with the recycle and the reuse of material at the center stage of it.

Secondary lead is essential in Brazil, since there is no primary lead production, the lead recovery process has high loss rates, and there are numerous small battery recycling facilities that are not regulated by the government and may result in lead contamination in the environment and a black market for secondary lead recovery.

2.3.4 Sustainable Supply Chain for Automotive Industry (Gupta and Patel, 2022)

The article aim is to show how the three areas of sustainability (environment, material, and humankind) can be integrated and can be the way toward a sustainable supply chain, using the automotive industry as an example.

In the analysis of the existing framework, it's underlined the importance of the following factors: working towards a net-zero value chain, reducing the environmental impact of activities, working on the sustainable transport system, working towards a circular economy, limiting the use of materials and substances of concern, and responsibly behaving across the value chain. Some instruments to reach sustainability nowadays has been named as the R framework within the circular economy (CE) theory, Material and Substance Composition Reporting (MDS) and the Green House Gas Protocol and Science-Based Target Initiative.

The proposed framework underline that all methods previously named are planned at a macro-level, while it's suggested that they need to be defined and planned at the micro-level for far better results. Setting annual goals that are in line with long-term objectives, evaluating current

year success in terms of sustainability, and then adjusting strategy for the following year are a few examples.

2.3.5 Multiple-sourcing in sustainable closed-loop supply chain network design: Tire industry case study (Mehrjerdi and Shafiee, 2020)

The literature on closed-loop supply chains has not fully explored how sustainability and resilience interact. This study examines the effect of multiple-sourcing in creating a supply chain network's resilience, filling this gap by taking both into account simultaneously in a closed-loop supply chain in tire industry. With the term *resilience* is meant the capacity of a supply chain to endure, adapt to, and advance in circumstances of sudden shifts (Ponis & Koronis, 2012).

In the prospering Iranian tire industry, there are nine tire manufacturing plants, with the largest production share of 36.4% belonging to the Barez factory, in Kurdistan, which is the one considered to validate the MILP model formulated in the paperwork.

Multiple-sourcing strategy is one of the most effective strategies in order to reach a desired level of resilience in the supply chain to overcome disruptions and sudden fluctuations: in facing low demand, single sourcing is usually more appropriate; nevertheless, multiple sourcing is beneficial when the company has to deal with high demand period (Burke *et al*., 2009). In case of disruptions, the most challenging activity for a tire producer is be provided with the raw materials, avoiding shortages during periods of high demand. A multiple-sourcing approach is precisely crucial for this when suppliers experience difficulties and are unable to provide the necessary raw materials.

Six main raw materials are used to make tires: caoutchouc, chemical substances, various types of lubricants, soot, wire, and fiber. More than ten suppliers may be involved with these basic ingredients. This shows how sensitive this issue is in the tire sector, as any disruptions in supplier operations causes problems throughout the whole supply chain.

The findings showed that demand variations have an impact on the notions of sustainability and resilience: the total cost of the CLSC, energy use, pollution emissions, and employment opportunities are in line with the demand changes, while, on the other hand, for the high demands of the product, more backup suppliers and more human labor are needed. These results confirm that resilience concept should be applied to deal with the disruptions of a sustainable CLSC.

2.3.6 Developing Return Supply Chain: A Research on the Automotive Supply Chain (Pinho Santos and Proença, 2022)

The goal of this study is to investigate the barriers that prevent the automobile sector from developing return supply chain policies and how to overcome them.

According to the research, several factors could hinder or favor the establishment of return supply chain regulations in the Portuguese automobile sector. Innovative initiatives, strategic partnerships, and governmental policies are some of the aspects that can have a positive impact and enhancing the most return supply chains. However, it has been discovered that organizational and cultural factors are associated to the inhibitors to return supply chains as for instance procrastination and resistance to change, as shown in Figure 5.

Last but not least, the positive role of training and of partnerships between business firms and universities or research centers to support the recycling of the product or to rethinking the supply chain design, can have a practical impact in this context too. Managers have a key role because with their contributions in the day by day can interconnect these partnerships with innovation of processes, of products and with technological development to lead to a more sustainable future in a faster way.

It is of remarkable mention the *cradle-to-cradle* design framework that is suggested to be incorporated in the supply chain. This is peculiar since the product's development team set out to make recycling less expensive than buying new materials.

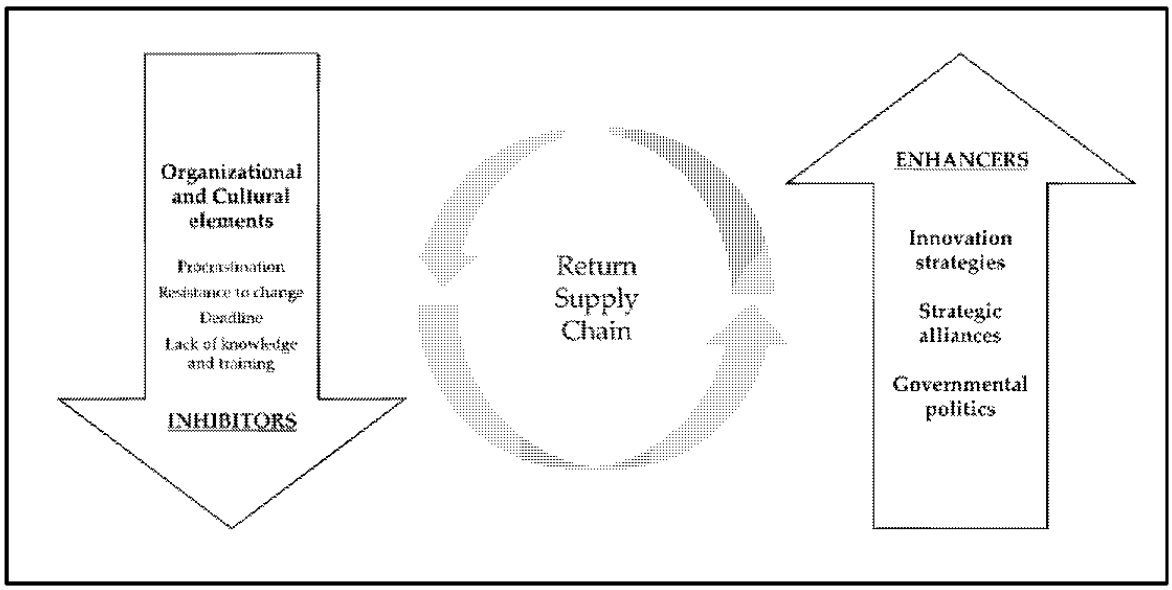

Figure 5: Enhancers and inhibitors for reverse supply chain (Pinho Santos and Proença, 2022)

2.3.7 Sustainable supply chain management of automotive sector in context to the circular economy: A strategic framework (Sonar *et al*., 2022)

The aim of the article is to identify and assign a priority to the inhibitors that prevent to achieved sustainability goals in the automotive supply chain management, with an emphasis on the Indian automobile industry, and to establish the causal connection between them.

Ten different barriers are identified through literature: lack of top management commitment, complex monitoring of suppliers, lack of government assistance, the challenge of creating products that can be recycled or reused, lack of awareness that impede the adoption of reverse logistics, expenditure on gathering end-of-life products, lack of corporate social responsibility (CSR), lower percentage of return on investments (ROI), lack of knowledge of sustainable methods and challenging identification of environmental alternatives.

These barriers are then ranked by experts and categorized as cause and effect firstly applying DEMATEL approach, and after that, following the ISM approach, an inter-relation matrix has been constructed.

The results provided by the ISM model show that the lack of top management commitment is is the most influential factor, placed at the bottom of the hierarchy with strong driving power. To implement sustainable supply chain processes, management commitment must be constant and unwavering. Two significant impediments, a lack of CSR and the assessment and monitoring of environmental actions by suppliers, make up the next level of the ISM model. At the top of the hierarchy, meaning that depend more heavily on bottom-level barriers, it's possible to find the expenditure on gathering end-of-life goods and lower ROI.

2.3.8 Environmental impact of passenger car tire supply chain in Thailand using the life cycle assessment method (Buadit *et al*., 2023)

Although, Thailand's economy benefits from the tire sector, every step of its supply chain holds the potential to have a significant negative impact on the environment.

The life cycle assessment (LCA) method was used in this study to examine the negative consequences of the Thai automobile tire supply chain, from rubber plantations through tire manufacture to end-of-life product management.

To determine the best method of disposal, two management techniques for end-of-life tires, pyrolysis and reclaimed rubber, were evaluated. Recycled rubber significantly decreased the score for both water use and terrestrial ecotoxicity across the supply chain. This highlights the benefit of using recycled tires instead of pyrolysis, which yielded a positive score and so a worse result, to replace standard synthetic rubber.

In conclusion, this study recommends waste tire management technology to be utilized to recover valuable materials in conjunction with the development and research of a new tire model to decrease gasoline consumption and doing so, reducing pollution in the atmosphere, boosting the overall efficiency of the system.

2.4 GSCM and Green Practices

In the present paragraph it will be summarized one by one the articles clustered within this class, putting the accent on the distinctive features of each article related to the theme of sustainability linked in this case to the Green Supply Chain Management and to the Green Practices employed in the industry to pursue sustainability goals.

2.4.1 The application of the triple bottom line approach to sustainability assessment: The case study of the UK automotive supply chain (Azevedo and Barros, 2017)

The aim of the study is to evaluate the degree of sustainability of the UK automotive supply chain while concurrently taking into consideration the three sustainability dimensions that represent the Triple Bottom Line (TBL) approach, using the Simple Additive Weighting (SAW) method to combine economic, environmental, and social dimensions into a single index. The input data is taken from sustainability reports published by UK automakers between 1999 and 2014.

According to the report, the economic sustainability index has been on the rise, mainly after 2010. Government policies that were implemented in response to the decline in auto sales after 2007 could be used to explain the behavior of the economy. These policies included new temporary measures such as subsidized credit facilities and bonuses for purchasing new vehicles instead of used ones. In exchange, governments have occasionally demanded the creation of more energy-efficient vehicles.

It is possible to highlight some outcomes following the implementation of the framework with the related sustainability index, and the three calculated sub-indices: it is feasible to affirm that, aside minor oscillations, the economic sustainability index shows a growing tendency, especially after 2010 when considering each of the three sustainability's pillars, economic, social, and environmental aspects.

This shift is related to how the three variables that make up the economic sustainability dimension, namely total new vehicle production, value added in the automotive industry, and turnover in the automotive manufacturing sector, behave.

2.4.2 Sustainable development model for measuring and managing sustainability in the automotive sector (Jasiński *et al*., 2022)

The study analyze the Automotive Sustainability Assessment Model (A-SAM) that distinguishes three major dimensions of sustainability based on the triple bottom line approach. During the literature review a few enablers, necessary for developing change-capable capacities and assisting with the implementation of sustainability, have been found.

The literature offers a wide variety of tools to measure sustainability level of companies. Amongst these, only the environmental management accounting tools (EMA) have the capacity to deliver sustainability information converted in terms of money. The following five main tools and systems are included in EMA: Life-Cycle Costing (LCC), Full Cost Accounting (FCA), Cost–Benefit Analysis (CBA), Balanced Scorecard for Sustainability (BSS), and Material Flow Cost Accounting (MFCA) (Sonar *et al*., 2022).

Only the FCA method, out of the five EMA technologies, satisfied all four criteria, making it possibly a desirable alternative to create a framework for the automotive sustainability evaluation. FCA is a useful tool for explaining trade-offs, win-win situations, and outcomes for difficult, cross-disciplinary sustainability decisions since it converts a variety of incorporating contradicting sustainability data into a monetary value score. The Sustainability Assessment Model (SAM) was identified as the most comprehensive FCA technique in the literature and a potentially appealing choice for automotive firms. When evaluating a project, the SAM presents economic, resource, environmental, and social issues as performance indicators that are later converted into monetary values. SAM, having over the years exhibited strong adaptability and flexibility to a variety of options, is perfect in the automotive domain that needs instruments that are adaptable to assist choices at various levels and in various forms, including product mix, manufacturing process design, evaluation of transportation options, and product disposal tactics, etc.

The study presents a fictitious example of a corporate strategic choice in the automobile sector to show how the A-SAM might function in practice. The A-SAM has been promised as a potentially useful instrument for assisting sustainability decisions in a business environment, even though it presents still some flaws.

2.4.3 The fallacy of profitable green supply chains: The role of green information systems (GIS) in attenuating the sustainability trade-offs (Esfahbodi *et al*., 2023)

In order to determine if the GSCM implementation results in sustainability-profitability trade-offs, this study looks at the impacts that green information systems (GIS) could determine on performance enhancements in the UK automotive context.

Survey information was gathered from 189 UK automotive companies, and moderated hierarchical regression was used to analyze the results. The study is focused on the following four distinguished green practices: green purchasing, eco-design, green, and investment recovery.

The findings show that, while GSCM techniques lead to enhancements in environmental performance, on the other hand not all sustainability initiatives are successful throughout the supply network. For instance, it has been discovered that eco-design and green logistics are detrimental to economic performance. One factor might be that rising expenses for acquiring the necessary green resources and skills balance out eco-design's capacity to reduce products' environmental impact. In addition, when compared to traditional third-party logistics companies, environmentally friendly logistics services usually deliver at higher pricing, which may account for the lack of a discernible impact on economic performance.

Contrary to a common misconception in the GSCM literature that frequently overemphasizes the *easy wins*, it is argued that pursuing supply chain environmental measures can result in trade-offs between sustainability and profitability. But this isn't always the case as explained above.

2.4.4 Impact of supply chain management practices on sustainability (Govindan *et al*., 2014)

This study aims to develop a conceptual framework for analyzing how lean, resilient, and GSCM techniques influencing supply chain sustainability. To learn how Portuguese automotive industry professionals perceive the effects of targeted supply chain management practices on supply chain sustainability, 18 research hypotheses are suggested and assessed using empirical data from five case studies and a semi-structured interview.

The recommended collection of green, resilient, and lean approaches was developed, suggested as follow:

- Lean paradigm: where the main principles regards just-in-time arrival of material, EOL goods elimination, total quality management.

- Green paradigm: cleaner production focusing on reduction use of natural resources, ISO 14001 standards and reverse logistics are the main points highlighted.
- Resilient paradigm: with flexible sourcing, SC risk management and flexible transportation as key concepts.

A few propositions are derived a conceptual model is built. As can be seen in Figure 6, the economic sustainability is the dimension with more arrows towards it, this indicates that there is greater evidence in the literature about the effects of lean, resilient, and green SCM techniques on the economic aspect of sustainability. Only a small number of lean, resilient, and green SCM methods have an impact on social sustainability. After the case study on the automotive Portuguese industry being applied, it has been discovered that resilient strategies like flexible sourcing and transportation, as well as green practices like ISO 14001 certification and "reverse logistics," do not significantly affect sustainability in the supply chain domain.
In conclusion, waste elimination, supply chain risk management, and cleaner manufacturing are the green strategies with considerable impact on SC sustainability, according to the content analysis and case study evaluation. This is true because only these three lean-green techniques have any real effect on the long-term social, economic, and environmental performance and can help the supply chain of a company to become more resilient too.

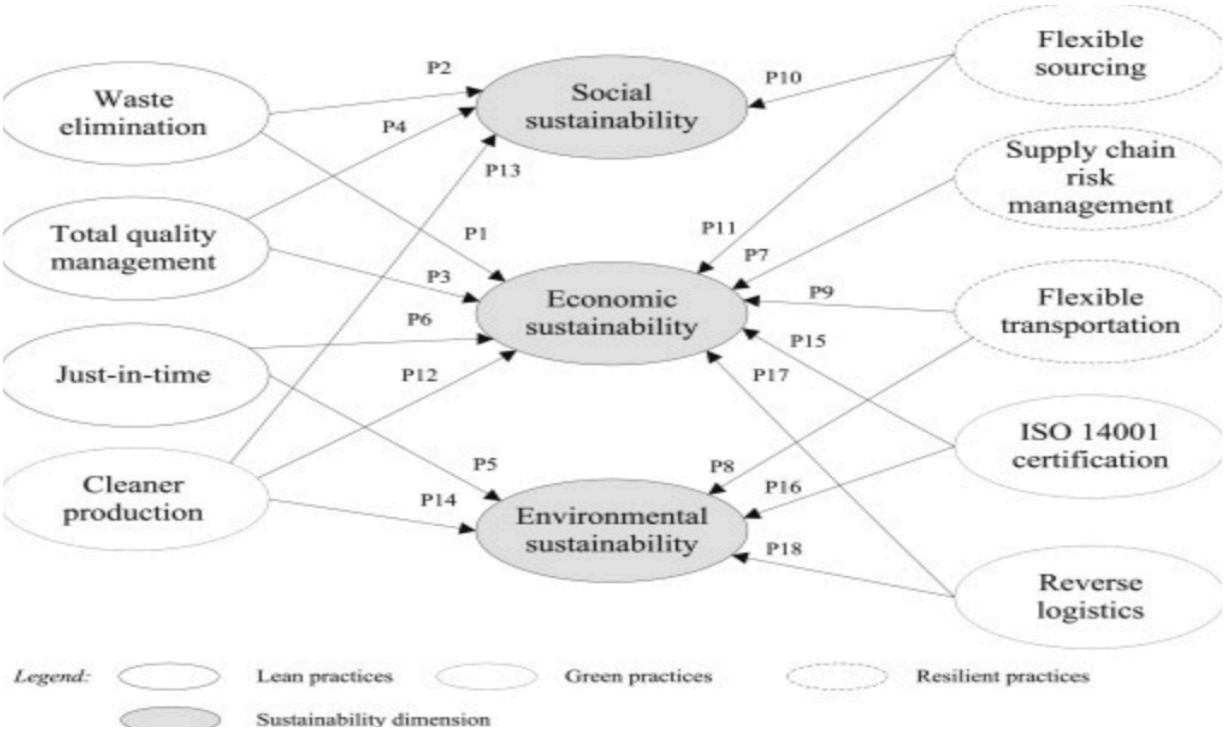

Figure 6: Framework that summarize the intercorrelations between the dimensions (Govindan *et al*., 2014)

2.4.5 System oriented Sustainable Supply Chain Management innovations in automotive industry - SKODA auto case study (Cee *et al*., 2016)

The article's goal is to investigate and define the essential principles of system-oriented innovations used in the automotive industry's SSCM. The case study focuses on the SCM at SKODA's inbound logistics flow.

