

## The importance of Reverse Logistics and Green Logistics for Sustainability in Supply Chains

La importancia de la Logística Inversa y de la Logística Verde para la sostenibilidad en las Cadenas de Suministro

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### ABSTRACT

Production and consumption practices that follow the "take-make-dispose" flow have had a negative impact on the environment over time. Global waste problems are alarming for the environment. Over time, these problems will become more serious and will require special attention. In this regard, reverse and green logistics are very timely and critical areas for achieving sustainable development, as well as meeting some of the targets set out in the Sustainable Development Goals (SDGs). However, the current literature on reverse logistics, green logistics and sustainability are scattered. Therefore, in this article we aim to review the state of recent literature (2018 - 2021), with a focus on applications in different industrial sectors. It was observed that although the application of reverse logistics, green logistics principles are sustainable, there are barriers to their implementation among which include lack of top

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Page 46-72

management commitment, lack of strategic plan to implement reverse and green logistics activities, lack of marketing strategy for remanufactured products and secondary market. This review may be of interest to industry policy makers.

**Keywords:** Reverse logistics; green logistics; sustainability; SDGs.

## RESUMEN

Las prácticas de producción y consumo que siguen el flujo de "tomar-hacer-desechar" han tenido un impacto negativo en el medio ambiente a lo largo del tiempo. Los problemas mundiales de residuos son alarmantes para el medio ambiente. Con el tiempo, estos problemas se volverán más serios y requerirán una atención especial. En este sentido, la logística inversa y verde son áreas muy oportunas y críticas para lograr el desarrollo sostenible, así como para cumplir con algunas de las metas establecidas en los Objetivos de Desarrollo Sostenibles (ODS). No obstante, la literatura actual sobre logística inversa, logística verde y sustentabilidad están dispersos. Por ello, en este artículo pretendemos revisar el estado de la literatura reciente (2018 – 2021), con un enfoque en las aplicaciones en distintos sectores industriales. Se observó que, aunque la aplicación de los principios de logística inversa, logística verde son sustentables, existen barreras para su implementación entre las cuales se incluyen la falta de compromiso de la alta gerencia, falta de plan estratégico para implementar actividades de logística inversa y verde, falta de estrategia de marketing para productos remanufacturados y mercado secundario. Esta revisión puede ser de interés para los responsables de formulación de políticas de la industria.

**Palabras clave:** Logística inversa; logística verde; sustentabilidad; ODS.

## INTRODUCTION

Logistics aims to implement a set of decisions that include the purchase of raw materials, parts and components, the handling and storage of inventories, and the transportation of goods from one place to another (Zhang et al., 2022). The effectiveness and efficiency of the logistics system largely determine a company's performance in costs, customer satisfaction, and profitability.

However, rapid industrialization and population growth have led to an increase in the production and consumption of a wide variety of products. This fact is considered to be due to unplanned industrialization, whereby human life and the natural environment are affected by energy waste and pollution (Khan Sharif, et al., 2019; Zhang et al., 2022).

The generation of enormous waste causes substantial damage to the planet (Prajapati et al., 2019). Moreover, logistics activities mainly depend on the transportation of goods, which consumes a lot of non-renewable energy. In the context of the global supply chain, the demand for energy becomes larger and larger. On the other hand, the use of fossil fuels (e.g., coal, natural gas, and oil) will release a large amount of carbon dioxide and toxic gases, which will cause greenhouse effects and endanger human health (Khan Sharif, et al., 2019).

Environmental disruption, government policies, sustainability, market globalization, warranty returns, end-of-life components, among other factors, have led to the recognition and adoption of reverse logistics practices (Chileshe et al., 2018; Vienažindienė et al., 2021).

Based on the American Reverse Logistics Executive Council, reverse logistics is defined as "The process of planning, implementing, and controlling the efficient and cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recovering value or proper disposal." (Vienažindienė et al., 2021).

In other words, reverse logistics seeks to ecologically evaluate products at the end of their useful life and to make this as environmentally friendly as possible (Chileshe et al., 2018).

According to Prajapati et al., (2019), reverse logistics is the driving force behind circular material flows, as they promote the return of products to the supply chain for value extraction. On the other hand, the sustainable supply chain concept presents an

integrated approach that considers that direct and reverse supply chains are fulfilled simultaneously (Scavarda et al., 2019)..

Green logistics is concerned with producing and distributing goods in a sustainable manner, taking into account environmental and social factors (Viennažindienė et al., 2021).. Therefore, the objectives set out in the principles of green logistics are not only concerned with the economic impact of logistics policies on the organization that implements them, but also with the broader effects on society, such as the effects of pollution on the environment (Khan, Sharif, et al., 2019)..

