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Achieving Sustainable Development in Logistics: a Path to Environmental and Economic Efficiency

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Abstract
The logistics sector plays a crucial role in global trade and economic growth. However, the rapid expansion of this sector has led to significant environmental impacts, including increased greenhouse gas emissions, resource depletion, and pollution. In order to address these challenges and achieve sustainable development in logistics, a comprehensive approach is necessary that considers both environmental and economic efficiency. This article explores the concept of sustainable development in logistics and its underlying principles. It first examines the environmental challenges associated with the logistics sector, highlighting the need for reducing emissions, minimizing waste generation, and conserving resources. The economic benefits of sustainable logistics are also discussed, including cost savings through energy efficiency, improved resource management, and increased competitiveness in the global market. The aim of the article is to identify solutions that can contribute to achieving the concept of sustainable development in the context of the logistics industry. The article tries to answer the question: what solutions and strategies can be used in the logistics industry to achieve economic efficiency and reduce the impact on the environment? Overall, this article provides a comprehensive overview of the challenges and strategies for achieving sustainable development in logistics. It underscores the pivotal role of logistics in achieving sustainable development goals through environmentally friendly practices and a holistic approach to economic and environmental efficiency.

Keywords: Sustainable Development, Logistics, Green Logistics, Ecologistics, Environment.

INTRODUCTION

The concept of sustainable development was first defined in 1980 in the World Conservation Strategy, stating that "Current international research must focus on

the fundamental relationships among nature, society, ecology, economy, and the use of natural resources to ensure sustainable global development." Then the document "Our Common Future" prepared by the World Commission on Environment and Development (WCED) emphasized that "Sustainable development is a development that meets the present without compromising the ability of future generations to meet their own needs." [1] The concept of sustainable development is therefore about searching for a sustainable and parallel development path between economic profit, social harmony and environmental protection. The main goal of this assumption is to achieve economic benefits without damaging people's daily lives and natural resources [2] This concept applies to the logistics industry and confirms the validity of this article.

Logistics plays a key role in today's global world, for both businesses and communities. However, its intensive activity may have a negative impact on the natural environment and the local community. In the face of growing concerns about climate change, loss of natural resources and uneven social development, it is necessary to achieve sustainable development.

Logistics is important in achieving sustainable development, building ecological supply chains and minimizing the negative impact of transport activities on the natural environment. The implementation of various solutions in logistics activities, such as the use of efficient transport routes and advanced transport technologies, can significantly affect the ability to achieve the concept of sustainable development by reducing greenhouse gas emissions and pollutants.

The purpose of this article is to identify solutions that may contribute to achieving the concept of sustainable development in the context of the logistics industry. Based on the presented research purpose of the article, the research problem took the form of the following question - what solutions and strategies can be used in the logistics industry to achieve economic efficiency and reduce the impact on the environment?

1. LITERATURE REVIEW

This part of the article will present the theoretical framework of current research on sustainable development, its elements, goals and related topics. The literature review will be the basis for further considerations in the article.

1.1 Sustainable Development

Sustainable development can be a broadly understood concept that can be interpreted depending on various areas of research. It should be assumed that the basis and most common definition of sustainable development is the one developed by WCED in 1987, which states that sustainable development aims to meet current needs without limiting the ability of future generations to meet their needs. This is the definition that has been accepted as the basic and most accurate one, which forms the basis for further research. [1] It is worth emphasizing that WCED introduces three aspects of sustainable development: economic, social and environmental growth. These three elements are interconnected and influence each other (Figure 1).

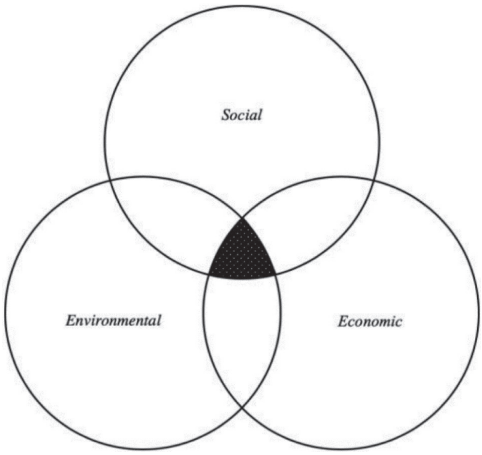

Fig. 1. Model of Sustainability
Source: J. Hedberg, K. Raadik, Sustainable Logistics: A quantitative study of the importance of stakeholder alignment for sustainable business development, UMEA UNIVERSITY, 2020, p. 19

The figure shows how the three elements of economic, environmental and social development are interconnected. The black point in the illustration represents space for sustainable development. The social dimension is closely linked to the community and its capacity to prioritize productive policies aimed at sustainable solutions [3]. The second aspect, economic sustainability, is frequently employed to assist organizations in determining their profitability and overall economic viability. This perspective assesses whether an activity or product creates greater value than it costs. Environmental - the final aspect is crucial in discussions

of sustainable solutions. Historically, this aspect has been handled primarily through environmental regulations rather than pricing mechanisms [4]. To facilitate businesses in transitioning to more sustainable practices, the environmental aspect must be integrated into all organizational processes. When it comes to logistics and transportation methods, end-users should consider both the social and environmental impacts, rather than solely relying on pricing strategies implemented by organizations.