It stated that *system thinking* is one of the fundamental techniques for research in the supply chain domain, aiding in the quick improvement of supply chain operations' productivity, not just in the automobile sector.

Difficulties in the original delivery concept of SKODA has been identified as follow: dealing with an increase in truck deliveries brought on by rising components and output numbers; overcoming obstacles to truck loading optimization to get the optimal amount of items to store in warehouses; trying to find a solution that stop the harmful emission especially of the diesel engine's truck. To deal with these problems, SKODA AUTO developed the Efficient, Electronic, and Ecology Delivery Concept (EDM), designed to enabling effectively, rapidly, easily, and sustainably interactions in the supply chain management approach. It's based on four pillars, summarized in Figure 7 below: QCI, FOLAB, GTL and CNG as shown below.

25% less was spent on logistics than the current system, including gasoline and pallet costs, expenditure related to items storage in the logistic warehouses lowered by 55%, and CO2 emissions reduced by 50% through the use of CNG are just the main benefits of EDC theory.

Summarizing, enhancing mutual interactions between the parties involved in the chain is the primary and key principle according to the study to reach supply chain sustainability.

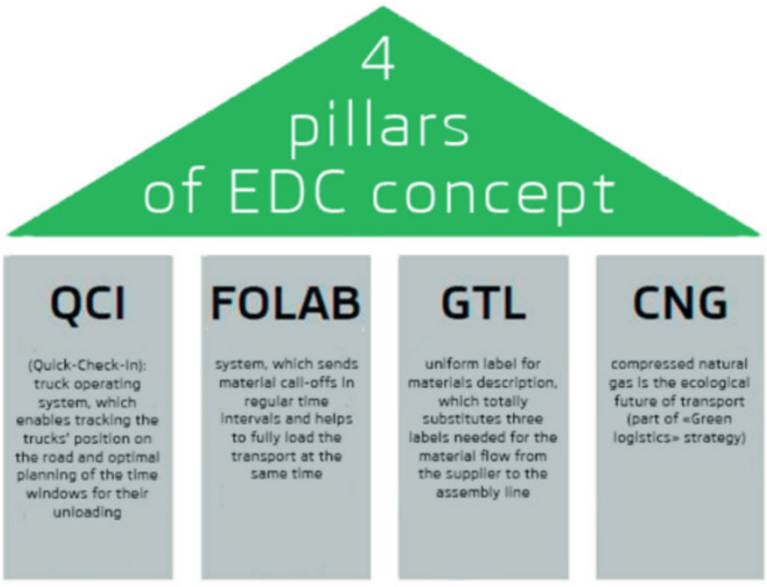

Figure 7: The 4 pillars of EDC concept (Cee *et al*., 2016)

2.4.6 Hard-to-recycle plastics in the automotive sector: economic, environmental and technical analyses of possible actions (Ravina *et al*., 2023)

The relatively low production costs of plastics make them more advantageous for usage in the automotive sector, thus discouraging their recycling. The purpose of this project is to help identify best practices for increasing the rate at which plastic materials are recovered from end-of-life vehicles.

One of the key challenges in the dismantling process is its economic sustainability; often, it is uneconomically to dismantle small components, even though they have a high recyclability rate. Therefore, the economic criterion which considers the total cost of disassembling, recovering, and disposing of the components added to the environmental cost of the entire procedure, was used to evaluate the viability of recycling certain plastic components from end-of-life vehicle.

With a single goal of maximizing the recycling of plastic materials from ELVs, this study took into account three operational areas: recycling, dismantling and the recovery of material.

The analysis was carried out by writing a script in the Matlab program and processing a huge volume of cost computations. The results show that there is chance for improvement in the amount of plastic recoverable from obsolete vehicles. The attainment of EU targets is still challenging despite this. It was confirmed that in the current scenario a component's recyclability is exclusively determined by economic factors, when considering the disposal process as a potential phase for increasing the recovered quota to reach EU targets. The operation's feasibility is primarily determined by the cost of labor and the quantity of recyclable material.

The key finding of this study is that increasing the environmental compatibility of plastic recycling procedures in the automobile industry is a viable strategy for meeting EU recovery targets as well as GHG emission reduction targets.

2.4.7 Competitive Priorities and Lean-Green Practices - A Comparative Study in the Automotive Chain' Suppliers (Queiroz *et al*., 2023)

Through two case studies, this study attempts to validate the competitive priorities of two first-tier (that sell directly to OEMs) automotive suppliers that have embraced lean and green techniques. Environmental performance is now considered a competitive priority across the supply chain. A structured questionnaire was used as the first part of the data gathering process to help identify the key traits of the businesses, their strategies, their priorities in order of importance, and their practices. A semi-structured interview was used in the second phase to

better identify the key complementarities and conflicts that lean and green practices generated among competing priorities by the lean principles and green routines.

According to the lean-green literature, adopting lean methods can have a positive impact on a company's environmental performance, even if generally the environmental benefits isn't a primary objective of the lean manufacturing approach: as an example, the trade-offs existing between just-in-time arrival of materials and the environment, given the fact just-in-time can increase emissions as the frequency of deliveries that become higher allowing the company to save in inventory and stock related expenditure.

In the case study, the findings show interviewees agreed with the literature, given the fact that the environmental priority is not seen as the most crucial one and often not considered in lean manufacturing, but it could facilitate the inclusion of the environmental concern in the daily operations strategy and supply chain management as a consequence.

This study showed that the importance of the environment has turned into a competitive advantage. In the circumstances discussed above, quality, cost, and delivery are nevertheless prioritized as being more crucial.

2.4.8 Sustainability in the aerospace, naval, and automotive supply chain 4.0: Descriptive review (Ramirez-Pena *et al*., 2020)

The research technique used in this work is a descriptive review to present the most recent developments in supply chain management aiming to analyze the different methodologies used to make more sustainable the automotive sector.

The combination of lean and Industry 4,0 and of lean and green practices are highlighted in the study. Some researches show that these new technologies rarely enhance the performance of the lean supply chain, and state that it might be harmful to believe that Industry 4.0 acquisition would produce superior results than management guidelines consolidated through the experience in years. Other studies, on the other hand, suggest that the adoption of the latest technologies can enhance green and lean approach especially by modifying product and designing processes, manufacturing planning and control, supplier collaboration, information sharing, and saving customer energy through flexibility and process re-engineering, with engagement between supply chain players that plays a crucial role. The key characteristics to which the company would benefits from, are higher flexibility and deep visibility across each step of the entire chain.

Although there are challenges in the transition from Industry 3.0 to 4.0, this type of circular economy is encouraged by the interconnection advocated by the latter as for real-time data gathering, communication, and data analysis.

Lack of labor experts in Industry 4.0, ineffective laws and regulations, and tactical business goals are however some of the obstacles to its implementation. Initiatives from the organizational, legal, ethical, and technological perspectives are identified to reach the desired level of efficacy brought by these new technologies in the sustainability of logistics and supply chain domain, such as the requirement for data-sharing protocols, technology platform integration, and network infrastructure optimization (Figure 8).

Figure 8: Areas to tackle to reach sustainability in the automotive supply chain (Ramirez-Pena *et al*., 2020)

2.4.9 Sustainability and innovation in the automotive sector: A structured content analysis (Vaz *et al*., 2017)

In this study, the scientific literature on sustainability and innovation in the automobile industry will be analyzed gathering input data from papers published within the industrial engineering domain in the timespan that goes from 2004 to 2016.

The selected studies some of the practices employed in the automotive sector that have the primary objective to favor the environment and fight climate change. The following are some examples cited in the papers: minimization of greenhouse gas emissions, life-cycle assessment, cleaner manufacturing avoiding excess use of natural resources, reverse logistics and eco-innovation.

As stated in the study, the internal combustion engine could be referred as the most unsustainable component of a vehicle nowadays as it's associated to the emissions, the use of fossil fuel and noise's pollution which are problems affecting more and more quality of life in big cities. The development of fuel cell vehicles in which the fuel cell substitutes the combustion engine and hybrid engine technology can be seen as a campaign to maintain offering customers the security of an internal combustion engine while also recognizing certain environmental benefits. In this way the user begins to become sensitive to the issue and aware for the next purchases.

In order to lessen the production's impact on the environment, the sector has concentrated on acquiring recyclable and renewable resources, and as part of their attempts to cut back on material inputs, businesses have modified their production procedures to reuse waste products and, whenever possible, find substitutes for toxic materials.

Through content analysis, it was finally assessed that the automotive sector is well consolidated and structured to respond to the urgency of process innovation and adoption sustainability schemes compared to other industries, testifying the awareness of producing a more polluting product than average.

Since they are less expensive and less complex, process-based incremental advancements make up most innovations in this field. However, according to other experts, profound innovations are required to comply with current global environmental requirements.

2.4.10 Reverse supply chain practices in the Moroccan automotive industry: An exploratory study (El Oueldrhiri and Lemtaoui, 2019)

The aim of this paperwork is to investigate the impacts of Reverse Supply Chain management (RSC) on business performance in the Moroccan automotive industry, describing the RSC's procedures, the elements that influence decision-making and result implementation, and finally their impact on performance. The approach was a poll that ran from April 2018 to September of that year and involved most respondents employees being questioned in-person at the company's location. All after-sales service chain-related operations, including those involving returns and disposal are covered by RL. involving three main stepsThree macro steps can summarize reverse logistic process: gather returned items from customers, examine the items that have been collected, and then either recover or demolish the items through appropriate procedures.

Direct reuse, repair, refurbishment, re-production, cannibalization, recycling, incineration and land filling are all the possible disposal or recovery options illustrated in the study.

Environment, social and economic aspects would benefit from the adoption of an RSC strategy: When it comes to environmental laws, RL assists in following recycling requirements and packaging guidelines, bringing economic benefits of recovering obsolete products or goods that still have worthwhile value and strengthening corporate social responsibility.
According to the case study, it shows that most businesses only partially comply with RSC actions and only enforce them because of pressure and obligation.
Green business strategies are a burden for organizations with a reactive attitude. Therefore, these companies simply react, if necessary, in the most straightforward manner possible in compliance with the law. Instead, firms with a proactive mindset, however, view reverse supply chain as a way to progress and to bring added value to the organization. As a result, they go above and above what is required by law to apply these practices properly and effectively.
According to the findings, it appears that the Moroccan businesses under study have a negative view regarding the RSC, translated in a reactive attitude, as for now.

2.5 New Technologies to reach Sustainability

In this paragraph the articles inserted in this class will be summarized one by one, putting the focus on the distinctive features related to the theme of sustainability linked in this case to the new technologies that have already been employed in the industry and the ones that can be exploited in the next future to reach a desired level of sustainability within the firm supply chain processes.

2.5.1 Blockchain Technology and Sustainability in Supply Chains and a Closer Look at Different Industries: A Mixed Method Approach (Yasmin and Devi, 2023)

This report provides an in-depth evaluation of blockchain technology (BT) with a focus on sustainability in supply chains and logistics in different sectors, including the automotive. Data refer to over 550 papers, published from 2017 to 2022, extracted from Scopus and Web of Science database.
Lack of information transparency in many automotive supply chains might cause uncertainties over product quality. The role of BT become crucial if adopted, since it helps in building trustworthy peer-to-peer network that support the flow of information from raw materials suppliers to sales distribution along the chain. This functionality of BT is endlessly useful and should be developed for automotive products, given the number of components and the level of complexity existing in the industry.

By integrating blockchain, supply chain's operational efficiency will grow as item traceability increase and waiting times are reduced. The adoption of blockchain can pave the way for the automotive supply chain's long-term viability in terms of information monitoring, raw material traceability, cost-cutting and immutability.

When considering the next pathways of research, it is emphasized that more effort needs to be done, governments should work together in this field, boosting incentives and trying to expand the adoption of BT by using technologies like RFID, IoT, big data, digital twins and AI.

2.5.2 Impact of Recycling Automotive Lightweighting Materials on Sustainability (Jody *et al*., 2009)

The automotive sector is adopting more lightweighting raw materials in the manufacturing of its final products to decrease its energy consumption and greenhouse gas emissions, replacing the conventional steel and iron with alternatives such as polymers, metals like magnesium and aluminum, and synthetic materials to make cars lighter. In addition to that, new materials like lithium, cobalt, and nickel will become more necessary as interest in hybrid vehicles grows. In order to lessen the carbon footprint, bio-based components are also anticipated to be used in automobiles at rising rates.

Technological, economic, and social aspects surrounding the recycling of car elements are covered in this essay: more than 95% of these EOL cars are recycled for their metals, which account for 75% of the vehicle's weight. In this way, repurposing materials for from obsolete vehicles will lead to lower cost of material compared to their virgin counterparts, saving energy, increase recyclability of the process and reducing waste that would be reversed in the landfills. Many processes are still under development in the overseas that can represent a turning point to recover more easily and cheaply polymers and leftover metals contained in shredder residues. An example composed by two phases, mechanical separation system and flotation separation system, is described in the paper.

In conclusion, since the resources on our planet are not infinite, recycling is a necessary action to save energy in the present and conserves them for future generations. It’s true that at the same time is lacking in technology a proved method that allow the full recovery, efficient and cost-effective material purification and recycling.

2.5.3 Improving agility and resilience of automotive spares supply chain: The additive manufacturing enabled truck model (Basu *et al*., 2023)

The study aims at improving resilience of the automotive spare parts supply chain by proposing a Viable Supply Chain (VSC) framework design that incorporates Additive Manufacturing enabled trucks in the network.

From the customers' point of view, the accessibility and availability of replacement components at the local repair facility has a significant impact on their purchasing decision. Therefore, resilience is essential to maintain the position in the market and to safeguard a certain brand's reputation in terms of the availability and effective delivery of spare parts to the existing market. For geographically large countries like the United States, India and China, distribution and logistics of spare parts is a complicated task, when it comes to balancing the supply and demand for replacement parts. This is due to the fact that while manufacturing of spare parts takes place in one location (at an OEM facility), they must also be delivered to all service locations worldwide using a sophisticated inventory management system including thousands of stock keeping unit (SKU). Beside this, it is practically impossible to have all the replacement parts for every model of a specific manufacturer in store in every repair center due to volume and variety of components. The problem is made more serious by the ongoing release of new models, continuous updates of already established models in automotive industries across the world.

The capabilities of additive manufacturing in the supply chain for spare parts can mitigate this risk and enhance the functionality of the system in the event of any disruptions.

The methodology is based on recent papers published on the adoption of AM.

A new framework is suggested for the ASPs supply chain utilizing AM and is based on a workable supply chain model that tries to offer the supply chain structure agility, robustness, and sustainability.

At the customer's location, the AM-enabled vehicle may be made accessible for immediate order processing and delivery with the use of GPS capability. The vehicle receives the order information and uses AM technology to begin manufacturing the desired component while simultaneously moving toward the customer's location to make a last-mile delivery of the component. The following propositions are given based on the study to understand the circumstance and approach the problem-solving process more fully (Basu *et al*., 2023):

P1. *Delivery lead time depends on total part manufacturing time and traveling time to reach the customer*.

P2. *The performance of the AM enabled truck is dependent on*: (*a*) *the availability and speed of the Internet connectivity and accurate GPS navigation guide systems*, (*b*) *comprehensive data files of all parts and components*.

P3. *The versatility of proposed model* (*AM enabled truck*) *is dependent on a highly integrated and shared data files details guided by a well-designed business terms and conditions*.

The innovation of AM-enabled trucks for ASPs is the switch from a push-production system (make to stock) to a pull-production system (make to order).

2.5.4 Using emerging technologies to improve the sustainability and resilience of supply chains in a fuzzy environment in the context of COVID-19 (Kazancoglu *et al*., 2023)

This study, contextualized in the Turkish automotive industry, seeks to determine the challenges faced in building a resilient and sustainable supply chain both before and after COVID-19 pandemic, and also to provide solutions by detecting a new suitable technology that can apply to solve those problems.

Concerning resilient and sustainable supply networks, six issues were identified in the paper: Inventory Management, Optimization in Logistics, Purchasing Process Planning, Demand Planning and Production Management, SC Traceability and Top Management Support.

Different AI driven technologies are considered: ant colony optimization algorithms, machine learning, artificial neural network, data clustering.

According to the fuzzy DEMATEL results, the most important change is seen in the top management' cooperation which, during COVID-19, became the most important dimension within the cause group.