Green logistics activities include measuring the environmental impact of different distribution strategies, reducing energy use in logistics activities, reducing waste and managing its treatment (Khan, Jian, et al., 2019; Liu et al., 2018; Vienažindienė et al., 2021)..

Improving environmental performance is a key way in which companies can improve their corporate social responsibility and brand image. (Al-Minhas et al., 2020)..

This research aims to review the state of the literature related to reverse logistics, green logistics and sustainability produced during the last 4 years, focusing on application cases and barriers to their application in the industry.

## MATERIALS AND METHODS

A literature search was conducted on studies based on the strategies and experiences acquired by different industrial sectors regarding the application of reverse logistics, green logistics and sustainability. Table I shows the selection process.

**Table I.** *Analysis of scientific articles for review*

Stages of the process	Document selection criteria	Result
Key words in the Scopus search engine	The keywords applied to the search engine were "Reverse logistics", "Green logistics" and "Sustainability". These words were applied with the "AND" operator in the Scopus search engine. Only literature published in English was considered, from 2018 to 2022.	51

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Exclusion of articles focused on other areas and document type	Articles referring to other areas of research were excluded. Research and review articles were selected.	30
Relevance	The abstract and methodology of each study were reviewed. Those that were not considered related to this research were discarded.	20

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This article is organized as follows: The first section of this article reviewed the principles of traditional logistics, its global impact and new trends. The second section deals with the characteristics, barriers and application of reverse logistics.

The third section deals with the application and barriers to the implementation of green logistics.

Finally, the importance of sustainability in logistics was analyzed, as well as its barriers and challenges

## RESULTS

Logistics (or traditional logistics) is a process of strategically managing the acquisition, movement, and storage of materials, parts, and finished products (and the related flow of information) through organizations and their marketing channels (Sureeyatanapas et al., 2018; Wijewickrama et al., 2021).

On the one hand, logistics development can promote economic growth, but on the other hand, it will have a negative impact on the environment and energy. Global procurement requires large investment in transportation and long delivery time, which seriously affects environmental sustainability (Plaza-Úbeda et al., 2021)..

The logistics system is generally claimed to be one of the main contributors to the overall greenhouse gas (GHG) emission and energy consumption in the world (Khan, Jian, et al., 2019; Liu et al., 2018; Sureeyatanapas et al., 2018; Vienažindienė et al., 2021)..

Transportation caused almost 22% of global carbon dioxide emissions according to the United Nations, and will increase to 60% by 2050 without environmental protection measures (Khan, Sharif, et al., 2019; Srivastav et al., 2019). According to Eurostat, the transport sector is responsible for 24% of CO<sub>2</sub> emissions in Europe, and road transport is the main source of this (Liu et al., 2018).

In addition, the transportation industry is mainly dependent on oil and fossil fuels because their consumption accounts for 96% of all energy demand.

Excessive energy consumption exacerbates greenhouse gas (GHG) emissions, in addition to increasing energy demand.

In recent years, there has been increasing concern about the environmental effects of human activity on the planet and current logistics practices may not be sustainable in the long term (Sureeyatanapas et al., 2018).

The issues of climate change and emissions reduction have been a focus of international organizations and governments around the world for the past several decades (Khan, Sharif, et al., 2019; Waqas et al., 2018)..

Therefore, companies and decision makers pay more and more attention to environmental protection and sustainable development (Larina et al., 2021), and the concept of green logistics emerges.

Logistics is currently undergoing a shift towards greater automation and technology integration, such as the use of drones and autonomous vehicles for delivery, and the implementation of blockchain and artificial intelligence for supply chain management (Chileshe et al., 2018; Plaza-Úbeda et al., 2021)..

In addition, the current COVID-19 pandemic has accelerated the shift to e-commerce and contactless delivery, further driving the need for efficient and flexible logistics solutions.

Currently, there is a focus on reducing the environmental impact of logistics operations (reverse and green logistics) and sustainability. as the number of publications on the subject has been increasing almost linearly.

Leading manufacturing nations, such as China, the United States and Brazil, demonstrate a high level of interest in developing innovative strategies for sustainable logistics, showing collaborations between countries to drive the development of these new

strategies. The intensity of the blue color refers to the level of collaboration and development in reverse and green logistics. The red lines show the collaboration links.

Reverse logistics is the process of managing the return, disposal and reuse of products and materials. It includes activities such as product return, repair and refurbishment, and end-of-life product disposal, this will depend on the method of product treatment (Prajapati et al., 2019).