These three elements were described in detail in a document created by the UN General Assembly in 2015 called the "2030 Agenda for Sustainable Development" [5]. This document contains the Sustainable Development Goals (SDG) to address the challenges facing the global economy, society and environment in achieving sustainable development. Of the 17 SDG listed in this Agenda, the author selected and analyzed those goals that concern logistics issues:

- **SDG-7 Affordable and clean energy** - in 2022, for the first time in history, investment in renewable energy exceeded investment in fossil fuels. The cost of wind power, solar power and lithium-ion battery technology has decreased by over 85%, around 50% and over 50% respectively since 2010. [6] Renewable sources power nearly 30 per cent of energy consumption in the electricity sector, but challenges remain in heating and transport sectors. [7] (Figure 2)

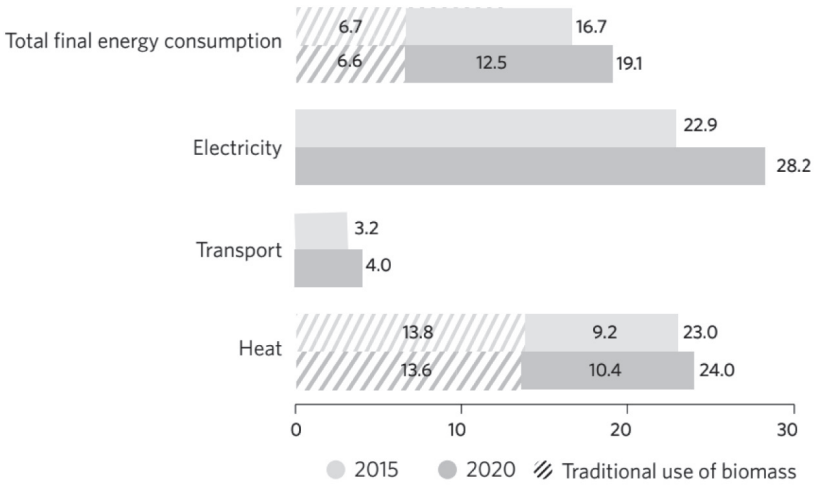

Fig. 2. Share of renewable sources in final energy consumption and by end use, 2015 and 2022

Source: UNSTATS (2023) https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf (access: 11.02.2026)

Transport is a big challenge in the use of renewable energy sources. Compared to 2015, in 2022 there was a slight increase of 0.8 per cent.

- **SDG-11 Sustainable cities and communities** - in urban areas, the decline in the poverty rate is slower than in rural areas. More than 80% of global GDP comes from cities and at the same time is responsible for 70% of greenhouse gas emissions (Figure 3). [7] Rapid urbanization can result in significant inequalities in housing, transportation and the availability of essentials.

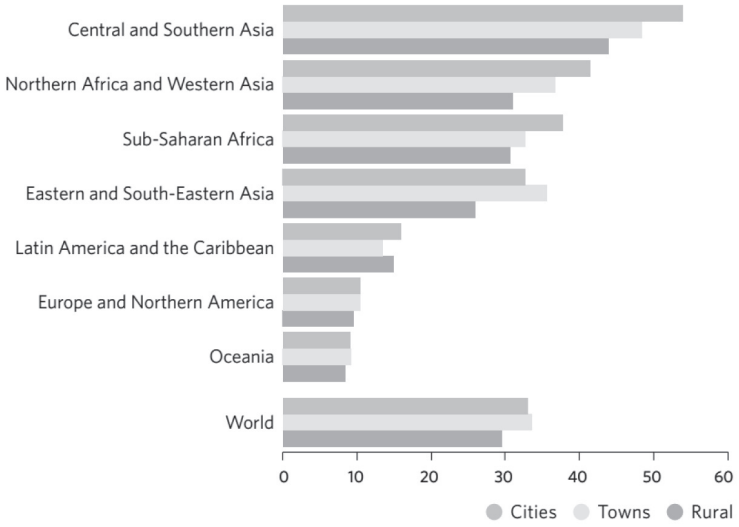

Fig. 3. Population-weighted particulate matter (PM2.5) concentrations in cities, towns and rural areas, 2019 (micrograms per cubic metre)
Source: UNSTATS (2023) https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf (access: 12.02.2026)

On a global scale, there has been improvement in air quality, primarily driven by progress in high-income nations. Addressing air pollution necessitates a shift in mindset, recognizing that it is not exclusively an urban problem. While urban areas remain significant, adopting a comprehensive approach that takes into account small towns and rural areas is essential for effectively combating air pollution.