This probably explained because to secure funding, give the employees the assistance they need, and handle the ongoing crisis, top management backing becomes essential. To this end, the emerging technology of Artificial Intelligence (AI) has the ability to support the executive level in taking decisions more quickly, which improves SSCs' resilience to face such disruptions. (Rodríguez-Espíndola *et al*., 2020).

Demand planning is one of the challenging areas impacted by demand changes during the pandemic. Also, the production's control since dependent on the demand planning dynamics, results as affected. Once more, managers can benefit from AI-driven apps in such circumstances, with machine learning and artificial neural networks as the best options. Last

but not least, among the significant trouble spots prior to COVID-19 is managing stock and automation in logistical operations: despite being in the effect group for both occasions, their level of effect has sharply increased. Machine learning and the ant colony optimization method are two of the five mentioned most suitable AI technologies that may be applied to logistics operations optimization and inventory management.
In conclusion, it's a fact that the robustness of SSCs will rise with the implementation of AI technology in the supply chain domain.

2.5.5 No more flat tires: Overcoming data defects to achieve supply chain resilience (Pehlken and Baumann, 2021)

In order to examine data flaws that weaken supply chain resilience, this research utilizes a case study of tires. It looks at various information technologies to prevent the supply chain's data gaps so that despite the difficulties brought on by business secrets, the recycling loop for natural rubber from used tires can be completed. Through contact between all parties involved in the tire supply chain, it is auspicial to strengthen the natural rubber supply chain's resilience.
The literature study describes how IT solutions may possibly boost resilience and presents the idea of resilient supply chains. Further, the case study of scrap tires has presented and at the end of the paper, the tire supply chain is used to test the suggested IT solutions to assess whether these could enhance the level of resilience along the chain.
Resilience can be built in the planning stage studying a strategy that provides a range of alternatives in case of disruption. Supply chain (re)-engineering, high degree of cooperation within the supply network between the various stakeholders and agility focused on achieve robustness are the key principles identified to create resilient supply chains. Secondly, building a culture of supply chain risk management, from the top managers to standard employees, helps increase resilience.
Another point to emphasize in the article is that recyclers often receive products at end-of-life products with little information on the product composition, whereas producers have access to all the data they need to develop and sell their products. This is because manufacturers frequently do not share information on product compositions, their processes, and related material with actors not fully integrated in the chain, but positioned at the beginning or end of it. To put it another way, the scrap material that is handed to the recycler is therefore more similar to a black box plenty of data flaws to be discovered more precisely. Both missing data and uncertain information are assumed to be data defects.

Focusing on the tire recycling, synthetic rubber is typically more prevalent in passenger tires than natural rubber, which is more used for truck and off-the-road tires. Another degree of complexity in the recycling process is added by the fact that during the production process after being molded and vulcanized, the two types of rubber are no longer separable. The solution is combining crushed rubber and plastic particles creating a new blend. In this way, tire waste rubber can be recycled and so utilized in place of virgin rubber in new applications. Retreaded tires have though a relatively tiny market in the passenger automobile industry because consumers believe "used" tires to be of significantly poorer quality.

As a conclusion, successful recycling requires the precise physical composition of the discarded tires. As the case study have demonstrated, improving supply chain resilience for tires by partially substituting recycled rubber for natural rubber necessitates data sharing along the whole supply chain and involves all players in the ecosystem of tire manufacturing.

2.5.6 Investigating environmental and economic impacts of the 3D printing technology on supply chains: The case of tire production (Shahpasand *et al*., 2023)

This paper aims to add to the body of literature by setting up a closed-loop supply chain for 3D tire manufacturing and introducing a MILP model that suggests the best options to create a network of facility locations connected by material flows among them. All of this is done while examining the 3D technology's effects on the economy and the environment, which is a study gap to be filled.

By decentralizing production, encouraging product differentiation, lowering production complexity, increasing resource efficiency, accelerating time-to-market, and rationalizing stock management and logistics, the additive manufacturing (AM), often known as 3D printing, can offer industries previously unheard-of benefits in the field.

The current study examines the economic and environmental impacts of AM on the tire supply chain, that represent an expensive supply chain compared to others, and also presents substantial environmental concerns. The suggested models are used, using parameters taken from the pertinent literature, to analyze the supply chain of an Iranian tire manufacturer.

Eliminating molds enhances production quality and efficiency, uses less raw materials, allows for the consideration of complicated designs, and lowers maintenance costs. This is one of the fundamental advantages of 3D printing over traditional manufacturing.

The supply chain dynamics and performances are also better of using 3D printing, implementing the manufacture to order system indeed is advantageous for businesses because

it reduces the expenses of shipping and warehousing and enables them to better manage production planning in the event of demand volatility.

The objective function of the proposed MILP model comprises income and a variety of expenditures, such as the opening of the plant, manufacturing, lost demand, transportation, and carbon emission expenses. The findings imply that, in comparison to traditional production, the productivity of the chain using AM technology is less sensitive to the management's level of risk-seeking. Depending on the management's plan, the profit of a 3D-printed CLSC might be 51-61% more than that of a standard CLSC.

Environmentally speaking, the supply chain's total carbon emissions could be reduced by 9–10% thanks to the additive manufacturing adoption, paving the way to a cleaner tire production and distribution in the next future.

2.5.7 Blockchain and Cloud-based Technology in Automotive Supply Chain (Yasmin and Devi, 2023)

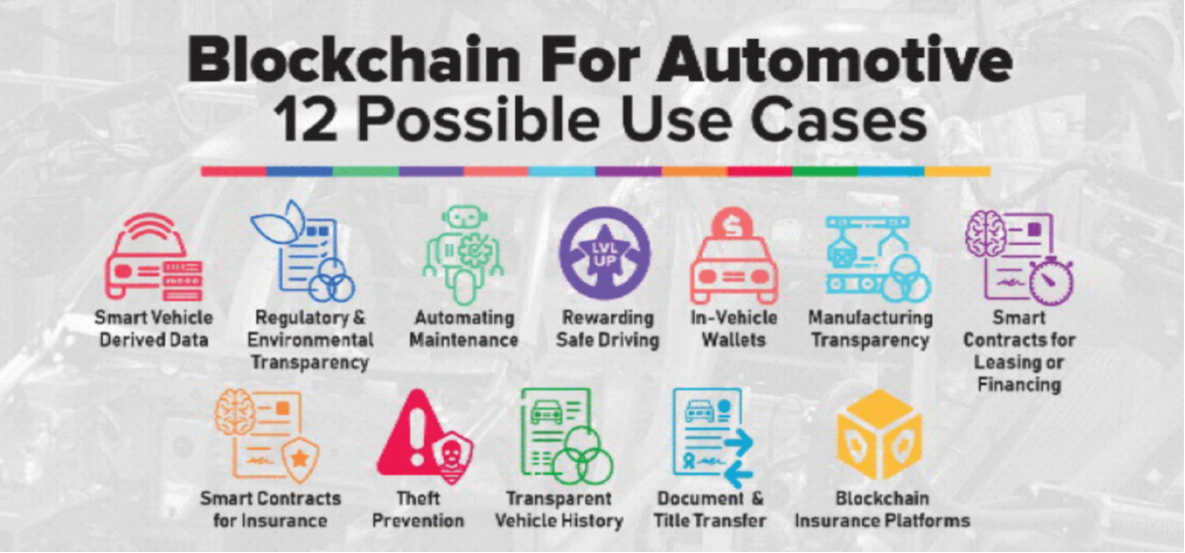

Figure 9: Use cases for blockchain in the automotive (Yasmin and Devi, 2023)

This piece of work investigates the nature and utilization of Blockchain and Cloud based technologies adoption in automobile sector, assessing the degree of blockchain integration in the Indian industry's supply chain.

Blockchain is an online distributed (not governed by a single, centralized legal or financial body) ledger technology that allows for peer-to-peer transactions over a secure channel.

Over 75 corporate executives from the Indian automotive industry participated in a questionnaire-based survey that was carried out using a Google Form platform, and a descriptive analysis was then carried out.

According to the study's findings, the amount of blockchain technology adoption in the Indian automobile industry is impressive. The use of blockchain technology is widely recognized not only in the mainstream manufacturing process but also in the supply chain that includes suppliers of raw materials and transporters of final goods (Figure 9).

2.5.8 Readiness and Maturity of Smart and Sustainable Supply Chains: A Model Proposal (Demir *et al*., 2023)

According to the literature study thus far, no readiness and maturity model cover smart systems with sustainability. Therefore, in this article, it's proposed a novel model, "Smart and Sustainable Supply chain Readiness and Maturity model (S3RM)" to fill up this research gap, and a case about the automotive industry is conducted to validate it.

Artificial intelligence (AI), big data, cyber-physical systems (CPS), and) are Internet of Things (IoT) the technologies leaders towards an Industry 4.0 approach within a firm. Through the use of information and communication technologies, Industry 4.0 unifies business and technical systems. As stated by Hofmann & Rüsch (2017), is not sufficient for a firm to migrate to Industry 4.0 internally; the supply chain as a whole must advance in this shift.

Maturity models are strategic tools used to define and assessing a company's maturity level in a particular sector or activity connected to a business purpose. It's crucial for companies acknowledge evaluate their current state in digital transformation and if their approach to Industry 4.0 is sufficient for the desired future growth. Instead, a readiness model's objective is to establish a starting point and kick off the development process.

The concept developed in the paper called S3RM model merges the notorious TBL scheme of sustainability with TBL of smartness which constitute the originality of this work.

As known, TBL of sustainability consists of social, environmental, and economic sub-dimensions, whereas TBL of smartness that identifies the digitalization of SCM contains the following dimensions: availability, adaptability, and integrity.

The numeric outcome of the model helps firms discover and assess their existing level of maturity and readiness for smart and SSCs, and it directs managers in identifying strategic decisions for the future course.

2.5.9 Link between Industry 4.0 and green supply chain management: Evidence from the automotive industry (Ghadge *et al*., 2022)

This study aims to fill the research gap by experimentally evaluating the relationship between two paradigms, Industry 4.0 and sustainability performance. The generated hypotheses were put to the test using over 240 questionnaire responses gathered from European automotive supply chain managers. To create a multi-level hierarchical structure for examining the relationship between Industry 4.0 and GSC performance, an integrated, two-stage approach integrating ISM and SEM is used.

In automotive supply chains, the application of big data analytics (BDA) may considerably increase forecast accuracy and demand planning and the enormous amounts of data that IoT devices collect allows efficient decision-making and for intercommunication between different electronic sensors, devices, and various identifying codes.

Large-scale product and supply chain information can be supported by blockchain (BC) through data gathering, storage, and administration.

AM makes use of additive manufacturing to create components on-demand at flexible geographic areas close to customer locations and conditions that offer customized and low volume goods.

A harmonic and proactive cooperation among supply chain managers is crucial to reduce the environmental impact along supply chains stages (Tseng et al., 2019).

As the underlying causes of the dependent variables, IoT, CPS, and A&RT are examples of Industry 4.0 technologies that come under the category of independent factors that affect how well GSCM performs. IoT is a crucial aspect among the different driving and independent variables, as it has the maximum driving power of 13 in the MICMAC matrix.

The results show that the technologies of Industry 4.0 will help enterprises complete the transition to sustainable development thanks to the positive impact on green supply chain performance measures.

2.6 Sustainable Supplier Selection

In this paragraph the articles clustered within this class will be summarized one by one, putting the accent on the distinctive features related to the theme of sustainability linked in this case to the sustainable supplier selection process, that plays a crucial role as already discussed in a green supply chain.

2.6.1 Explanatory factors for variation in supplier sustainability performance in the automotive sector – A quantitative analysis (Bartos *et al.,* 2022).

This article uses a multiple regression approach to analyze variations in sustainability performances across supplier groups in the automotive industry, using an SSP (sustainability supplier's performance) evaluation method regularly used in the automotive field, namely the "Self-Assessment Questionnaire on Customer Social Responsibility", known also as SAQ.

It has been monitored if the SSP score varies depending on three dimensions: the size of a company as determined by the number of employees, the location of the company's place of business, and the sector within it serves. Finding patterns and trends enables policymakers to obtain recommendations on how to formulate laws and regulations and permit to infer conclusions for OEMs' sustainable supply chain management strategy.

The results show that, as assessed by the SAQ, bigger suppliers perform significantly better in terms of sustainability than smaller suppliers, where the expense of putting sustainable practices into place is still deemed to be a significant problem. At the same time, the higher performance of bigger firms can be due to the higher customer expectations that push the company to embrace sustainability goals in a serious way.

Surprisingly, suppliers based in in the Americas and Europe appear to perform worse when it comes to the SAQ scores of the various regions than suppliers located in Africa or Asia that appear to perform best. However, for the latter the standard deviation is significantly higher.

However, overall, it appears that suppliers headquartered in industrialized nations do marginally better than those based in developing nations in terms of sustainability. Another finding reveal that manufacturing suppliers outperform service providers in terms of SSP.

To conclude, it's stated that OEM requirements are an important factor in driving SSP, although it should be noted that rather than the requirements themselves, what appears to be driving SSP as measured by the SAQ score are the monitoring OEMs do be compliant with these requirements.

2.6.2 How car producers are driving toward sustainable supplier development (Hąbek *et al*., 2022)

This article attempts to study the sustainable supplier development practices of 6 European car producers (PSA, BMW, Volvo, Volkswagen, Stellantis, Daimler), applying the content analysis method.

The purpose of this article is to demonstrate how automakers are addressing the issue of enhancing their sustainability performance by integrating sustainability into the supplier development process. Data was gathered from the sustainability/CSR reports of the firms mentioned above, downloaded from Global Reporting Initiative database.

A strategy known as "sustainable supplier development" assists suppliers in developing their innovative proficiencies and competencies while also promoting a culture of cooperation and quality improvement with the buyer organization (Kiwili and Ismail, 2016).

A company should spend time and effort in developing its suppliers over time to attain and maintain the appropriate level of quality, on-time delivery, and supply chain productivity (Webb, 2017).

Four different categories of practices that car producers can put in place have been identified: prevention as code of conduct, training or self-assessment; detection as risk-based audits; reaction as action plans and support in a form of dedicated supplier's portal.

Here as follow, the most important trends that have been found regarding sustainable supplier development in this research:

- the standardization of many procedures, including self-evaluation, training, and audits, is frequently done in cooperation with industry associations. In the end, this reduces the burden on suppliers to adjust to every auto manufacturer's requirement.
- the particular focus on the decarbonization of the supply chain.
- the use of a risk management strategy to optimize resources during the sustainable supplier development process.

2.6.3 Green supply chain management in Brazilian automotive sector (Vanalle and Santos, 2014)

The purpose of this study is to identify the most highly regarded sustainable practices, assess them, and investigate how environmental, financial, and operational performance impact supplier development and selection in the Brazilian automotive sector.

After a brief literature review, an exploratory field study through a questionnaire has been performed. As result, it's clear that companies regard strategies that reduce or eliminate the usage of hazardous materials the most. In fact, these procedures are taken into account while choosing, developing, and evaluating suppliers' environmental performance. In addition to this, also the monitoring and the decrease of the production of hazardous waste and industrial effluents is another procedure that Brazilian firms value.

Compliance with regulations requirements pertaining to the environment, can be witnessed by the fact that businesses are expanding their environmental responsibilities to the members in their supply networks: the cooperation between suppliers and the buyer company for a greener production and lean methods, as well as their participation in the design, monitoring, and reduction of natural resource consumption, are also recognized in the internal management of businesses.

2.7 Critical analysis of the literature

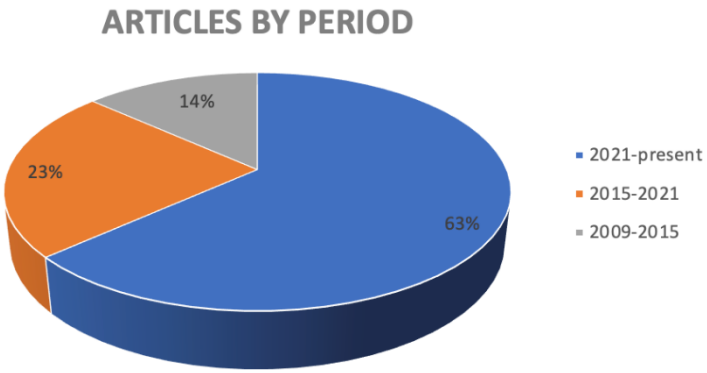

Figure 10: Articles by period

It has been verified that of the 30 articles chosen, the great majority of 63% have been published in the last two years, while just 24% of the total been published from 2005 to 2009 and only 13% before 2015 (Figure 10). The oldest article considered in the research is dated as of 2009.