In this context, product returns are the most common form of reverse logistics and involve managing the process of receiving and processing goods returned by customers. Repair and refurbishment involves fixing or upgrading products for resale, while end-of-life disposal involves properly disposing of products that cannot be repaired or resold.

The objective of reverse logistics is to minimize waste and maximize the value of products and materials through efficient planning and management.

In reverse logistics, the network structure is mainly composed of consumers, collection centers, treatment plants, and markets (Chileshe et al., 2018; Waqas et al., 2018; Zhang et al., 2022)..

Compared with the other categories of reverse logistics, reverse logistics remanufacturing (RRL) has a different network structure (Zhang et al., 2022). Some RRLs use hybrid facilities that integrate remanufacturing sites with manufacturing sites (Prajapati et al., 2019), or some rely on pick centers within distribution centers (Chileshe et al., 2018).. Different RRL structures have different utilization efficiency of scrap products, which has become a research topic.

Despite the evolution of reverse logistics, many companies still do not appreciate its relevance, but a change in mindset is taking place (Chileshe et al., 2018; Zhang et al., 2022).. Perhaps deeper contact between companies and researchers could be helpful to achieve this kind of management transformation (Prajapati et al., 2019)..

Reverse logistics is undoubtedly a key aspect of sustainable supply chain management and is becoming increasingly important as companies look for ways to reduce their environmental impact and improve their bottom line.

According to Plaza-Úbeda et al., (2021) reverse logistics has the following characteristics:

Reverse of the traditional logistics process: Reverse logistics is the opposite of the traditional logistics process, which focuses on moving products from suppliers to

customers. In reverse logistics, the goal is to move products from customers to suppliers or other locations.

**Complexity:** Reverse logistics is often more complex than traditional logistics, as it involves managing the return of products that may be in different states of preservation, and may require different types of handling and processing.

**Cost:** Reverse logistics can be costly, as it requires additional resources to manage returned products, such as transportation, storage and inspection.

**Recycling and disposal:** Reverse logistics usually involves recycling or disposal of returned products that cannot be resold.

**Compliance:** Reverse logistics may be subject to compliance with regulations and laws regarding the disposal of returned products, depending on the type of products and disposal location.

**Environmental impact:** Reverse logistics can play an important role in reducing environmental impact by recovering and recycling resources, reducing waste and pollution, and conserving energy.

Reverse logistics offers environmental and economic benefits, and can enhance a company's reputation and customer satisfaction by providing efficient and effective return and repair services. However, successfully implementing a reverse logistics program can be challenging and requires careful coordination between different departments and partners, such as suppliers, logistics providers, and repair facilities (Waqas et al., 2018; Zhang et al., 2022)..

In this regard, Prajapati et al., (2019)., developed a study to identify barriers and solutions for reverse logistics implementation, which revealed that Strategic Barriers are the most crucial barriers to implementing reverse logistics, followed by Environmental and Regulatory Barriers, Operational Barriers, Economic Barriers, Technological Barriers and Sociocultural Barriers.

Strategic barriers and operational barriers are related to the way the organization does business, which depends mainly on the management approach to technology adoption. It is concluded that good management guidance is required to address these barriers (Zhang et al., 2022).



On the other hand, Waqas et al., (2018) indicates that The most critical barriers are: high cost of reverse logistics adoption (finance and economics), lack of qualified professionals (knowledge and experience), lack of government support policies (law and regulation), poor organizational culture (management), lack of human resources (infrastructure and technology), lack of awareness of environmental law (environment), lack of community pressure (market) and company policies (reverse logistics in policy). They also indicate that the implementation of reverse logistics is difficult in developing countries.

Reverse logistics has emerged as one of the remedies in the construction industry, whereby most of the demolition waste is returned to the production cycle. In this section, we will review some application cases found in the literature:

Chileshe et al., (2018)., quantified the effects of known drivers on reverse logistics and, in doing so, identified the action items with the greatest potential to positively improve reverse logistics outcomes. In addition, they developed and tested a conceptual model with questionnaire results drawn from 49 expert respondents active in the South Australian construction industry. The results were analyzed using structured equation modeling. This study showed that economic and environmental factors, such as the relatively high cost of recovered items, together with the desirability of cost, time and quality targets that overshadow regulatory demands for the use of such recovered items, predict 34% of the variations in reverse logistics implementation. Therefore, the roadmap for improving reverse logistics performance lies in reducing the costs of recovered materials, increasing environmental policies that promoted their use, and initiating a regulatory framework to generate compliance.