- **SDG-12 Responsible consumption and production** - pollution, loss of biodiversity and climate change are caused by, among others, excessive consumption, waste and inefficient use of natural resources. "Between 2000

and 2019, global domestic material consumption (DMC) – the amount of raw materials directly used for production processes in a country – increased by 66 per cent, tripling since the 1970s to reach 95.1 billion metric tons. In 2019, the corresponding material footprint – the amount of materials extracted to satisfy final consumption demand in a country – was 95.9 billion metric tons". [7] (Figure 4).

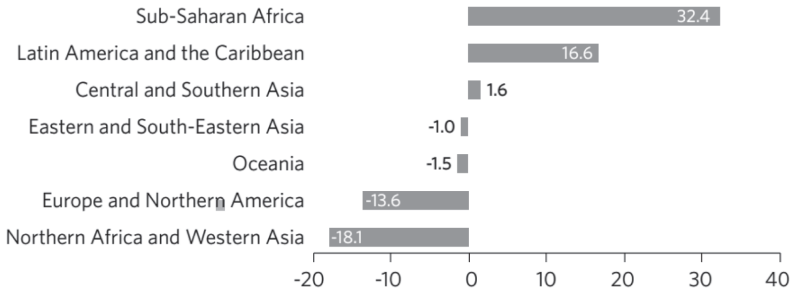

Fig. 4. Excess of domestic material consumption over material footprint, 2019 (percentage)
Source: UNSTATS (2023) https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf (access: 16.02.2026)

Based on the attached figure 4, it should be noted that there are significant inequalities in the environmental impact of individual regions of the world. In North Africa and West Asia, as well as in Europe and North America, the material footprint in 2019 exceeded the GVWR by 18%, respectively. and 14 percent, while in Latin America and the Caribbean and Sub-Saharan Africa, the material footprint was lower than DMC by 17 percent, respectively. and 32 percent These differences indicate disproportions in consumption. In high-income countries, the per capita material footprint is 10 times greater than in low-income countries.

1.2 Sustainable Logistics

Sustainable logistics is defined as "supply chain management practices and strategies that reduce the ecological and energy footprints of the distribution of goods which focuses on material handling, waste management, packaging and transport" [8]. Sustainable logistics is synonymous with green logistics. In this article, these two terms will be used interchangeably.

The logistics industry is a sector that plays a critical role in the increased production of carbon dioxide and, consequently, air pollution. Over the past few decades, there has been ongoing research, strategic planning, social initiatives, and structural changes geared towards addressing the pressing question of how to minimize the adverse environmental effects of human activity within rapidly expanding economies and growing industries, particularly those reliant on energy resources [9].

Logistics is a crucial component of the supply chain, yet it is a significant contributor to air pollution. Transportation is a key operational aspect of logistics and is responsible for 24% of global CO_2 emissions [10]. To address environmental concerns, there are increasingly stringent environmental policies being implemented in Europe and worldwide that are fostering new technologies and innovations in regional and international transportation. Minimizing environmental pollution is a top priority of environmental European Union policies that extend until 2050 [11]. Such initiatives have been pursued by laws and policies, especially in the second decade of the 21st century, resulting in dynamic technological advancements. Nonetheless, studies indicate that it remains challenging to change people's attitudes towards unfamiliar alternative fuel technologies; thus, it is suggested to start by changing entrepreneurs' attitudes towards eco-friendly technologies.

1.3 Circular Economy

The concept of Circular Economy (CE) was first introduced in Kenneth Boulding's 1966 book, The Economics of the Coming Spaceship Earth [12]. Boulding envisioned Earth as a closed economic system where the economy and environment have an interdependent, circular relationship. He argued that a linear economic model of resource extraction, production, and consumption could be transformed into a CE through the recycling of waste materials. This circular economic system was later expanded upon by Pearce and Turner in their 1990 book, Economics of Natural Resources and the Environment [13], which explored the economic and ecological aspects of the concept. The authors emphasized that neglecting environmental concerns would result in viewing the economy as a linear system. They highlighted how in a linear economy, every stage (resources, production, consumption) generates waste, with some being recyclable and reused, while the rest becomes environmental pollutants. Pearce and Turner also noted that the lack of recycling is often due to missed opportunities for value creation in the supply chain.