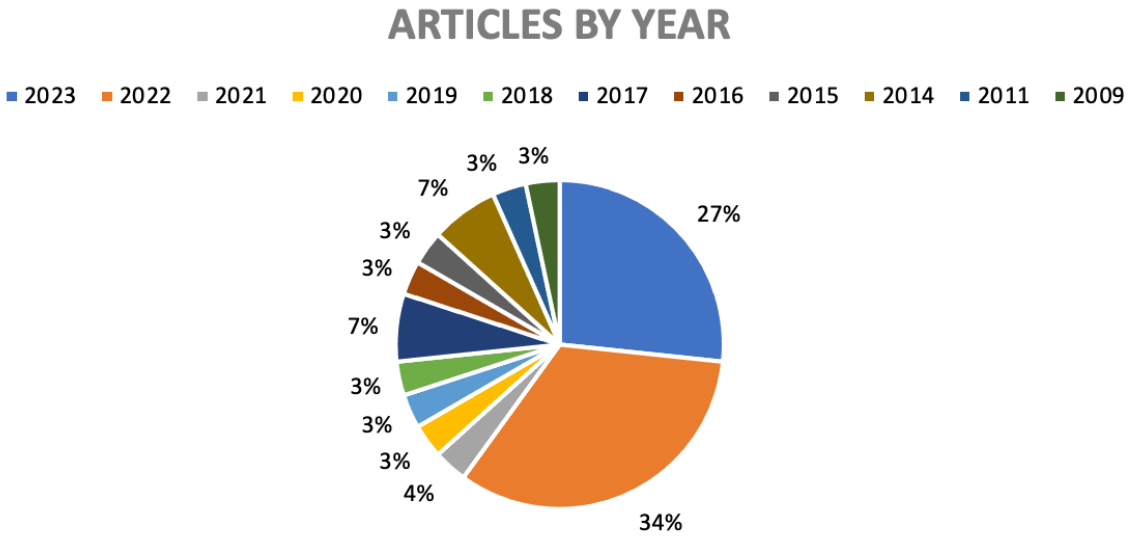

Figure 11: Articles by year

The literature concerning supply chain sustainability is emerging more and more in the last few years, as shown in Figure 11. Governments attitude to push schemes, implement regulations and policies towards the reach of sustainability in the industry has become central in the last decade.

This explains why the frequency of publications regards sustainability in the last years increased dramatically in all the fields, including automotive industry.

Dividing the articles based on the country of birth of their authors, it's possible to denote a great variety of nationalities that permit to have different visions and points of view on the topics treated during the paperwork.

Cultural aspects can affect directly and influence an automotive firm in reaching sustainability within the firm, and the structure of the article database allow to compare different case study belonging to different part of the world, from Asia to Africa, Europe and Latin America.

In the graph below (Figure 12), it's possible to see a slight majority of Indian authors with 5 articles in the database looking at the totality of articles. A lot of articles belong to country like Brazil, Turkey and Iran where the automotive sector is pretty important looking at the GDP of each country. It may be interesting to investigate whether a nationality's high database contribution reflects its high relevance in terms of the country's automobile industry's income.

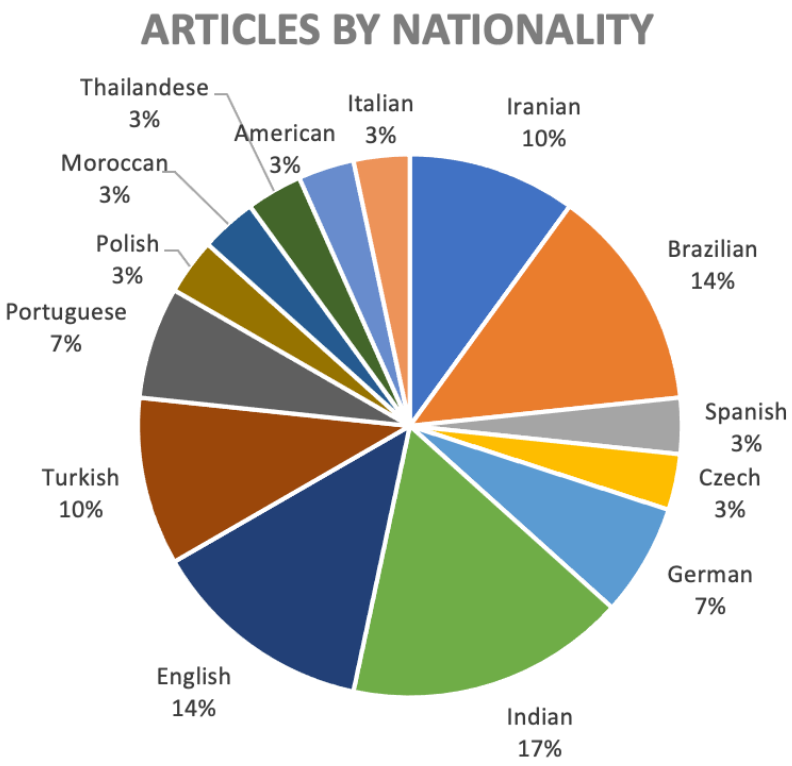

Figure 12: Articles by nationality

From Figure 13, it's clear that the type of methodology that present more articles are literature review and survey.

For what concerns modelling, articles that elaborate a simulation model and articles that propose an optimization model are equally distributed in the database.

There are also a few articles proposing a LCA analysis, for determining how a commercial product's life cycle affects the environment at each step.

Targeting the surveys, it's not surprising they correspond to the most frequent methodology through the database. Several surveys indeed were conducted inside the automotive plants themselves or headquarters, talking with operators or more usually with managers giving their point of view about the new sustainable practices inside their firms.

Interesting modelling elaborates with complicated objective functions are usually constructed in various articles to try validating the hypothesis derived from the literature review of each articles.

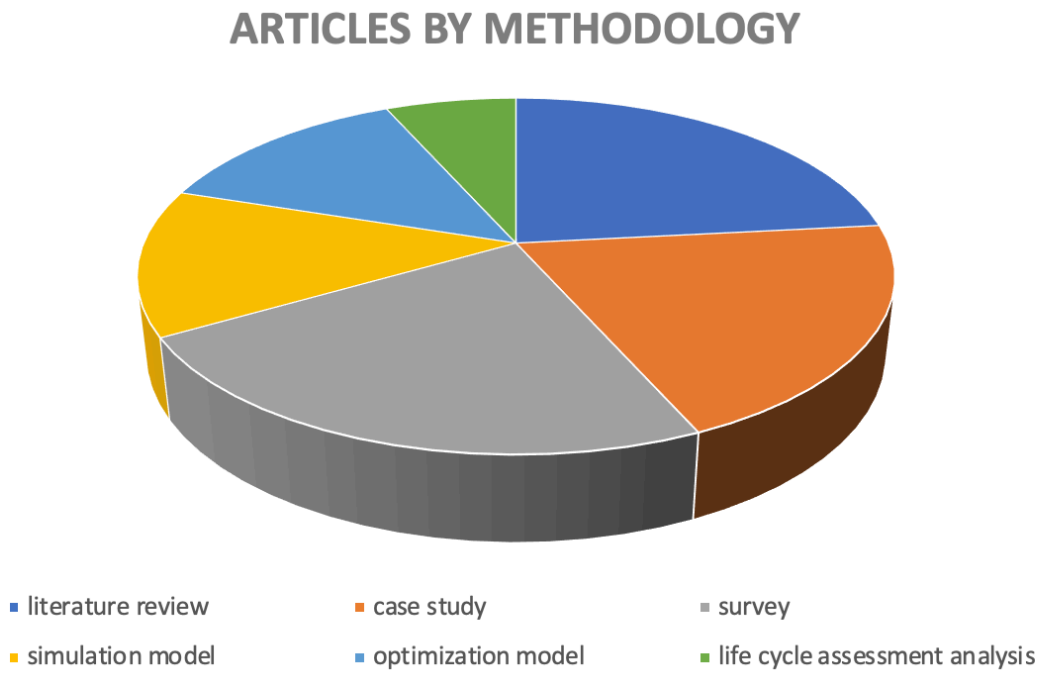

Figure 13: Articles by methodology

The term "research keywords" means the words used in the research bar inside the Scopus database during the preparation phase of finding the articles related to thesis topic.

As shown in Figure 14, more than a half of the entirety of the articles were found under the broad topic 'automotive supply chain sustainability' that is the essence of the thesis. From the articles appearing under this category, it was possible to see how the theme is further developed deeply through its subtopics.
Other articles related to subtopics like tyres supply chain sustainability, sustainability green practises, just in time material or reverse logistics were found tightening the research using more specific terms.

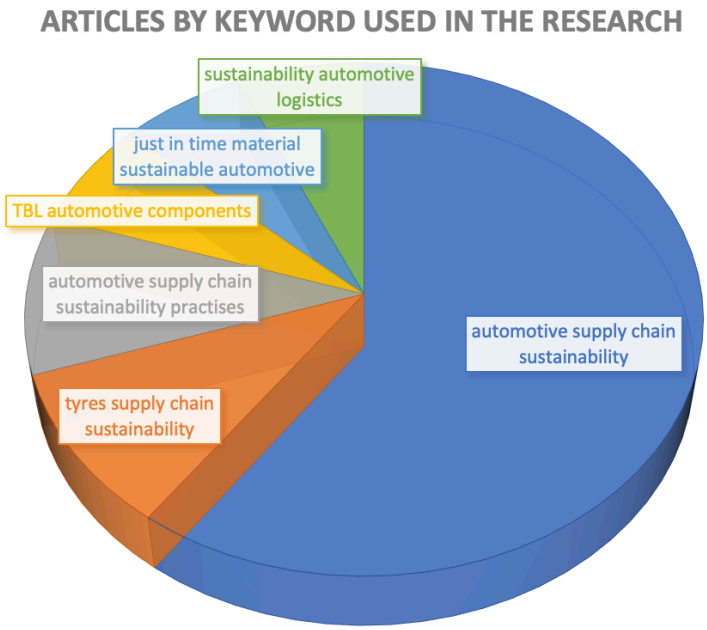

Figure 14: Articles by keyword

The term "author's keywords" means the words used by the author to summarize in some way the content of the article highlighting the themes treated in it. Looking at Figure 15, basically almost the totality of the articles presents the keyword "supply chain", "sustainability" which are the main traits of the research. The term "automotive" is slightly less present.
Of course, even if the term isn't in the keyword list of the article, there might be some references inside the article or the theme can be treated anyway, independently if present or not. Sure, if the word is present in the keyword, then it represents a central point of that piece of work and will be largely discussed in it.
Other keywords with a significant number of references are "resilience" related to the supply chain, "green" related to practises and GSCM, "technologies" and "tire" on which in the research there will be a deep dive analysing case study in the specific sector found in the articles related.

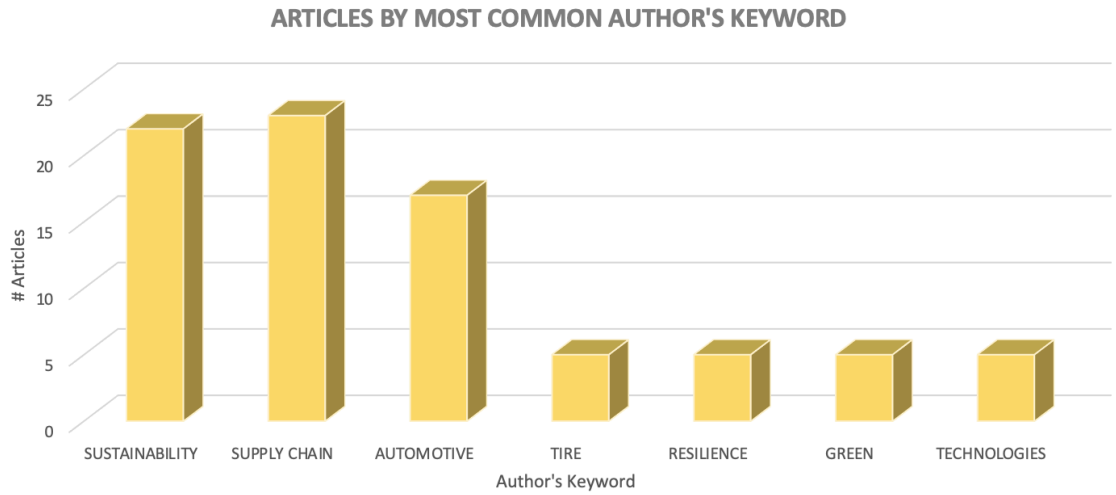

Figure 15: Articles by author's keyword

The great majority of the articles present in the database are taken from technical journal as for example *The Journal of Cleaner Production* and *Sustainability* that are the two more represented in the list (Figure 16). It's not surprising that 4 articles were taken from The *Journal of Cleaner Production* that is a global, transdisciplinary journal that focuses on study and application in cleaner production, the environment, and sustainability. The main objective of this paper is through its published articles, aiming at helping societies become more sustainable. The same applies to *Sustainability* newspaper, which easily comprehensive from the name.

Two of the articles taken from the Journal of Cleaner Production discuss optimization models regarding the supplier selection based on their level of sustainability and the design of a closed-loop supply chain to produce tyres. Only 4 articles are proceedings of Conferences as the IEEE International Conference on Engineering, Technology and Innovation or International Colloquium on Logistics and Supply Chain Management, just to name two of them. The fact that a few conferences and speech have as main argument the sustainability in the supply chain can be explained in two different ways: it might not be as crucial as other theme regarding the optimization of the supply chain to reach a new level of efficiency and higher profitability consequence, but that might not be primary reason. Indeed, much more likely the topic of sustainability in supply chain still haven't arrived at his apex. Professionals are studying about

it; in the last decade publications have reached high numbers but still it is a subject relatively new.

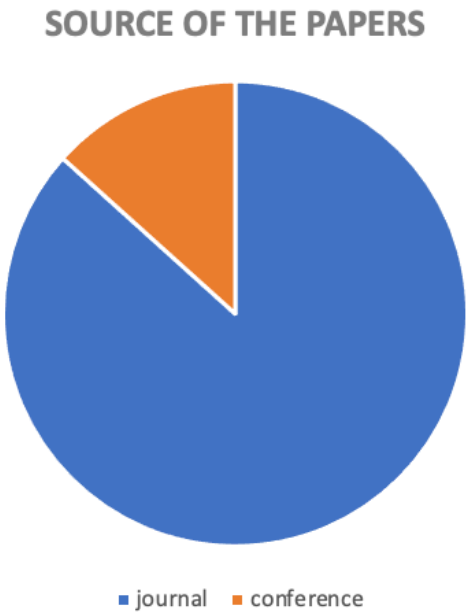

Figure 16: Articles by source

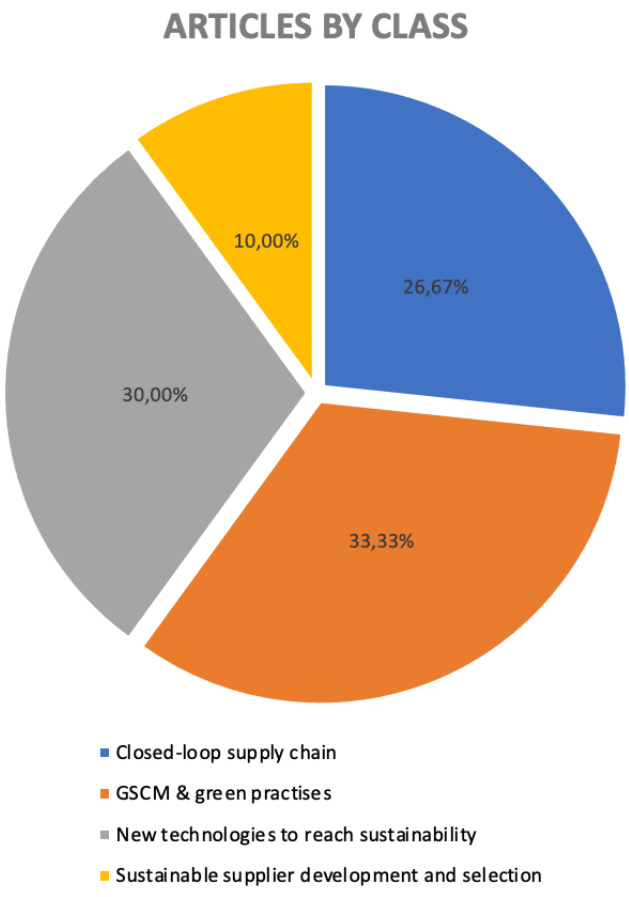

Figure 17: Articles by class

As displayed in Figure 17, the articles were divided into 4 different classes based on how car automakers act towards reaching a desired level of sustainability inside the firm: we can clearly see that the predominant way to reach sustainability is through green practises and Green Supply Chain Management rules; the articles that treat this topic represent 1/3 of the entire database.

Green Supply Chain Management represent by far the most debated topic looking at the total number of articles by class. However, closed loop supply chain and new technologies related topic represent another big piece of the 'cake' database, looking at the percentual.
The selection and sustainable supplier development is the topic on which there aren't a lot of pieces of work and so the least debated. Might be an idea to focus on it for future studies since the subject seems unexplored.
As the graph below (Figure 18) shows, the distribution of the n° of citations though the four different classes isn't that homogenous.
In this case, contrary to what happens in the graph above, the 'new technologies to reach sustainability' topic it's by far the most debated looking at the amount of citations (227), even if it belongs to this class the highest number of articles (9 out of 30).

GSCM & practices presents a high number of citations, given the fact that probably is the broadest topic of the four classes and these leads potentially to numerous discussions regard its subtopics (i.e., reverse logistics, reverse supply chain, recycling, etc.)