Wijewickrama et al., (2021).found that regulatory uncertainties in the construction industry are the root causes that propagate through incentive and contractual uncertainties to influence quality control in the reverse logistics supply chain. External stakeholders could employ measures such as "reforming regulatory instruments", "employing effective incentive schemes" and "forward supply chain stakeholder involvement" to minimize uncertainties at their source.

In the leather footwear industry, it is possible to recycle and reuse waste, which means that it is possible to implement the principles of reverse logistics, in this sense the system could increase the return on investment and give a competitive advantage (Moktadir et al., 2020)..

Tire waste management is an important aspect of sustainable development due to its environmental, economic and social impacts (Bernal-Figueroa et al., 2021).. According

to Uriarte-Miranda et al., (2018)., key aspects of reverse logistics and green logistics, such as recycling, remanufacturing and reusable packaging, can improve tire waste management and support sustainability. By implementing an effective reverse logistics program, companies can reduce costs, increase revenues, and improve their environmental and social impact.

To optimize the reverse logistics process, companies can use a variety of tools, such as radio frequency identification (RFID), barcode scanning and warehouse management systems to track and manage returned products. Predictive modeling and data analytics can also be used to identify trends in returns and predict future product demand.

In addition, reverse logistics can also play a role in the circular economy, where products and materials are kept in use for as long as possible. This can be achieved by designing products that can be repaired, remanufactured and recycled. Reverse logistics can also be used to recover valuable resources and materials from end-of-life products, such as precious metals, plastics and other valuable raw materials.

Green logistics in supply chain management can be explained as an environmentally beneficial supply chain management system consisting of product design, raw material selection, manufacturing steps, and delivery and preparation of the final product through a stable and sustainable process (Srivastav et al., 2019)..

According to Larina et al., (2021) green logistics is the part of a company's activities aimed at measuring and minimizing the impact of logistics activities on the environment. Such actions are dictated by the possibility of achieving a competitive advantage in the market, because customers require it. Transportation is a particularly important area with a major impact on the environment, as it is identified as the fastest growing source of greenhouse gas emissions (Plaza-Úbeda et al., 2021)..

In this sense, green logistics refers to the environmentally friendly management of the movement and storage of goods and materials. It includes practices such as reducing carbon emissions, using renewable energy sources, and implementing recycling and waste reduction programs. The goal of green logistics is to minimize the environmental impact of supply chain operations while maintaining efficiency and cost-effectiveness. It is therefore an integration of environmental objectives into traditional logistics operations (Sureeyatanapas et al., 2018).

Green transport is an environmentally friendly, low-emission mode of travel. The goals of green transport are not only to reduce greenhouse gas emissions, air pollution, noise,

and space use, but also to reduce poverty and promote economic growth (Khan, Sharif, et al., 2019; Srivastav et al., 2019)..

Green transport is considered when it supports the sustainability of the environment, but also supports the other two pillars of sustainable development, i.e. economic and social (Larina et al., 2021)..

An overall green logistics performance is reflected in a company's ability to protect the environment by conserving natural resources and reducing waste through efficient product flow and storage (Liao et al., 2018a).

Therefore, green logistics is a type of value-added service offered to customers, and this creates an opportunity to gain an advantage over competitors (Liao et al., 2018a; Sureeyatanapas et al., 2018)..

According to Liao et al., (2018a). the main characteristics of green logistics are

**Reducing carbon emissions:** This includes the use of fuel-efficient vehicles and alternative forms of transportation, such as electric vehicles or bicycles.

**Increased use of recycling and reuse:** Green logistics aims to reduce waste by finding ways to recycle and reuse materials.

**Improved energy efficiency:** This includes the use of renewable energy sources and energy-efficient technologies in logistics operations.

**Better planning and coordination:** Green logistics involves optimizing the flow of goods and materials to reduce unnecessary transportation and improve overall efficiency.

**Increased focus on sustainability:** Green logistics prioritizes the long-term health of the planet and the well-being of future generations.

**Compliance with legal and regulatory requirements** regarding environmental impact.

**Benefits and barriers to green logistics implementation**

The implementation of green logistics can bring many benefits to both companies and the environment, such as:

**Cost savings:** By reducing waste and improving efficiency, companies can save money on fuel, transportation, and materials (Larina et al., 2021)..

**Increased competitiveness:** Adopting green logistics can help a company stand out in the marketplace and attract environmentally conscious consumers. (Plaza-Úbeda et al., 2021)..

**Reputation enhancement:** Being seen as a socially responsible and environmentally friendly company can enhance a company's reputation and brand image (Al-Minhas et al., 2020)..