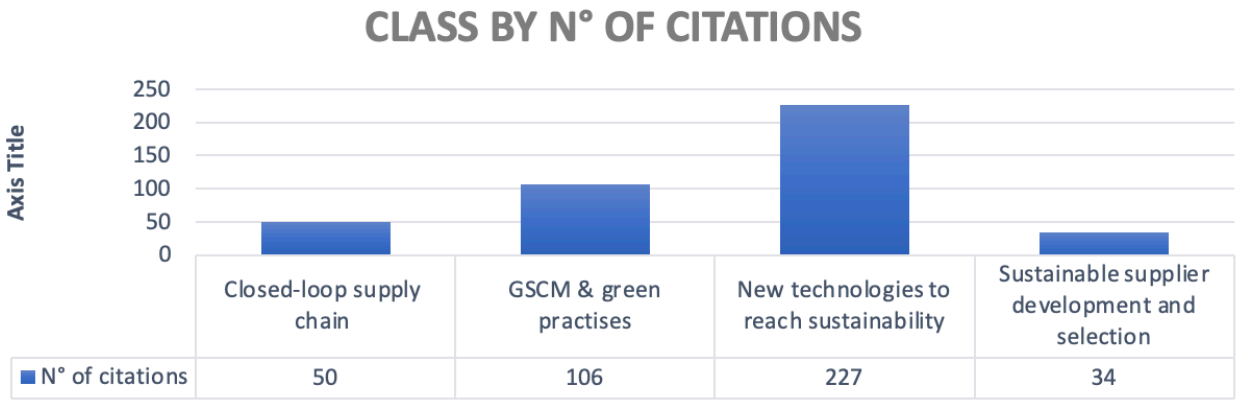

Figure 18: Articles by n° of citations

CLOSED LOOP SUPPLY CHAIN

The graph below (Figure 19) highlights the 5 different nationality to which the papers of this class belong: regarding CLSCs there are 3 articles related to India's automotive sector, predicted to be the world's third-largest automotive market in terms of volume by 2026.

It would be interesting to compare the articles n°14 and n°24 that display analysis attempting in identify critical barriers in India SSCM in the automotive: in the n°24 is stated how in the automotive industry keeping the tires in circulation and minimizing leakages by retreading all tires that could be re-treaded would be key values in the push toward the Circular Economy (CE). Recycle is a key element in a CLSC. The analysis reveals ten critical barriers to push toward a CSC. While in article n°14 the topic is wider, treating barriers to implement sustainable supply chain management without focusing on some part of the chain like recycling.

I think strategic alliances (i.e., between an OEM and a re-treader or a recycling firm) and strong governmental policies, especially in the more developed country that can bear it and cruise the sustainability revolution being the example for less developed country in the next decades, are the two major actions than can push the adoption of the CLSC scheme.

The absence of American or European authors can be due to the fact that developed countries are far ahead in the process of implementing sustainability through the supply chain that are much more modern and automized. This results in non-necessary publications since the topic might be faced years ago in these countries. But more likely the reason can be found in the fact that the concept of sustainability in the industry is much more spread and acknowledged in Europe or in the US, while in developing countries the discussion and talking about sustainability and its adoption in the industry might be vital to bring the importance of the topic

to the public opinion and consequently push the governments in studying policies and regulations to face directly the problem, and stop pretending like nothing is happening.

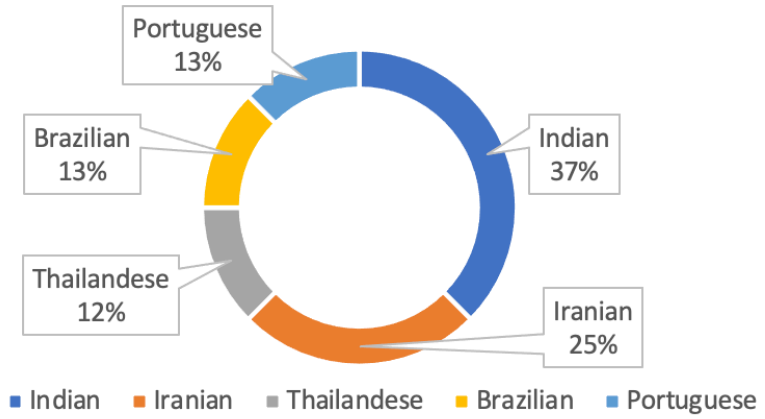

Figure 19: CLSC papers by nationality

GSCM & GREEN PRACTISES

GSCM & green practises are the most debated topic and the one more diversified in terms of nationalities of the authors concerning our database (Figure 20).

The subtopics in these articles are diverse: in n°4 and n°26 lean is a central theme while in n°19 Triple Bottom Line approach is the key element.

This class is the most variegated in terms of subtopics that will further be analysed in the thesis.

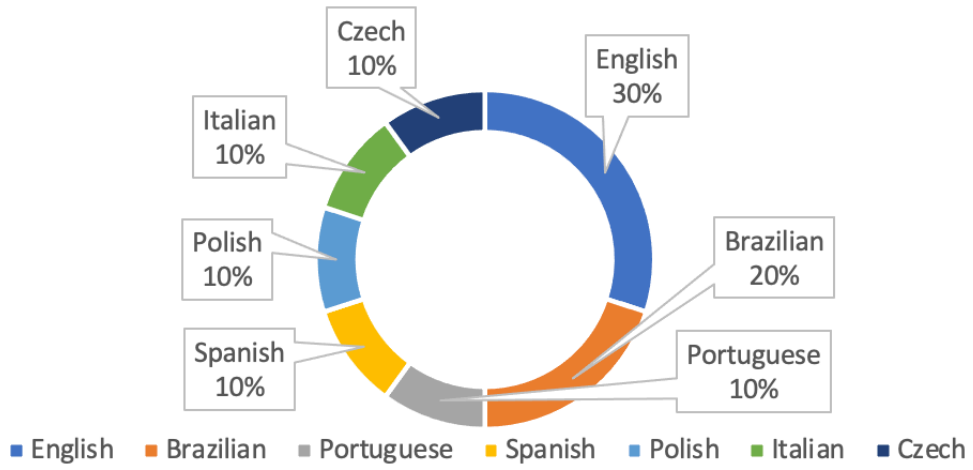

Figure 20: GSCM papers by nationality

NEW TECHNOLOGIES

The database articles treating new technologies to reach sustainability are pretty diversified, as displayed in Figure 21, in terms of nationality of the author: articles n°13 and n°8, both written by Turkish authors analyse the blockchain technology the first, while the second present a list of the emerging technologies contextualized in the Turkish automotive industry. Also, articles n°6 focus on blockchain technology but looking at the Indian automotive sector.

It can be interesting to deep dive into the differences in the adoption of these new technologies, from the more developed country to the least developed country present in the database.

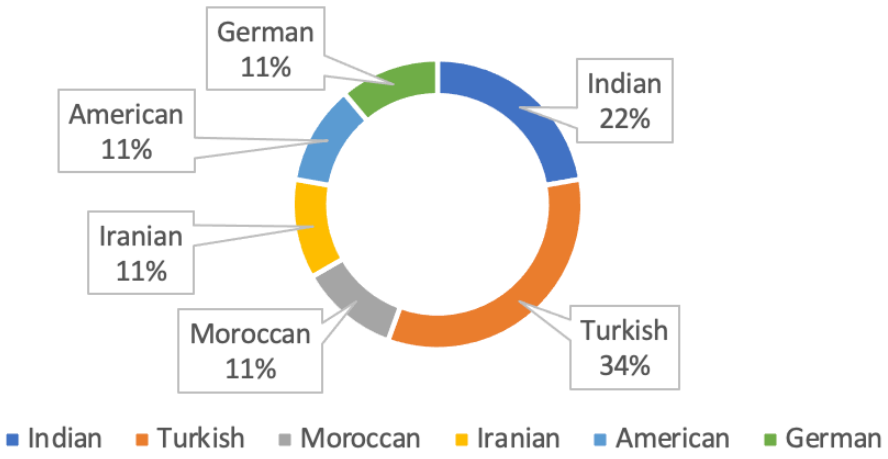

Figure 21: New technologies papers by nationality

SUSTAINABLE SUPPLIER DEVELOPMENT AND SELECTION

Few articles have considered company data to analyse reported supplier sustainability performance (SSP) and belong to Brazil, Germany and UK (Figure 22). These papers allowed to reason on which are the drivers that push a firm towards a supplier rather than another supplier based on their sustainability performance.

Between these, the one that has most citations is the Brazilian case article (12) identifying the most valued practices of sustainability, as well as factors related to environmental, financial, and operational performance considered in the process of selecting and developing suppliers to became members of supply chains in the Brazilian automotive sector.

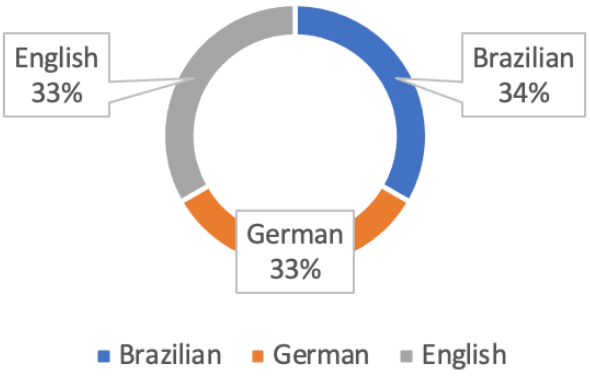

Figure 22: Sustainable supplier development papers by nationality

Chapter 3

Conclusions and perspectives

After a careful and precise analysis of the data that had been gathered, it was possible to comprehend and debate the challenges affecting automobile producers when they chase sustainability goals as part of their business strategy. In this chapter the principles that have been inferred from this analysis will be listed and argued.

3.1 Results and discussion

Based on the findings and the graph analysis performed in Chapter 2, a few basic principles regarding how sustainability goals have been pursued in the industry in the last decade and what must be expected in the upcoming years, could have been defined and are presented in this section:

- The Closed-Loop Supply Chain is found to be widely adopted in the automotive sector and it seems the be the foundation on which companies can count to start planning their own sustainability strategy.

Basically, in the majority of the papers taken into account is present a glimpse of CLSC, under the form of cradle-to-cradle approach, disposal of end-of-life products, recycling and reusing of materials, etc. On top of that, companies then built other green practices or routines related to the SSCM, use new technologies or select and incorporate the best sustainable suppliers with their chain, but CLSC constitute the basic pattern for all of it. It's fair to state that even in developing countries, as was shown the example of India, Iran or Brazil, within the sector, companies are putting efforts in making the supply chain more sustainable and the wide adoption of CLSC scheme confirm that.

- The common denominator seems to be the challenge of overcoming the threat for the environment that higher scale and growing production can bring in the next future,

through recycling and reusing end-of-life products or part of them for manufacturing new products.

Throughout the thesis, it was possible to see how the sustainability goals apply to suppliers that deliver to the automobile producer different raw materials, spare parts and components as for example LAB vehicle batteries, tires, etc. Like previously said in Chapter 1, the global automotive market is expected to grow from 23 billion dollars in 2022 to 28.7 billion dollars by 2030 [5] but driving to a greener future too. By reusing materials, carbon emissions are reduced while profits also rise. In addition, the sales of hybrid and electric vehicles will skyrocket. According to International Energy Agency, the share of electric cars in total sales has more than tripled in three years, from around 4% in 2020 to 14% in 2022. By 2030 per IEA [6], the amount of EV sales is expected to avoid the need for 5 million barrels of oil per day, based on the present trend.

- Green Supply Chain Management practices are often thought as an easy win from the economic and social point of view for all types of companies in the automotive sector but the findings reveal that unfortunately this isn't not the case, as there is an abysmal difference between big and small companies.

Indeed, it is still very expensive to adopt these practices today, and small and medium-sized enterprises often cannot afford such a high level of investment that it does not bring its results in the short term but rather in the long term. A lot of medium and small size company in the automotive sector react just when it's necessary to comply with the law and the regulations, especially in developing countries. Their focus relies more on the process-based innovations, which are less expensive than a complete re-design of a product or of business strategy consolidated in the past years, considering also the resistance to change that usually is a characteristic of small and medium businesses.
Eco-design, the just-in-time lean approach and green logistics are just a few example that have a detrimental effect on the economic side in the short term.
On the other hand, big size company have the possibility and the funding needed to embrace in a more concrete and continued way sustainability goals. Let's not forget that of course the latter, have much more pressure from governments and consumers given their brand image.

- As it’s possible to see from the graphs in the previous chapter, the far most debated theme in the sustainable supply chain management domain are nowadays the new technologies have the potential of shaping the future of processes within the automotive sector.
  Industry 4.0, blockchain, additive manufacturing, the use of lightweight materials, the application of specific simulation model, cyber-physical systems, big data, AI are just a few of the technologies that are bringing innovation in the automotive sector.
  Their potential still hasn’t been fully exploited, especially in the developing countries but it’s certain they represent game changing instruments for growth of sustainable supply chain management in the upcoming years.

- The sustainable suppliers selection approach is far more efficient if the latter are incorporated vertically in the chains without remaining at its margins. This applies also to the recycling enterprises that belongs to the supply chain.

External recycling enterprises usually get items at the end of their useful lives with little knowledge about their composition. Incorporating suppliers and recycling firms within the chain allow a much more precise exchange of information to streamline processes, lead to reduce time and costs and consequently obtain more efficient results in terms of profits.

These findings demonstrate the automobile industry's dedication to sustainability, which is motivated by consumer preferences, regulatory pressures, technology advancements, and environmental concerns. Further research and ongoing efforts are essential to continue advancing sustainability in this sector.

Focusing now on the tire industry, it’s possible to denote from the findings that the Closed-Loop Supply Chain approach is widely embraced in the sector. A few cases study all around the world, as in Iran or Thailand, displays that in the industry is now well established the importance of recycling and reuse. Companies in the sector are conscious of the fact that the tires at the end-of-life stage are a product far more polluting than the average and must deal with it. These goods have short lifespans and can harm multiple ecosystem creatures if released into the environment. Since it requires millions of years for these tires to be decomposed in the

nature and given the severe potential effects on ecosystems, adopting the closed loop tire supply chain approach is crucial for companies (Cheraghalipour *et al*., 2017).

Retreading is another key end-of-life activity that consists in reusing a tire of which the carcass is still in good condition, by replacing the rubber layer on top of it, that became too thin.

Another important insight, it's the fundamental role of resilience in this sector to face the fluctuations of demand: providing raw materials on time is crucial in this case and backup suppliers must be considered. Given the high amount of different material needed to start the process, multiple sourcing is suggested as the best way to face high demand shifts. Resilience is another key factor in making the chain more sustainable.

Resilience in the sector is also challenged because of the scarcity of its primary component, rubber. Indeed, rubber can available as synthetic rubber, which is created in labs using hydrocarbons, or natural rubber, from gum trees. The latter, is becoming scarcely available and is already considered critical for the EU [1].

3.2 Contribution to the literature

The main contributions of this research are as follows:

- Investigating the role of new potential technologies in the supply chain management that can improve performance not only under the economic and organizational but consequently also from the sustainability point of view.
- Comparing the supply chain management from country to country thanks to the high number of different nationalities of authors and the variety of case studies from various countries stored in the database (Iran, Turkey, Brazil, UK, etc.).
- Focusing deeply in one of the most polluting sectors nowadays, the tire industry, sorting out the ways to a greener future thanks especially to activities as recycling and reusing of end-of-life products.

3.3 Limitations

This work presents some limitations. Firstly, there are few papers in this articles' database that bring examples of how supply chain management does work considering sustainability issues in the automotive sector in high developed and skilled countries in this specific field, as USA, Germany, Italy, France, UK, Japan, or South Korea to which belong the most important automobile brands in the world (i.e., Ferrari, Stellantis, Mercedes, Toyota, Ford).

Secondly, the research is limited to the automotive sector and this does not allow the comparison of how sustainability targets and objectives are pursued across other industries. Having a yardstick comparing different sectors of the world economy would be useful to understand if it is going in the right direction or if much further efforts are needed.
In addition, for some topics as the new technologies (i.e., AI, big data) utilized for sustainability purpose or some of the green practices named (i.e. eco-design, green logistics), this research has given relevance to their usefulness in the field and their utility from the macro point of view without deeply study their concrete use in the industry, in the factories, focusing on them one by one.
In conclusion some of the very interesting simulation and optimization model present in the papers have been explained and acknowledged but have not been applied in other automotive contexts outside their country of origin.

3.4 Future research

Future research is crucial to sustaining the progress of sustainability in entire automotive industry, also including the tire sector. Contrary to how it was done during this thesis work in which the articles examined came from different continents, it would be useful and recommended for future research to focus specifically on a part of the world, or even a specific nation. Narrowing the perimeter, perhaps more precise and concrete results would be obtained related to sustainability of the supply chain in that determined area. This would lead to more focused and constructed considerations. Secondly, referring to the fact mentioned above that no examples of companies of the Western world were considered, it would be interesting to understand how sustainability goals are being pursued in the biggest automotive group as Toyota, Mercedes, Volkswagen or Stellantis who run their operations perhaps in a different way on this side of the world compared to developing countries.
Future work might also be carried out to validate the findings perhaps applying different analytical methods or simulation model, considering all the variables and dimensions found in this work. The results of this study can be expanded further by future academics in order to achieve a sustainable outcome also in other industries.

References

Alves, R-A., Steinberg, G. (2022), " How sustainable supply chains are driving business transformation ", available at: https://www.ey.com/en_gl/supply-chain/supply-chain-sustainability-2022 (accessed 28 July 2023).

Ayan, B., Güner, E., Son-Turan, S. (2022), "Blockchain Technology and Sustainability in Supply Chains and a Closer Look at Different Industries: A Mixed Method Approach", *Logistics*, December 2022, Vol. 6(4) No. 85.