**Regulatory compliance:** Implementing green logistics can help companies comply with environmental regulations and avoid potential penalties (Li et al., 2021).

**Improved resource management:** Green logistics helps companies minimize the use of natural resources and reduce the environmental impact of their operations (Al-Minhas et al., 2020)..

**Reducing carbon footprint:** Green logistics can help reduce a company's carbon emissions, which can contribute to reducing global warming and climate change (Agyabeng-Mensah et al., 2022)..

**Increased resilience:** green logistics can also help companies to be more resilient and adaptable to changes in the supply chain, such as natural disasters, oil price spikes, among others (Sureeyatanapas et al., 2018)..

However, Kaur et al., (2019), in their study identifies that "difficulty in transforming positive environmental attitudes into actions" and "lack of awareness of reverse logistics adoption" are the most important priority barriers, followed by "high cost of hazardous waste disposal", "perceived "out of responsibility" area", "lack of ESER (Environmental and Sustainability Educational Research) R&D capacity" and "lack of corporate social responsibility". These barriers are related to awareness, cost, commitment and resources.

Therefore, stakeholder organizations must focus on these barriers for green supply chain practices to be successful.

Reducing harmful effects on the environment is not only one of the world's major challenges, but also a priority objective for implementing the provisions of the sustainable development strategy (Viennažindienė et al., 2021).. In this regard, the transport sector

is a major contributor to these emissions, and technological and policy initiatives, such as vehicle redesign, alternative fuels, and taxes and subsidies have been undertaken in all modes to reduce emissions (Randrianarisoa & Gillen, 2022)..

These goals and challenges are relevant to companies in all sectors of the economy, including logistics (Sun et al., 2022).

Logistics, on the one hand, is vital to the economy and daily life of countries, and on the other hand, it is one of the main sources of pollution and resource users (Tsimisaraka et al., 2022)..

The logistics sector is facing increasingly stringent environmental requirements. This is largely due to two reasons. First, in recent years, the growth of freight services has had a significant impact on congestion, safety and environmental pollution. Secondly, the need for more sustainable logistics services is growing in the countries concerned (Agyabeng-Mensah et al., 2022).. As a result, there is an increasing diversification of the implementation of green logistics initiatives in companies (Liao et al., 2018a; Viennažindienė et al., 2021)..

With increasing globalization and complexity of supplier networks, there is greater business interest in managing the sustainable performance of these networks (Al-Minhas et al., 2020)..

More and more organizations are implementing green practices in the supply chain to stay competitive in the business marketplace, gain customer loyalty, enhance brand image, and minimize negative environmental impact (Kaur et al., 2019).

Examples of these practices are green design, green purchasing, green manufacturing, green packaging, green logistics and green marketing.

Examples of green logistics activities include using alternative fuels in transportation, optimizing transportation routes to reduce miles, shifting transportation modes from road to rail, or using recyclable packaging materials (Khan, Sharif, et al., 2019)..

The focus of green logistics is not only on environmental performance, but on traditional objectives for logistics management to reduce costs and improve product value (Khan, Sharif, et al., 2019; Liao et al., 2018a; Vienažindienė et al., 2021)..

Reverse logistics and green logistics are concerned with managing the flow of goods and services from the point of origin to the point of consumption (Li et al., 2021; Uriarte-Miranda et al., 2018)..

The main difference between the two is that green logistics focuses on minimizing the ecological impact of logistics activities, while reverse logistics focuses on the upstream movement of products and materials (Chileshe et al., 2018; Larina et al., 2021)..

Reverse logistics can include activities such as product returns, recycling and repackaging, while green logistics can include activities such as using alternative fuels, reducing packaging waste and using more efficient transportation methods. The two may overlap in certain areas, such as recycling and disposal, but they are distinct concepts with different objectives (Larina et al., 2021; Prajapati et al., 2019; Zhang et al., 2022)..

It is important to specify that the objective of reverse logistics is to minimize waste and reduce the costs associated with the disposal of products and materials. Green logistics, on the other hand, focuses on reducing the environmental impact of logistics activities along the entire supply chain.

These principles are of importance to supply chain management and can help organizations achieve their sustainability goals.

Today, market competition is becoming increasingly fierce due to diversified customer needs, stringent environmental requirements and global competitors. One of the most important factors for companies to not only survive but also thrive in today's competitive market is their logistics performance (Sun et al., 2021). In this regard, sustainability is the main key to the supply chain, which starts with understanding through all phases of production to final distribution (Srivastav et al., 2019)..