Azevedo, S., Barros, M. (2017), "The application of the triple bottom line approach to sustainability assessment: The case study of the UK automotive supply chain", *Journal of Industrial Engineering and Management,* May 2017, Vol. 10(2 Special Issue), pp. 286 - 322.

Bartos, K.E., Schwarzkopf, J., Mueller, M., Hofmann-Stoelting, C.(2022), "Explanatory factors for variation in supplier sustainability performance in the automotive sector – A quantitative analysis", *Cleaner Logistics and Supply Chain*, December 2022, Vol. 5 No. 100068

Basu R, J., Abdulrahman, M.D., Yuvaraj, M. (2023), "Improving agility and resilience of automotive spares supply chain: The additive manufacturing enabled truck model", *Socio-Economic Planning Sciences*, , February 2023, Vol. 85 No. 101401.

Bhattacharya, S., Kalakbandi, V.K. (2022), "Barriers to circular supply chain: the case of unorganized tire retreading in India", *International Journal of Logistics Management*, 28 April 2022, Vol. 34(3), pp. 523 - 552.

Buadit, T., Ussawarujikulchai, A., Suchiva, K., (...), Ma, H.W., Rattanapan, C. (2023), "Environmental impact of passenger car tire supply chain in Thailand using the life cycle

assessment method", *Sustainable Production and Consumption*, 23 May 2023, Vol. 37, pp. 156 - 168.

Cee, J., Dieiev, O., Holman, D., (...), Stas, D., Wicher, P. (2016), "System oriented Sustainable Supply Chain Management innovations in automotive industry - SKODA auto case study", *Communications - Scientific Letters of the University of Žilina*, 10 August 2016, Vol. 18(3), pp. 54 - 59.

Demir, S., Gunduz, M.A., Kayikci, Y., Paksoy, T. (2023), "Readiness and Maturity of Smart and Sustainable Supply Chains: A Model Proposal", *EMJ - Engineering Management Journal*, 24 March 2023, Vol. 35(2), pp. 181 - 206.

Ebrahimi, S.B. (2018), "A stochastic multi-objective location-allocation-routing problem for tire supply chain considering sustainability aspects and quantity discounts", *Journal of Cleaner Production*, 10 October 2018, Vol. 198, pp. 704 - 720.

Esfahbodi, A., Zhang, Y., Liu, Y., Geng, D. (2023), "The fallacy of profitable green supply chains: The role of green information systems (GIS) in attenuating the sustainability trade-offs", *International Journal of Production Economics*, January 2023, Vol. 255 No. 108703.

Ghadge, A., Mogale, D.G., Bourlakis, M., M. Maiyar, L., Moradlou, H. (2022), "Link between Industry 4.0 and green supply chain management: Evidence from the automotive industry", *Computers and Industrial Engineering*, July 2022, Vol. 169 No. 108303.

Golicic, S.L., Smith, C.D. (2013), "A meta-analysis of environmentally sustainable supply chain management practices and firm performance", *Journal of Supply Chain Management*, 16 April 2013, pp. 78 - 95.

Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V. (2014), "Impact of supply chain management practices on sustainability", *Journal of Cleaner Production*, 15 December 2014, Vol. 85, pp. 212 – 225.

Gupta, C.P., Patel, A.R. (2022), “Sustainable Supply Chain for Automotive Industry”, in *IEEE Region 10 Humanitarian Technology Conference, R10-HTC*, 2022, Institute of Electrical and Electronics Engineers Inc., Hyderabad, pp. 155 - 160.

Hąbek, P., Lavios, J.J., Krupah, E. (2022), “How car producers are driving toward sustainable supplier development”, *Production Engineering Archives*, 1 September 2022, Vol. 28(3), pp. 268 - 278.

Hafeez, S. (2023), "Sustainability in Supply Chain Management and the Role of AI- Pioneering a Greener Future", available at: https://www.linkedin.com/pulse/sustainability-supply-chain-management-role-ai-pioneering-shah (accessed 28 July 2023).

Hayes, A. (2023), "The Supply Chain: From Raw Materials to Order Fulfillment", available at: https://www.investopedia.com/terms/s/supplychain.asp (accessed 25 July 2023).

Jansson, E., Nordh, M. (2016), "Cost comparison model on total landed cost for purchased items", working paper, Umeå University, 3 June 2016.

Jasiński, D., Meredith, J., Kirwan, K. (2021), “Sustainable development model for measuring and managing sustainability in the automotive sector”, *Sustainable Development*, November/December 2021, Vol. 29(6), pp. 1123 -1137.

Jenkins, A. (2022), "Supply Chain Efficiency: Definitions, Metrics and Steps to Improve", available at: https://www.netsuite.com/portal/resource/articles/inventory-management/supply-chain-efficiency.shtml (accessed 26 July 2023).

Jody, B.J., Pomykala Jr., J.A., Spangenberger, J.S., Daniels, E.J. (2009), “Impact of recycling automotive lightweighting materials on sustainability” in *SAE World Congress & Exhibition, 20th April 2009,* SAE International, Detroit, SAE Technical Papers.

Kazancoglu, I., Ozbiltekin-Pala, M., Mangla, S.K., Kumar, A., Kazancoglu, Y. (2023), “Using emerging technologies to improve the sustainability and resilience of supply chains in a fuzzy environment in the context of COVID-19”, *Annals of Operations Research*, March 2023, Vol. 322(1), pp. 217 - 240.

Lemtaoui, M., El Oueldrhiri, S. (2019), “Reverse supply chain practices in the Moroccan automotive industry: An exploratory study” in *International Colloquium on Logistics and Supply Chain Management, LOGISTIQUA 12-14 June 2019*, Montreuil - Paris, Institute of Electrical and Electronics Engineers Inc., No. 8907276.

Mehrjerdi, Y.Z., Shafiee, M. (2020), “Multiple-sourcing in sustainable closed-loop supply chain network design: Tire industry case study”, *International Journal of Supply and Operations Management*, 26 August 2020, Vol. 7(3), pp. 202 - 221.

Pehlken, A., Baumann, S. (2021), “No more flat tires: Overcoming data defects to achieve supply chain resilience” in *2021 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2021 - Proceedings, 21 June 2021*, Institute of Electrical and Electronics Engineers Inc, Cardiff, No. 173401.

Pinho Santos, L., Proença, J.F. (2022), “Developing Return Supply Chain: A Research on the Automotive Supply Chain”, *Sustainability (Switzerland)*, 1 June 2022, Vol. 14(11) No. 6587.

Queiroz, G.A., Filho, A.G.A., Costa Melo, I. (2023), “Competitive Priorities and Lean–Green Practices – A Comparative Study in the Automotive Chain’ Suppliers”, *Machines*, January 2023, Vol. 11(1) No. 50.

Ramirez-Peña, M., Mayuet, P.F., Vazquez-Martinez, J.M., Batista, M. (2020), “Sustainability in the aerospace, naval, and automotive supply chain 4.0: Descriptive review”, *Materials*, 2 December 2020, Vol. 13(24) No. 5635, pp. 1- 23.

Ravina, M., Bianco, I., Ruffino, B., (...), Panepinto, D., Zanetti, M. (2023), “Hard-to-recycle plastics in the automotive sector: Economic, environmental and technical analyses of possible actions.”, *Journal of Cleaner Production*, 25 March 2023, Vol. 394 No. 136227.

Scur, G., Mattos, C., Hilsdorf, W., Armelin, M. (2022), “Lead Acid Batteries (LABs) Closed-Loop Supply Chain: The Brazilian Case”, *Batteries*, October 2022, Vol. 8(10) No. 139.

Simchi-Levi, D., Simchi-Levi, E., Watson, M. (2004), “Tactical planning for reinventing the supply chain”, *The Practice of Supply Chain Management: Where Theory and Application*

Converge. International Series in Operations Research & Management Science, January 2004, Vol. 62, pp. 14 – 30.

Shahpasand, R., Talebian, A., Mishra, S.S. (2023), "Investigating environmental and economic impacts of the 3D printing technology on supply chains: The case of tire production", *Journal of Cleaner Production*, 1 March 2023, Vol. 390 No. 135917.

Sonar, H., Mukherjee, A., Gunasekaran, A., Singh, R.K. (2022), "Sustainable supply chain management of automotive sector in context to the circular economy: A strategic framework", *Business Strategy and the Environment*, 7 November 2022, Vol. 31(7), pp. 3635 - 3648.

Wellbrock, W., Ludin, D., Röhrle, L., Gerstlberger, W. (2020), "Sustainability in the automotive industry, importance of and impact on automobile interior – insights from an empirical survey", *International Journal of Corporate Social Responsibility*, 30 December 2020, Vo. 5 No.10.

Yasmin, S., Devi, G.S. (2023), "Blockchain and Cloud-based Technology in Automotive Supply Chain" in *Proceedings - 5th International Conference on Smart Systems and Inventive Technology, ICSSIT 2023, 23-25 January 2023*, Institute of Electrical and Electronics Engineers Inc., Tirunelveli, No. 187202, pp. 771 - 775.

Vanalle, R.M., Santos, L.B. (2014), "Green supply chain management in Brazilian automotive sector", *Management of Environmental Quality: An International Journal*, 1 August 2014, Vol. 25(5), pp. 523 - 541.

Vaz, C.R., Shoeninger Rauen, T.R., Rojas Lezana, A.G. (2017), "Sustainability and innovation in the automotive sector: A structured content analysis", *Sustainability (Switzerland)*, 23 May 2017, Vol. 9(6) No. 880.

Vela, R. (2023), "The Crucial Role of Supply Chains: A Pathway to Business Success", available at: https://www.linkedin.com/pulse/crucial-role-supply-chains-pathway-business-success-rafael-a-vela (accessed 25 July 2023).

Cited websites

[1] https://bluglacier.com/why-is-sustainability-important/

[2] https://www.supplychainpartners.co/articles/the-importance-of-sustainability-in-supply-chains

[3] https://www.akconsulting.com/en/magazine/supply-chain-planning-2/supply-chain-definition-what-it-is-for-and-why-is-it-important-to-manage/

[4] https://blog.shift4shop.com/mitigate-supply-chain-disruption

[5] https://www.techtarget.com/whatis/definition/supply-chain

[6] https://www.ccjdigital.com/business/article/15064727/how-to-improve-procurement-for-a-competitive-advantage

[7] https://www.netsuite.com/portal/resource/articles/inventory-management/production-planning.shtml

[8] https://oboloo.com/blog/the-5-essential-elements-of-supply-chain-management-you-need-to-know/

[9] https://www.ifm.eng.cam.ac.uk/research/dstools/jit-just-in-time-manufacturing/

[10] https://www.technologyreview.com/2022/05/12/1052201/transforming-the-automotive-supply-chain-for-the-21st-century/

[11] https://www.alvarezandmarsal.com/sites/default/files/2022-01/400914_Continued%20Challenges%20in%20the%20Automotive%20Supply%20Chain%20v2.pdf

[12] https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

[13] https://www.technologyreview.com/2022/05/12/1052201/transforming-the-automotive-supply-chain-for-the-21st-century/

[14] https://dhl-freight-connections.com/en/sustainability/green-supply-chain-automotive-industry/

[15] https://www.netsuite.com/portal/resource/articles/erp/supply-chain-sustainability.shtml

[16] https://www.ey.com/en_gl/supply-chain/supply-chain-sustainability-2022

[17] https://www.capgemini.com/in-en/insights/expert-perspectives/sustainability-circular-economy-across-automotive-value-chain/

[18] https://www.businesswire.com/news/home/20220518005677/en/Global-Tire-Market-Report-2022-Industry-Trends-Share-Size-Growth-Opportunity-and-Forecast-2017-2021-2022-2027---ResearchAndMarkets.com

[19] https://www.businesswire.com/news/home/20220518005677/en/Global-Tire-Market-Report-2022-Industry-Trends-Share-Size-Growth-Opportunity-and-Forecast-2017-2021-2022-2027---ResearchAndMarkets.com

[20] https://www.mckinsey.com/featured-insights/future-of-asia/asias-consumers-on-the-move-the-future-of-mobility

[21] https://www.ustires.org/how-tire-made

[22] https://www.forest2market.com/blog/automotive-supply-chains-of-the-future-tyre-sector-circularity-0

[23] https://www.european-rubber-journal.com/article/2091486/tire-supply-chains-to-reshape-for-the-future

[24] https://weibold.com/why-life-cycle-assessment-studies-are-important-in-tire-recycling-and-pyrolysis-industry

Appendix

Articles' Database

The following database contains all the documents considered in the literature review.

This table serves as a summary of the objectives and contents of each article, presenting also main information such as the author, the year of publication, the source of the article, the methodology used, etc. Each paper is identified with an ID number and presents a relevance level based on which article is considered more relevant and more interesting to develop reasonings about it, compared to the others.