Supply chain management is one of the most important elements of sustainable development. And due to the fact that the global market is driven by supply and demand, and the determinant of access to products is regional and international (Klimecka-Tatar et al., 2021).

There is a growing market and institutional demands for companies to implement sustainable practices to produce environmentally friendly products and services (Khan, Sharif, et al., 2019).

Therefore, more companies are integrating sustainable practices into their operations, which have increased competition in the marketplace. In order to improve their

competitiveness in the marketplace, companies are forced to adapt to changing market requirements by implementing practices that will differentiate themselves (Shamsuddin et al., 2020)..

Likewise, the development of new technologies and innovations in logistics are expectations that will bring a positive outcome in the field of sustainability and preservation of environmental quality worldwide (Khan, Jian, et al., 2019).

These benefits include energy savings, reduced emissions, improved recycling, reduced environmental pollution (Rashidi & Cullinane, 2019). Thus it can also reduce waste and environmental damage to the planet, provide better goods and services at a lower cost, and create jobs for people (Khan, Sharif, et al., 2019). In contrast, some authors argue that sustainable innovation and design are not necessarily related to new technologies, but to rethinking approaches to address the need for growth while reducing negative environmental and social impacts (Liao et al., 2018a; Rashidi & Cullinane, 2019; Sureeyatanapas et al., 2018)..

In general, innovation can be considered a key factor in the sustainability of companies. It does not matter what type of innovation it is. Sustainability refers to both product and process innovations. Also if we talk about technological, social, environmental innovations. Green product innovation has been formed as a result of the interplay between sustainability and innovation (Rashidi & Cullinane, 2019)..

If a company wants to apply the principles of sustainability, individual steps need to be included in different areas of business activity (Klimecka-Tatar et al., 2021)..

According to Julianelli et al. environmental innovation provides an important key to sustainability, provided that a close association between quality and green practices is considered in terms of competitiveness.

Sustainability in logistics refers to the practice of applying environmentally friendly and socially responsible processes and practices throughout the logistics supply chain. This includes reducing carbon emissions, using environmentally friendly transportation methods and applying sustainable packaging and materials. It also involves ensuring fair treatment of workers and promoting ethical business practices. By adopting sustainable logistics practices, companies can enhance their reputation, reduce costs and help protect the environment.

A dramatic increase in companies has begun to incorporate sustainability into logistics operations to improve their social image and competitive advantage (Rashidi & Cullinane,

2019). Sustainable logistics initially focused initially from the environmental perspective on reducing the ecological footprint related to logistics activities (Sun et al., 2021). This logistics model aims to balance the socio-economic performance of a logistics system with its eco-environmental soundness in the management of the system's activities. This balance is materialized in decision making by considering the interaction of different logistics functions, i.e. network configuration, transportation, purchasing, demand allocation and resource management. The optimization of a sustainable logistics system depends largely on the ability to balance the trade-offs among the three dimensions of sustainability (Liao et al., 2018a; Sun et al., 2021)..

In logistics, energy is a resource that significantly influences not only economic performance but also environmental sustainability. In the process, however, logistics operations consume vast energy resources and, in turn, produce a significant portion of the Earth's greenhouse gas emissions (Rashidi & Cullinane, 2019; Sun et al., 2021; Wehner et al., 2021)..

Although freight transportation and business logistics can improve their environmental sustainability by pursuing energy efficiency, relative to the manufacturing sector, which has long pursued energy efficiency due to rising energy costs (Wehner et al., 2021)..

The logistics sector recently responded, in large part to comply with EU Directives (EU, 2018) and the United Nations Sustainable Development Goals (United Nations, 2018) requiring transport operations to reduce their carbon emissions (Klimecka-Tatar et al., 2021)..

Thus, that various sustainability initiatives undertaken by logistics service providers (LSPs), which pursue energy efficiency as a means to achieve environmental sustainability, especially through decarbonization of logistics operations and systems, have been proposed and examined, have remained poorly understood (Wehner et al., 2021)..

In logistics, energy efficiency, as a performance measure, refers to energy use in activities such as transportation and storage (Yu et al., 2021). Although various initiatives have been conceptualized to improve energy efficiency in logistics, Srivastav et al., (2019) have postulated that such environmentally oriented initiatives are essentially transportation-related initiatives (e.g., related to fuel, vehicle technology, modal choice, behavioral aspects, and transportation management) or initiatives beyond transportation (e.g., related to logistics system design, environmental management systems, and emissions). Tsimisaraka et al., (2022) have divided such environmental initiatives into two different broad categories, intra-organizational and interorganizational, while VienažindienViennažindienė et al., (2021) have distinguished them according to their



short-term versus long-term perspectives. Taking alternative approaches to the issue, Yu et al., (2021) have examined which initiatives LSPs adopt in light of various drivers and barriers, and Agyabeng-Mensah et al., (2022) have extended that view by classifying LSPs according to the sustainability-oriented strategies they adopt.