RELEVANCE	ID	AUTHOR(S)	AUTHOR'S NATIONALITY	YEAR OF PUBLICATION	TITLE	PAPER	N° CITATIONS	VOL, N° PAGES	OBJECTIVES	METHODOLOGY	INPUT DATA	RESULTS	FUTURE RESEARCH	KEYWORDS USED	AUTHORS KEYWORDS	CLASS
VERY HIGH	1	Mehrjerdi, Yahia Zare; Shafiee, Mohammad.	Iranian	2020	**Multiple-sourcing in sustainable closed-loop supply chain network design: Tire industry case study**	*International Journal of Supply and Operations Management*	4	Volume 7, Issue 3, Pages 202 - 221	The interaction of sustainability and resilience has not been sufficiently addressed in the supply chain literature. This paper tries to fill this gap by considering them simultaneously in a closed-loop supply chain, investigating the role of multiple-sourcing in making a supply chain network resilient.	optimization model	In this research, different dimensions of sustainable development have been taken into account through reducing the total cost, energy consumption, and pollution and increasing job opportunities, and multiple-sourcing strategy has been applied for the resiliency of the supply chain A new multi-objective MILP model was developed for a closed-loop supply chain and to validate it, the real data of the Barez factory located at Kurdistan State (Iran) were applied to the model.	The results emphasized the necessity of combining sustainability and resilience in a closed-loop supply chain, where the high amounts of demand, in addition to increasing the cost, energy consumption, and pollution, increase job opportunities and the need to backup suppliers for raw materials. The results showed that the demand changes affect both sustainability and resilience concepts: total cost of the CLSC, energy consumption and pollutant emission, and job opportunities are in line with the demand changes; for the high demands of the product, more backup suppliers are needed.	Applying other strategies, other problem-solving approaches including heuristic and metaheuristic methods to boost resilience in closed-loop supply chain can be analyzed in future studies. The effects of integrating sustainability and resilience concepts can be investigated for closed loop supply chains (CLSCs) of other industries.	sustainability supply chain automotive sector	Multiple-sourcing; Resilience; Sustainability; Tire closed-loop supply chain; ε-Constraint.	closed-loop supply chain
HIGH	2	Queiroz, Geandra Alves; Filho, Alceu Gomes Alves; Costa Melo, Isotilia.	Brazilian	2023	**Competitive Priorities and Lean - Green Practices—A Comparative Study in the Automotive Chain' Suppliers**	*Machines*	0	Volume 11, Issue 1	Environmental performance is now included as a competitive priority throughout the supply chain, and this study aims to verify, through two case studies, the competitive priorities of two first-tier suppliers from the automotive chain that have adopted lean and green practices.	case study	The first step of the data collection consisted of a structured questionnaire that helped identify the main characteristics of the companies, the strategies adopted, the ranking priorities, and the practices adopted. The second part was a semi-structured interview to understand the major complementarities and conflicts generated between competitive priorities by the lean and green practices.	This study indicated that the environmental priority has become a factor of competitiveness. However, the priorities of quality, cost, and delivery in the cases presented here are still considered more important.	Development of further research on this theme is necessary, especially in other relevant markets and in other countries other than Brazil.	sustainability supply chain automotive sector	competitive priority; lean–green; operations strategy; supplier; sustainability.	GSCM & green practises
MEDIUM	3	Ebrahimi, Seyed Babak.	Iranian	2018	**A stochastic multi-objective location-allocation-routing problem for tire supply chain considering sustainability aspects and quantity discounts**	*Journal of Cleaner Production*	36	Volume 198, Pages 704 - 720	The primary and secondary objectives of the model is attempt to minimize total costs and environmental emission effects of a closed loop supply chain network taking into consideration sustainability aspects and quantity discounts under uncertainty. To this end, a stochastic multi-objective optimization for supplier selection and location-allocation-routing problems is formulated. The third objective attempts to maximize responsiveness of the integrated network.	optimization model	A case study placed in Iran is provided: among eight candidate suppliers, maximum six suppliers must be selected to provide five raw materials for three manufacturers. It should be noted that the suppliers can offer different quantity discounts. The manufacturers attempt to product four types of tires and these products are shipped to maximum five DCs among seven candidate DCs through one route out of two candidate routes. Then, DCs send these stored products to ten assumed customers. Customers returned some of these unusable tires to maximum three obsolete centers out of four existed obsolete centers. Finally, some of these recoverable returned products are sent to manufacturers and the rest is sent to two recycle centers for decomposition.	The model is verified by a real world case study using an augmented ε-constraint method, and based on experts and managers' opinions, a solution out of the obtained Pareto solutions is selected as the suitable manner for the case situation. To check the efficiency of the model, a sensitivity analysis of weight parameters in third objective function (λ) is performed. This parameter tunes the weight of the responsiveness in forward and reverse logistics. --> According to the results obtained, it can be concluded that the modelling considering quantity discount and routing problem have the best performance in terms of first and second objective functions. However, the third objective cannot be satisfied fully.	Applying other exact methods such as Lp-metric or developing heuristics, and metaheuristics to solve the problem. Considering disruption risks for suppliers and reliability in the model formulation. Developing a model under fuzzy formulation or robust optimization and.using this formulation for releted fields.	sustainability supply chain automotive sector	Closed loop sustainable supply chain; Multi-objective optimization; Stochastic programming; Tire industry; ε-constraint method.	closed-loop supply chain
HIGH	4	Ramirez-Peña, Magdalena; Mayuet, Pedro F.; Vazquez-Martinez, Juan Manuel; Batista, Moises.	Spanish	2015	**Sustainability in the aerospace, naval, and automotive supply chain 4.0: Descriptive review**	*Materials*	14	Volume 13, Issue 24, Pages 1 - 23	This study aims to analyse the different methodologies used to make more sustainable the automotive sector.	literature review	52 publications regarding the automotive sector from Scopus database.	Among the results obtained, Lean practices are common to the three sectors, as well as different technologies focused on sustainability. The Lean–Agile combination adopts strategies that help achieve the overall objectives of the organization. Another possible combination with Lean that is used as a lever to strengthen relationships is with Green practices. In addition, in order to carry out Green Manufacturing, a Closed-loop Supply Chain model was developed. Another way to achieve sustainability in production is through just in time material.	Further studies on why in the aerospace and shipbuilding sectors do not seem to be working on promoting a sustainable culture in the management of the Supply Chain or on including training programs for their personnel related to Industry 4.0.	sustainability supply chain automotive sector	Aerospace; Automotive; Manufacturing system; Shipbuilding; Supply chain management; Sustainability; Transports.	GSCM & green practises
VERY HIGH	5	Shahpasand, Reza; Talebian, Ahmadreza; Mishra, Sabyasachee	Iranian	2023	**Investigating environmental and economic impacts of the 3D printing technology on supply chains: The case of tire production**	*Journal of Cleaner Production*	0	Volume 390, Article number 135917	Aims to contributes to the literature by designing a closed-loop supply chain for the 3D production of tire and introducing a MILP model yielding optimal decisions including facility locations and the material flows among them. All this, exploring the economic and environmental impacts of the 3D technology that constitutes a research gap to be filled.	optimization model	To numerically investigate the impacts of the 3D printing technology on the tire supply chain, the proposed models are applied to the chain of an Iranian tire manufacturer. Modeling parameters are predominantly drawn from the relevant literature.	The 3D printing technology promises a brighter future for the tire supply chain as it can help improve the overall dynamics of the chain by eliminating some stages of the chain and highlighting the role of retreading in the tire industry. The results suggest that the productivity of the supply chain with the 3D printing is less sensitive to the management's risk-seeking level, compared to traditional production. The profit of 3D printing CLSC could be 51–61% greater than that of the traditional CLSC.	Extensive sensitivity analysis can be further conducted to understand how model outputs vary with changing input parameters.	tyre supply chain sustainability	3D printing; Economic impact analysis; Environmental impact assessment; Mixed integer linear programming; Supply chain; Tire production.	new technologies to reach sustainability
MEDIUM	6	Yasmin S.; Devi, G. Shree.	Indian	2023	**Blockchain and Cloud-based Technology in Automotive Supply Chain**	*Proceedings - 5th International Conference on Smart Systems and Inventive Technology, ICSSIT 2024*	0	Pages 771 - 775	Look into the nature of Blockchain adoption in automotive sector, examining the extent of blockchain integration in the supply chain of the Indian automotive industry.	survey	Questionnaire-based survey conducted through a Google Form based questionnaire over 75 company executives of automobile sector in India.	The study has concluded that the level of blockchain technology acceptance in Indian automotive sector is quite impressive. Not only in the mainstream production process, but also in the supply chain encompassing the suppliers and transporters, the usage of blockchain technology is widespread acknowledged. The customer services also embraces cloudbased Blockchain services to a greater extent.	Further studies on cloud integration for blockchain, that needs to be more sophisticated and gain industry-wide acceptance. The average SSCP scores of 3.88 to 4.04, resulting from the model, highlights the capability of the organizations of achieving sustainability in embracing Blockchain Technology.	sustainability supply chain automotive sector	Automotive sector; Blockchain Technology; Cloud services; Cryptography; Supply Chain; Sustainability.	new technologies to reach sustainability
HIGH	7	Esfahbodi, Ali; Zhang, Yufeng; Liu, Yang; Geng, Duanyang.	English	2023	**The fallacy of profitable green supply chains: The role of green information systems (GIS) in attenuating the sustainability trade-offs**	*International Journal of Production Economics*	2	Volume 255, Article number 108703	This study aims to ascertain whether the GSCM implementation yields sustainability–profitability trade-offs and examine the moderating effects of green information systems (GIS) on performance improvements in the UK automotive industry.	survey	Survey information was gathered from 189 UK automotive companies, and moderated hierarchical regression was used to analyze the results.	This study empirically assessed the impacts of GSCM implementation on performance improvements. Result show that while GSCM practices yield improvements in environmental performance, not all sustainability initiatives pay off across the supply chain. For example, is found that eco-design and green logistics has a negative effect on economic performance. --> Contrary to a general assumption in the GSCM literature that often overemphasizes the 'easy wins', it is contended that pursuing SC environmentally-related initiatives can bring trade-offs into play in terms of sustainability versus profitability.	Future research may examine and extend this theoretical framework beyond the automotive industry and even in other contexts, incorporating also the social dimension of sustainability, whoch in this study is neglected.	automotive supply chain sustainability practises	Green information systems (GIS); Green supply chain management (GSCM); Sustainability trade-offs; UK Automotive industry.	GSCM & green practises

RELEVANCE	ID	AUTHOR(S)	AUTHOR'S NATIONALITY	YEAR OF PUBLICATION	TITLE	PAPER	N° CITATIONS	VOL, N° PAGES	OBJECTIVES	METHODOLOGY	INPUT DATA	RESULTS	FUTURE RESEARCH	KEYWORDS USED	AUTHORS KEYWORDS	CLASS
VERY HIGH	8	Kazancoglu, Ipek; Ozbiltekin-Pala, Melisa; Mangla, Sachin Kumar; Kumar, Ajay; Kazancoglu, Yigit.	Turkish	2023	**Using emerging technologies to improve the sustainability and resilience of supply chains in a fuzzy environment in the context of COVID-19**	*Annals of Operations Research*	6	Volume 322, Issue 1, Pages 217 - 240	Aims to identify the problematic areas encountered in building a resilient and sustainable supply chain in the pre-COVID-19 era and during COVID-19, and to offer solutions to those problematic areas tackled by an appropriate emerging technology. This research has been contextualized in the Turkish automotive industry.	case study	Through literature review and expert opinions has been identified the prolem areas encountered in SSCM pre and during COVID pandemic Six problematic areas related to sustainable and resilient supply chains were determined: Inventory Management, Optimization in Logistics Operations, Purchasing Process Planning, Demand Planning and Production Management, SC Traceability and Top Management Support. Different AI driven technologies are taken into account: ant colony optimization algorithms, machine learning, artificial neural network, data clustering. With DEMATEL method, a cause-effect mode has been built.	Inventory management and optimization of logistics operation are just some of the important problematic areas encountered in SSCM. With the help of AI, visibility, simultaneous tracking and planning can be included in stock management. Among the five listed AI technologies, machine learning and the ant colony optimization algorithm are technologies that can be used for optimization in logistics operations. AI driven technologies to the listed problematic areas to improve the overall sustainability and resilience of supply chains.	Further researches, maye in a different country and sector. Since AI driven technologies are a relatively new topic, there is a lack of in-depth literature, so maybe for future researches there will be for sure more material to work with.	automotive supply chain sustainability practises	Artificial intelligence; Decision support system; Emerging technologies; Resilience; Sustainable supply chain.	new technologies to reach sustainability
VERY HIGH	9	Vaz, Caroline Rodrigues; Shoeninger Rauen, Tania Regina; Rojas Lezana, álvaro Guillermo.	Brazilian	2017	**Sustainability and innovation in the automotive sector: A structured content analysis**	tainability (Switzerla	43	Volume 9, Issue 6 - Article number 880	This study aims to analyse the scientific literature on sustainability and innovation in the automotive sector in the last 13 years.	literature review	The most relevant articles, authors, keywords, countries, research centers and journals for the subject from 2004 to 2016 in the Industrial Engineering domain.	The selected studies show that environmental practices employed in the automotive sector are: the minimization of greenhouse gas emissions, life-cycle assessment, cleaner production, reverse logistics and eco-innovation.	Empirical future studies in automotive companies on the environmental practices employed and how these practices impact innovation.	sustainability in automotive sector	automotive industry; Innovation; Sustainability.	GSCM & green practises
VERY HIGH	10	Dominik Jasinski; James Meredith; Kerry Kirwan.	Polish	2011	**Sustainable development model for measuring and managing sustainability in the automotive sector**	*stainable Developme*	12	Volume 29, Issue 6, Pages 1123 - 1137	Analysis of the AutomotiveSustainability Assessment Model (A-SAM) that distinguishes three major areas of sustainability: economic, environmental, and social (TBL).	optimization model	Articles and publications that can be found in the references. There is a broad range of sustainability assessment methods and tools in the literature. Amongst these, only sustainability accounting, also known as Environmental Management Accounting (EMA), tools have the ability to provide monetized sustainability information. EMA encompasses the following five principal tools and systems: Life-Cycle Costing(LCC), Full Cost Accounting (FCA), Cost–Benefit Analysis (CBA), Balanced Scorecard for Sustainability (BSS), and Material Flow Cost Accounting (MFCA). These five EMA tools were evaluated against previously defined design attributes.	Out of five EMA technologies, only the FullCostAccounting method met all four attributes and so was potentially an attractive option to form a structure for the automotive sustainability assessment. The comparison of the FCA methods suggested the Sustainability Assessment Model (SAM) as the most complete FCA approach available in the literature This study has proved, using real-world data, an innovative model named the A-SAM to drive sustainable decision-making in the automotive sector. The model measures and translates a broad range of sustainability effects (both internal and external) into their monetary equivalents, enabling large car manufacturers to evaluate options, identify win–wins, and optimize trade-off, while making complex and sustainable decisions	Further analysis about applying the SAM model to other sectors, since can be adapted in organizations of any type to manage sustainability in a more comprehensive and integrated manner.	sustainability in automotive sector	automotive industry; business sustainability; sustainability assessment; sustainable development.	GSCM & green practises
MEDIUM	11	Lemtaoui, Morad; El Oueldrhiri, Sara.	Moroccan	2019	**Reverse supply chain practices in the Moroccan automotive industry: An exploratory study**	*International Colloquium on Logistics and Supply Chain Management, LOGISTIQUA 2019*	2	Article number 8907276	Investigate the impacts of Reverse Supply Chain management (RSC) on business performance in the Moroccan automotive sector. Describing the practices of the RSC, the decision-making factors that lead to the implementation of RSC and finally the impacts of the RSC on performance.	survey	The survey lasted from April 2018 to September 2018. Most respondents were interviewed face-to-face on the site of the company.	The implementation of RSC depends on several internal and external factors, but the attitude of management remains the most important catalyst. For companies with a reactive attitude, green practices are a burden. These companies therefore only respond where necessary and in the most basic way possible, in accordance with the legislation. However, companies with a proactive attitude consider RSC practices as a way of creating value for the company.	Further research should explore how companies could use their RSC initiatives as a source of competitive advantage. The results of this study could be useful for companies operating in the automotive sector elsewhere than in Morocco.	automotive supply chain sustainability practises	Decision-making factors; Performance; Qualitative study; RSC; RSC practices.	GSCM & green practises
HIGH	12	Vanalle, Rosangela Maria; Santos, Leandro Blanco.	Brazilian	2014	**Green supply chain management in Brazilian automotive sector**	*Management of Environmental Quality: An International Journal*	29	Volume 25, Issue 5, Pages 523 - 541	Identify and analyse the most valued practices of sustainability, as well as factors related to environmental, financial, and operational performance considered in the process of selecting and developing suppliers to members of supply chains in the Brazilian automotive sector.	literature review	The instrument used for data collection was a questionnaire, based in research of Zhu et al. (2007, 2008, 2010) and Ninlawan et al. (2010).	The results of this survey indicated that the practices most valued by businesses in the automotive supply chain located in the ABC region involve eliminating or reducing the use of hazardous substances. These practices are evaluated in the selection of suppliers. Another practice valued by companies is the monitoring and reduction of the generation of hazardous waste and industrial effluents. The involvement of suppliers in the stages of design, monitoring, and reducing the consumption of natural resources and customers' cooperation for cleaner production and lean practices are also valued in the internal management of companies.	Future research can investigate automakers' requirements of suppliers in its supply chain in terms of sustainability and the actions of suppliers to meet these requirements.	sustainable supply chain automotive	Automotive industry; Performance; Selection suppliers; Supply chain; Sustainable practices.	sustainable supplier development
MEDIUM	13	Ayan, Büşra; Güner, Elif; Son-Turan, Semen.	Turkish	2022	**Blockchain Technology and Sustainability in Supply Chains and a Closer Look at Different Industries: A Mixed Method Approach**	*Logistics*	1	Volume 6, Issue 4	This study presents a comprehensive review of blockchain technology with a sustainability orientation in supply chains and logistics in different sectors, including the automotive.	literature review	The publications are extracted from the Scopus and Web of Science databases, comprising 552 publications between 2017 and 2022.	Integrating blockchain increases item traceability and decreases waiting times, increasing supply chain operating efficiency. In terms of raw material traceability, information monitoring, immutability, and cost savings, blockchain has paved the way for the sustainable growth of the automotive supply chain	Identify the many obstacles that are delaying the diffusion of blockchhain inn the automotive sector as lack of digitization in the supply chain, security issues, difficulty in combining existing software, and procedures with the blockchain structure.	sustainable supply chain automotive	bibliometric analysis; biblioshiny; blockchain; Bradford's law; content analysis; logistics; Lotka's law; supply chains; sustainability; thematic map; three-field analysis.	new technologies to reach sustainability
HIGH	14	Sonar, Harshad; Mukherjee, Ayon; Gunasekaran, Angappa; Singh, Rajesh Kr.	Indian	2022	**Sustainable supply chain management of automotive sector in context to the circular economy: A strategic framework**	*Business Strategy and the Environment*	4	Volume 31, Issue 7, Pages 3635 - 3648	Identify and prioritize the barriers of sustainability in the automotive supply chain, with a focus on India automotive sector and to develop the cause–effect relationship between them.	survey + systematic analysis (DEMATEL methodology + interpretive structural modelling" ISM method)	10 barriers have been identified with literature support and expert opinions. The ISM-decision-making trial and evaluation laboratory method (DEMATEL) method was used to develop the causal relationship between the barriers.	From the ISM model, lack of top management commitment is at the bottom of the hierarchy, with high driving power. Continuous and uninterpreted management commitment is necessary to achieve sustainability practices in supply chains. Management should establish a proper action plan to implement sustainability practices based on priority rankings of various barriers.	Future work may also be carried out to validate the existing results with different analytical methods as AHP, TOPSIS, SEM. Further, the study can explore more barriers and validate them also in other sector.	sustainability automotive logistics	automotive; barriers; circular economy; DEMATEL; ISM; strategic framework; supply chain; sustainability.	closed-loop supply chain