In logistics, the dominant focus on achieving energy efficiency as a performance measure related to cost or quality undermines the interdependence between energy efficiency and sustainability (Kaur et al., 2019; Shamsuddin et al., 2020).. Although largely based on non-renewable resources that cause pollution, the concept of energy efficiency plays an important role in achieving environmentally sustainable development in logistics as well (Plaza-Úbeda et al., 2021).. As such, energy efficiency is not only a performance measure, but also an area for improvement. However, how such improvement enables the evolution towards sustainable development in logistics is another neglected aspect in the literature.

Some examples of sustainable logistics practices, according to Rashidi & Cullinane, (2019). are:

Use electric or hybrid vehicles for transportation to reduce carbon emissions.

Implementing telematics technology to optimize routes and improve fuel efficiency

Using intermodal transportation (i.e., a combination of multiple modes of transportation such as rail and truck) to reduce the number of single occupant vehicles on the road

Use sustainable packaging and materials, such as biodegradable or recycled materials.

Partner with suppliers that apply sustainable practices.

Develop and promote sustainable storage practices, such as energy-efficient lighting and HVAC systems.

By applying these practices, logistics companies can reduce their environmental impact, improve the well-being of their employees and communities, and increase their overall efficiency and competitiveness.

In addition, they will help to meet global sustainability goals (Tsimisaraka et al., 2022)..

Sustainability barriers and challenges

Sustainable logistics requires maximizing economic benefits and minimizing negative impacts on the environment (Klimecka-Tatar et al., 2021; Shamsuddin et al., 2020)..

From a theoretical perspective, studying the impact of logistics activities on the environment and energy is an important way to achieve economic and environmental sustainability. Since 2005, the impact of globalization on logistics and the supply chain has become increasingly obvious (Liao et al., 2018).

The contradiction between logistics, environmental sustainability and energy demand has become increasingly prominent in several countries (Shamsuddin et al., 2020)..

Liao et al., (2018) pointed out that for a company to truly achieve sustainable development, it is necessary to shift the company's strategy towards a priority of environmental sustainability. At the national level, improving trade logistics performance can drive a significant increase in exports (Yu et al., 2021)but environmental losses can far exceed economic benefits (Shamsuddin et al., 2021). (Shamsuddin et al., 2020)..

Therefore, it is particularly important to measure the relationship between economic factors, environment and energy from an international perspective. By exploring the impact of logistics activities on the environment and energy from a macro perspective, it is useful to enrich green supply chain theory and provide a theoretical basis for policy makers and member countries to balance economic interests and environmental sustainability.

Most research articles on sustainability and logistics focus on how Industry 4.0 supports sustainable logistics, but less effort has been put into understanding the challenges of this digital transformation. In this regard, Khan, Sharif, et al., (2019)., indicates that although new technologies have brought many opportunities, they also bring several challenges for sustainable logistics.

Sun et al., (2021), in their research discuss several major challenges and gaps of sustainable logistics in the Industry 4.0 era, including:

Lack of holistic consideration of multiple sustainable indicators

Unclear economic benefits and impacts of other sustainability indicators

Life cycle energy consumption and environmental footprint

Job losses and difficulties for workers

Inequity problems

Lack of general guidance

System integration and interoperability

Data quality and cybersecurity concerns

On the other hand, shipping, for example, accounted for 1 billion tons of GHG emissions between 2007 and 2018 (Yu et al., 2021); the average total sulfur emissions per year from shipping amounted to 11.3 million tons between 2007 and 2018, which represents about 13% of global emissions (Randrianarisoa & Gillen, 2022).. As evidence accumulates on the negative environmental and health-related impacts of shipping activities on populations living in port cities and adjacent to major shipping routes, reducing sulfur emissions has become a significant challenge of the sector (Randrianarisoa & Gillen, 2022; Srivastav et al., 2019)..

Today, shipping is facing more challenges than in its early days. Like any other industry, the maritime sector must adapt to the needs of the modern world and conduct its activities with respect for the environment (Hasanspahić et al., 2021).. Continuous technological development and increasing environmental awareness are the determinants of changes in modern shipping (Shamsuddin et al., 2020).. Therefore, one of the main challenges in shipping is to implement innovative solutions to protect the marine environment. However, it is quite difficult to achieve ecological and economic benefits at the same time. Therefore, it is very important to apply the win-win principle, which refers to the sustainable development of maritime transport.

International shipping was excluded from the Paris Climate Agreement, but the IMO (International Maritime Organization) has developed and continues to develop its own policies and strategies to reduce shipping emissions. Annex VI of the IMO's Maritime Pollution Convention (MARPOL) has mandated that total sulfur dioxide (SO<sub>2</sub>) emissions from shipping must be reduced and apparently at any cost, as the standard appears to have been set without an assessment of the incremental environmental benefits relative to the economic costs. To achieve this outcome, the IMO set a strict limit on the sulfur content of marine fuels used in all ships in all areas to 0.5% mass by mass (m/m) as of January 1, 2020 (Randrianarisoa & Gillen, 2022)..

Shipowners must comply with this new regulation, and have a number of (more or less costly) alternative strategies to comply with the IMO directive: switching to more expensive low-sulfur fuel, installing devices that clean exhaust gases (such devices are

called "scrubbers"), using engines capable of burning a variety of low- or zero-sulfur fuels, or simply scrapping the vessel (Klimecka-Tatar et al., 2021; Randrianarisoa & Gillen, 2022)..

Undoubtedly, this new regulation may lead to significant changes in the total amount of sulfur emissions related to shipping (Randrianarisoa & Gillen, 2022; Vienažindienė et al., 2021)..

However, the effect of such a directive on costs is not negligible. Vessel owners have to make substantial investments and/or incur additional costs to comply with this new rule. For example, the installation of scrubbers on a very large newbuild crude carrier would additionally cost \$US 1.14 million per voyage within a 6-year payback period, while the total additional costs of using liquefied natural gas (LNG) or low sulfur fuel oil are expected to be around \$US 1.5 million per voyage (Larina et al., 2021; Rashidi & Cullinane, 2019)..

For existing vessels, the lifetime costs of the available alternatives range from \$US 31 million (scrubbers) to \$US 82.8 million (LNG use), depending on the chosen solution and vessel size (Klimecka-Tatar et al., 2021; Randrianarisoa & Gillen, 2022; Rashidi & Cullinane, 2019)..

Increased costs can lead to higher shipping prices, and this can result in reduced international trade. Policymakers face the classic, but complex, challenge of achieving a so-called "win-win solution" (Randrianarisoa & Gillen, 2022; Vienažindienė et al., 2021).i.e., undertaking environmental initiatives while trying to balance commercial and economic objectives.

## CONCLUSIONS

Logistics is an important part of the supply chain and involves the efficient flow of goods and services from the point of origin to the point of consumption. Reverse logistics, on the other hand, involves the upstream movement of products and materials for activities such as product returns, recycling and repackaging. Green logistics focuses on minimizing the ecological impact of logistics activities, such as the use of alternative fuels and the reduction of packaging waste.

With the internationalization of green supply chain management and sustainable supply chain management, more and more scholars began to explore the field of green logistics. Green logistics is a multidisciplinary subject, which includes economic, environmental

and social factors. It focuses on taking measures to minimize harmful effects on the environment and introduces tools and behaviors that help improve the development of society and the economy.

Existing literature shows that most researchers focus on green technology innovation, e.g. reverse logistics, waste management, transportation route optimization and energy consumption.

There is currently a growing concern for environmental sustainability. Therefore, reverse logistics and green logistics processes and operations must be implemented within organizations to reduce the impact of waste and ensure proper disposal.

Several of the studies discussed in this article draw attention to the negative environmental impacts of logistics activities, such as the consumption of large amounts of fossil and natural resources and greenhouse gas (GHG) emissions.

In addition, due to the increasing demand for freight mobility, environmental issues are becoming critical for the logistics services industry. The literature points out that, in order to turn environmental issues into a business opportunity, environmental initiatives must be adopted in logistics activities. Unfortunately, there are still many constraints that hinder the implementation of reverse and green logistics, and these constraints are even greater in developing countries.

Some of these obstacles include additional costs, the desire for deep collaboration with suppliers and customers, and the belief of some managers who are managing reverse flow that it is not worth the trouble. Conversely, those who have internalized its importance and advantages are interested in new and innovative tools that could contribute to more effective and efficient outcomes. In addition, the findings suggest that consumers perceive products manufactured through some green and reverse logistics practices to be inferior to new products in terms of quality. However, it has been observed that most customers do not perceive any difference in quality between products made from recycled materials and new products. In this sense, companies wishing to employ the principles of green or reverse logistics could develop strategies such as low price or differentiate themselves on better service.

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