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MEDIUM	15	Gabriela Scur; Claudia Mattos; Wilson Hilsdorf; Marcelo Armelin.	Brazilian	2022	**Lead Acid Batteries (LABs) Closed-Loop Supply Chain: The Brazilian Case**	*Batteries*	0	Volume 8, Issue 10	Analyze the relationships between the actors in the lead acid battery chain and identify the mechanisms that induce recycling programs, and to propose an explanatory framework. The study contributes to the consolidation of the triple bottom line concepts in the lead acid battery production chain for automotive.	case study	Through an exploratory study of multiple cases, the Brazilian lead-based vehicle battery chain has been analyzed by investigating two main manufacturers, two recycling companies, and eight distributors/retailers.	It was possible to create a framework depicting how the closed-loop supply chain of batteries works in practice, from the perspective of TBL (environmental, social and economic aspect).	Externalities aren't involved in these annalysis. Therefore, it is suggested that future research analyze in depth the implementation of these programs seeking to mitigate risks.	sustainability automotive logistics	automotive industry; closed-loop supply chain; LABs; lead acid batteries; triple bottom line.	closed-loop supply chain
HIGH	16	Ghadge, Abhijeet; Mogale D.G.; Bourlakis, Michael; M. Maiyar, Lohithaksha; Moradlou, Hamid.	English	2022	**Link between Industry 4.0 and green supply chain management: Evidence from the automotive industry**	*Computers and Industrial Engineering*	14	Volume 169, Article number 108303	This study attempts to close the research gap by empirically assessing the link between two paradigm, the Industry 4.0 and sustainability performance.	survey	243 questionnaire survey responses from European automotive supply chain managers were used to test the developed hypotheses. An integrated, two-stage approach combining ISM and SEM is utilized to develop a multi-level hierarchical structure for investigating the link between Industry 4.0, Green Supply Chain practices and GSC performance.	Industry 4.0 technologies will positively improve GSC performance metrics and, therefore, provide evidence that the technologies of Industry 4.0 will assist organizations in transitioning towards sustainable development.	The data were mostly collected in developed countries (Europe and UK), the following research could benefit from a larger sample size, starting from the geographical area, capturing the perspective of automotive sectors in developing and under-developed countries	sustainable supply chain automotive	Automotive industry; Blockchain; Cyber-Physical Systems; Green practices; Green supply chain management; Industry 4.0; Internet of Things; Sustainability.	new technologies to reach sustainability
LOW	17	Jiri Cee; Oleksii Dieiev; David Holman; Radim Lenort; David Stas; Pavel Wicher.	Czech	2016	**System oriented Sustainable Supply Chain Management innovations in automotive industry - SKODA auto case study**	*Communications - Scientific Letters of the University of Žilina*	3	Volume 18, Issue 3, Pages 54 - 59	The aim of the article is to research and define the fundamental principles of system oriented innovations utilized in the Sustainable Supply Chain Management of automotive industry. The case study is focused on inbound logistics flow of SCM at SKODA.	case study	Literature review analysis of the problems regarding the original delivery concepts in inbound logistics at SKODA.	To deal with the problems, SKODA AUTO developed the EDM (Efficient, Electronic, and Ecology Delivery Concept), oriented to make interactions in the SSCM efficiently, quickly, smoothly and environmentally friendly. Logistics expenses, including fuel and pallets costs, reduced by 25% in comparison with the existing system, expenses on material inventories and associated with logistics space lowered by 55%, and CO2 emissions reduced by 50% through the use of CNG are just the main benefits of EDC theory.	/	sustainable supply chain automotive	Automotive industry; Innovations; Sustainable Supply Chain Management; System thinking.	GSCM & green practises
HIGH	18	Tarinee Buadit; Achara Ussawarujikulchai; Krisda Suchiva; Seksan Papong; Hwong-wen Ma; Cheerawit Rattanapan.	Thailandese	2023	**Environmental impact of passenger car tire supply chain in Thailand using the life cycle assessment method**	*Sustainable Production and Consumption*	0	Volume 37, May 2023, Pages 156-168	From a systematic literature review of a life cycle assessr	Life Cycle Assessment analysis	30 relevant studies carried out from 1999 to 2020 analyzinng the five steps for the life cycle assessment of the automotive tire supply chain comprise raw material acquisition, tire production, transportation, use, and disposal of scrap tires. A life cycle assessment of the Thai tire supply chain was performed in 4 processes, including raw materials acquisition, production process, use stage, and two waste tire management methods, pyrolysis (thermochemical decomposition) and reclaimed rubber.	Throughout the supply chain of one passenger car tire, the utilization phase is responsible for the highest impact in the entire life cycle. Fuel consumption in the usage phase was determined to be the most destructive, particularly in terms of global warming, the scarcity of fossil fuels, and the toxicity of terrestrial ecosystems. When comparing burden throughout the supply chain of both approaches was comparable, except in terres-trial ecotoxicity and water consumption, in which the reclaimed material produced a better outcome. -->The priority should be to focus on the stage of tire use as much as possible to minimize the impact, which is possible through the research and development of a new tire model to reduce gasoline consumption and discharge less air pollution.	Further researches on how recycling scrap tires for use as a raw material in tire production or other forms of production can encourage the circular economy concept and drive the tire supply chain to a better sustainability.	sustainable supply chain automotive	Environmental impact assessment; Life cycle assessment; Tire supply chain.	closed-loop supply chain
HIGH	19	Azevedo, Susana; Barros, Miguel.	English	2017	**The application of the triple bottom line approach to sustainability assessment: The case study of the UK automotive supply chain**	*Journal of Industrial Engineering and Management*	16	Volume 10, Issue 2Special Issue, Pages 286 - 322	Assess the level of sustainability of the UK automotive supply chain considering simultaneously the three dimensions of sustainability representing the Triple Bottom Line (TBL) approach, using the Simple Additive Weighting (SAW) method to aggregate economic, environmental and social indicators into a unique index.	simulation model	Sustainability reports of the UK' automotive companies from 1999 to 2014.	The study displays that the economic sustainability index presents a growing trend, mainly after 2010. The behaviour of the economic sustainability could be explained by governments policies, after the reduction in car sales after 2007, that introduced new temporary measures, including subsidised credit facilities and bonuses for replacing old cars by new cars and in return, governments have sometimes required the production of more energy-efficient cars.	A case study considering several companies from different industries is the recommended next step.	TBL automotive components	Automotive industry; Composite index; Framework; Supply chain; Sustainability.	GSCM & green practises
HIGH	20	Demir, Sercan; Gunduz, Mehmet Akif; Kayikci, Yasanur; Paksoy, Turan.	Turkish	2022	**Readiness and Maturity of Smart and Sustainable Supply Chains: A Model Proposal**	*EMJ - Engineering Management Journal*	1	/	The literature review so far reveals that no readiness and maturity model covers sustainability and smart systems together. Therefore, it's proposed a novel model, "S3RM" (Smart and Sustainable Supply chain Readiness and Maturity), to fill up this research gap.	simulation model	New model proposed titled "Smart and Sustainable Supply chain Readiness and Maturity model (S3RM)" and validate it by conducting a case study in the automotive industry. The data is collected by conducting interviews with operational managers in the facility of ABC company, while readiness and maturity scores are measured by using five-point Likert scales. Each sub-dimension of the smartness dimension and the sustainability dimension consists of questionnaire items.	Adaptability and environmental are the weakest sub-dimensions within the smartness and sustainability dimensions, respectively. For instance, the environmental sub-dimension is the most significant threat to sustainability since its readiness and maturity score is the lowest. More specifically, the lack of ecolabels and insufficient renewable energy usage are the impediments to sustain environmentally. -->When comparing the sustainability and smartness dimensions, available evidence indicates that the smartness readiness and maturity average score is lower than the sustainability score, considering smart technologies require more maturity of overall supply chain operations.	Future research activities will extend the case studies to several companies and proposing models reflecting industry-specific dimensions. Future studies might include opinions of multiple decision-makers giving unequal importance to SCM smartness and sustainability by weighting these dimensions with different coefficients. Further research is also needed to incorporate competitors' current states as a benchmarking tool.	TBL automotive components	supply chain management; digitalization; Industry 4.0; organizational & performance assessment; readiness and Maturity Model; smart and Sustainable Supply Chains; smartness; strategic management; sustainability; Technology management.	new technologies to reach sustainability
HIGH	21	B. J. Jody; Joseph A. Pomykala, Jr.; Jeffrey S. Spangenberger; E. J. Daniels.	American	2009	**Impact of Recycling Automotive Lightweighting Materials on Sustainability**	*SAE Technical Papers*	0	/	In order to reduce its energy consumption and greenhouse emissions the industry is using more lightweighting materials in manufacturing its products. This paper discusses technical, economic and societal issues associated with recycling of automotive materials.	literature review	Various articles and chapters, can be found in t	More lightweighting metals are expected to replace more of the conventional steel and iron in the vehicles. Composites are also making they way into vehicles and their use is likely to increase. Lightweighting of the vehicles reduces their fuel consumption. Recycling of the lightweighting materials is necessary to maintain the high recyclability of the vehicles. Recycling of materials from end-of-life objects saves energy, reduces pollution and conserves the world's limited resources.	Further studies on what is lacking about technology that will allow the recovery, purification and recycle of materials more efficiently and more economically.	just in time material sustainable automotive	Automotive industry; Energy utilization; Environmental impact; Greenhouses; Hybrid vehicles; Recycling; Sustainable development.	new technologies to reach sustainability

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MEDIUM	22	Marco Ravina; Isabella Bianco; Barara Ruffino; Marta Minardi; Deborah Panepinto; Mariachiara Zanetti.	Italian	2023	**Hard-to-recycle plastics in the automotive sector: economic, environmental and technical analyses of possible actions.**	*Journal of Cleaner Production*	0	Volume 394	The use of plastics in the automotive industry is favoured by the relatively low cost of production which further discourages their recycling. The objective of this study is to contribute to the identification of best practices to increase the recovery rate of plastic materials from end-of-life vehicles.	Life Cycle Assessment analysis	Literature review based on various publications that can be found in the references.	The main conclusion of this study is that improving the environmental compatibility of plastics recycling processes in the automotive sector is a valid approach not only for reducing GHG emissions but also for achieving EU recovery targets.	The cost analyses were has been carried out based on a limited set of dismantling tests, including only B-segment cars. Further analyses should include other segments	just in time material sustainable automotive	Automotive shredder residues; End-of-life vehicles; LCA; Plastic recycling; Waste valorization.	GSCM & green practises
MEDIUM	23	Pehlken, Alexandra; Baumann, Sabine.	German	2021	**No more flat tires: Overcoming data defects to achieve supply chain resilience**	*2021 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2021 - Proceedings*	0	/	This paper uses the case of tires to explore data defects t	case study	Review of articles and publication that can be found in the references.	Resilience is also contested due to missing or insufficient data which prevents the closing of the recycling loop for scrap tires as a secondary source of the natural raw material. Successful recycling requires knowledge of the exact composition of the scrap rubber products to determine the options and manufacturers do not want to share data on tire composition fully. --> implement better circular economy strategies for scrap tires and keep the material in the loop to reduce the stress on virgin rubber.	Future work is focusing on the interaction between tire manufacturer and the recycler within the tire manufacturing ecosystem, ncluding exploring other technologies such as "smart tires" that will enhance better- nformed recycling decisions and may help increase consumer acceptance for retreated tires.	tyre supply chain sustainability	Blockchain technologies; Circular economy; Digital twin; Natural rubber; Resilient supply chains; Scrap tires; Synthetic rubber; Tire manufacturing.	new technologies to reach sustainability
MEDIUM	24	Bhattacharya, Sourabh; Kalakbandi, Vinay Kumar.	Indian	2022	**Barriers to circular supply chain: the case of unorganized tire retreading in India**	*International Journal of Logistics Management*	1	/	This study emphasizes the importance of further investigating the potential role of the unorganized sector in fostering the transition to a CE in emerging economies. Based on the gaps identified in the literature, this study investigates the barriers to CE adoption in the unorganized tire retreading industry in India.	survey (interviews with 23 tire retreaders across 15 cities and 8 states of India)	The data were collected by conducting semi-structured interviews during our interaction with tire retreaders.	Ten critical barriers influencing the retreader's business growth has identified and a theoretical framework that explains the interrelationship between the barriers has been developed, identifying the most influential barriers.	Further researches on the the relationship between OTMs and retreaders: with the retreader assuming the role of customer, employee, investor, or business partner of the OTM.	tyre supply chain sustainability	Circular economy; Circular supply chain; India; Sustainable supply chain; Tire retreading industry; Unorganized sector.	closed-loop supply chain
MEDIUM	25	Basu R, Jothi; Abdulrahman, Muhammad D.; Yuvaraj M.	Indian	2023	**Improving agility and resilience of automotive spares supply chain: The additive manufacturing enabled truck model**	*Socio-Economic Planning Sciences*	4	Volume 85	The aim is to improve resilience of the automotive spare parts supply chain by proposing a Viable Supply Chain (VSC) framework design that incorporates Additive Manufacturing enabled trucks in the automotive spares supply chain network.	simulation model	Recent literature on implementation of AM in Supply Chain. A new framework is proposed for the ASPs supply chain using AM and based on the viable supply chain model which provides agility, resilience, and sustainability to the supply chain structure	The study showed how the addition of a network of AM enabled trucks into the existing conventional network can help ASPs supply chain to achieve agility, responsiveness, resilience, and sustainability and evolve as a Viable Supply Chain model.	Future researches to investigate the problem of real-time routing of a given AM-enabled truck where the total number of customers to be served is not fixed but may change while delivering orders.	sustainable supply chain automotive sector	Additive manufacturing; Automotive spares; Online platform; Routing and Scheduling; Supply chain resilience; Viable supply chain.	new technologies to reach sustainability
HIGH	26	Govindan, Kannan; Azevedo, Susana G.; Carvalho, Helena; Cruz-Machado V.	Portuguese	2014	**Impact of supply chain management practices on sustainability**	*Journal of Cleaner Production*	215	Volume 85, Pages 212 - 225	This study aims to propose a conceptual model to analyze the impact of lean, resilient and green SCM practices on SC sustainability.	case study	Eighteen research propositions are suggested and tested with empirical data derived from five case studies, based on a semi-structured interview to obtain the perception of the Portuguese automotive company professional regarding the impact of the focused SCM practices on SC sustainability. A conceptual model is then built.	Based on data obtained from five case studies of Portuguese companies belonging to the automotive SC, it was found that not all the lean, resilient and green SCM practices have significant impact on the SCs sustainability. Summing up, according to the literature review and also the case study approach, the lean, resilient and green SCM practices with significant impact on SC sustainability are: "waste elimination," "supply chain risk management" and "cleaner production."	It will also be interesting to perform the same study in the automotive supply chain sited in developing countries (ex. Brazil, China, India) and compare both results. The automotive industry in developing countries presents different characteristics, such as: capital-intensive, lack manufacturing and design technology, related industries are weak, and capital investment in production, marketing, and R&D activities is limited	automotive supply chain sustainability	Case study; Green; Lean; Resilient; Supply chain; Sustainability.	GSCM & green practises
HIGH	27	Pinho Santos, Liane; Proença, João F.	Portuguese	2022	**Developing Return Supply Chain: A Research on the Automotive Supply Chain**	tainability (Switzerla	5	Volume 14, Issue 11, Article number 6587	The purpose of this study is to investigate and discuss the barriers and solutions to developing return supply chain policies in the automotive industry.	literature review	Bibliometric analysis about subjects related to sustainable supply chains in the automotive industry in the Web of Science (WoS) database.	Inhibitors and enhancers of Return Supply Chain have been found: Inhibitors, as procastination and resistance to change, and enhancers for development such as innovation strategy, strategic alliances, and governmental policies that force companies to become more sustainable in several processes.	For further research investigate into the internal and external influences for the application of sustainability in companies. More studies are needed on innovation in recycling processes.	automotive supply chain sustainability	automotive supply chain; closed-loop supply chain; cradle-to-cradle supply chain; sustainability.	closed-loop supply chain
MEDIUM	28	Gupta, Chandra Prakash; Patel, Ashlesh Ramanbhai.	Indian	2022	**Sustainable Supply Chain for Automotive Industry**	*IEEE Region 10 Humanitarian Technology Conference, R10-HTC*	0	Volume 2022-September, Pages 155 - 160	The article aim is to show how the three areas of sustainability (Environment, Material, and Humankind.) can be integrated and can be the way toward a sustainable supply chain. (automotive industry has been taken as an example).	simulation model	Through the article, 6 ways of how the vehicle industry is owering greenhouse gas emissions are examined. The article focuses on sustainable ambitions that comprehensively cover three areas: Environment, Material, and Humankind. It includes the research and methodologies that have been followed to date for these three areas but in silos.	The proposed framework is that it must be defined and planned at the micro-level. For instance, annual targets that are consistent with long-term objectives, assessing current year performance on sustainability, and then revising tactics for the following year.	Further research to replicate the approach to any industry.	automotive supply chain sustainability	automotive industry; carbon footprint; circular economy; net-zero value chain; Sustainable supply chain.	closed-loop supply chain
HIGH	29	Bartos, Kristina Encinas; Schwarzkopf, Julia; Mueller, Martin; Hofmann-Stoelting, Christina.	German	2022	**Explanatory factors for variation in supplier sustainability performance in the automotive sector – A quantitative analysis**	*Cleaner Logistics and Supply Chain*	4	Volume 5, Article number 100068	Few articles have considered company data to analyze reported supplier sustainability performance (SSP) and explanatory factors for potential differences across certain groups of suppliers. The objective is to identify patterns in SSP to derive conclusions for automotive firms' sustainable supply chain management.	survey	Self-assessment questionnaire structured in the following six sections: Company Management (CM), Working Conditions and Human Rights (WCHR), Business Ethics (BE), Environment (E), Supplier Management (SM) and Responsible Sourcing of Raw Materials (RM). After completing the SAQ, suppliers obtain an overall score as well as sub-category scores.	It has been analyzed SSP varies depending on the size of the company measured by its headcount, geographical position, and the business category. The results support the hypotheses that suppliers' sustainability performances increase with their headcount and that manufacturing suppliers perform significantly better than service providers.	/	automotive supply chain sustainability	Automotive; Self-assessment tool; Supplier sustainability performance; Sustainability requirements; Sustainable supply chain management.	sustainable supplier development
HIGH	30	Hąbek, Patrycja; Lavios, Juan J.; Krupah, Edward.	English	2022	**How car producers are driving toward sustainable supplier development**	*Production Engineering Archives*	1	Volume 28, Issue 3, Pages 268 - 278	To study the sustainable supplier development practices of 6 european car producers (BMW, Daimler, Stellantis, PSA, Volkswagen, Volvo), a content analysis method has been applied. The aim is to present how car producers are responding to the challenge of improving their sustainability performance by incorporating sustainability into supplier development process.	literature review	Data was collected from the sustainability/CSR reports of six car producers located in European Union member state, downloaded from Global Reporting Initiative database (of 2020). Additional information was retrieved from the car producer's codes of conduct and from their supplier portal.	The analysis enable us to find out how the car producers are acting toward sustainable supplier development and the most important trends.	Future research on the efficiency of different types of sustainable supplier development activities to answer the question which practices are the most beneficial for both suppliers and buying companies.	automotive supply chain sustainability	automotive; CSR report; supplier development; sustainability.	sustainable supplier development