Recent studies have identified CE as a comprehensive concept that encompasses activities involving the reduction, reuse, and recycling of materials throughout the production, distribution, and consumption processes [14]. Despite the direct environmental benefits of these activities, CE is primarily viewed as an economic strategy rather than an environmental one [15]. Kirchherr et al. [16], after analyzing 114 CE definitions, defined CE as a framework aimed at achieving sustainable development by creating environmental, economic, and social value for current and future generations. In order to realize the broad objectives of CE, advancements are necessary to extract economic, environmental, and social value through exploring opportunities in circular supply chains [17]. Homrich et al. [18] noted in their research that existing studies have not explored CE from a triple bottom line perspective, and previous literature highlighted the absence of certain dimensions, particularly the social aspect, in CE models [19]. This study delves into sustainable logistics practices in relation to CE, focusing on the creation of economic and environmental value.

The CE concept revolves around fundamental principles including the 4R's (Reduce, Reuse, Recycle, Recover); waste hierarchy principles; system perspectives at micro, meso, and macro levels; utilizing business models as enablers; enabling consumers; aiming for sustainable development; prioritizing environmental quality; striving for economic prosperity; advocating for social equity; and considering the needs of future generations and long-term perspectives [8].

A key element of circular economy and sustainability involves closing the loop, in which waste from one process becomes a resource for another, being recycled, reused, or remanufactured. The butterfly diagram shown in Figure 5 illustrates a circular economy system with two main cycles: the technical cycle, which keeps materials in circulation through reuse, repair, remanufacture, and recycling; and the biological cycle, which returns biodegradable materials back to the earth as nutrients to regenerate nature.

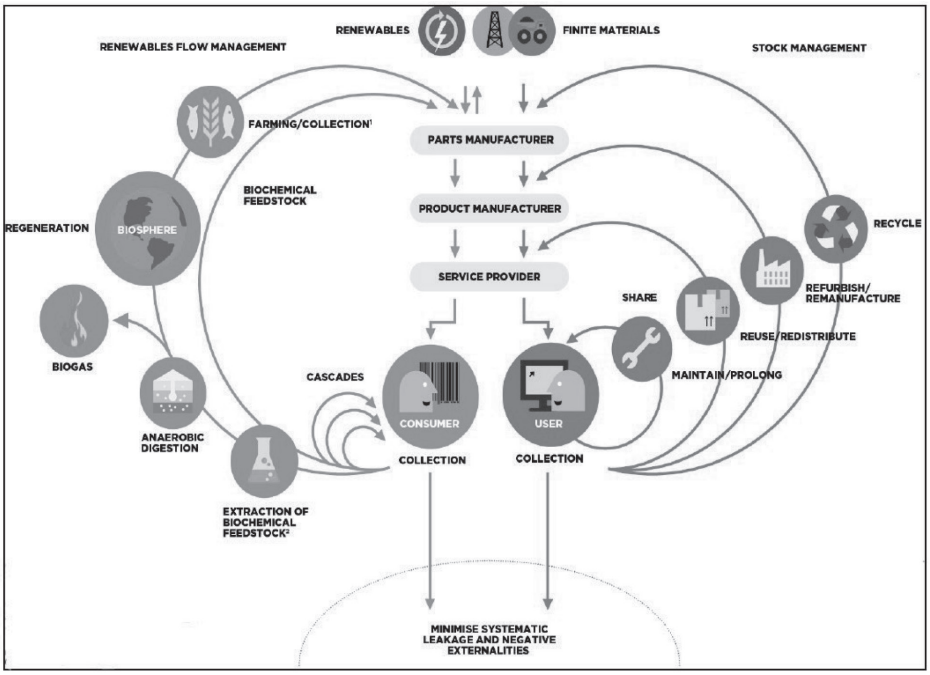

Fig. 5. Circular Economy Systems based on Cradle-to-Cradle
Source: Ellen MacArthur Foundation. (2013). Towards the Circular Economy Vol. 1: An Economic and Business Rationale for an Accelerated Transition.

2. GREEN LOGISTICS PRACTICES IN VALUE CREATION PERSPECTIVE

Since logistics refers to the entire supply chain and plays a key role from the moment the raw materials are ordered to create the goods until their delivery to the customer, green logistics practices are identified in terms of different categories with the overall goal of reducing emissions and conserving resources (table 1).

Table 1. Analysis of different GL practices in terms of value creation

TYPES OF GL PRACTICES	***VALUE CREATION PERSPECTIVE***	
	ENVIRONMENTAL	***ECONOMIC***
Alternative energy	*v*	
Low carbon transportation	*v*	
Transport modes	*v*	*v*

Recycling materials and packaging	*v*	*v*
Eco-driving	*v*	*v*
Reverse logistics	*v*	*v*
Energy efficiency	*v*	*v*
Fleet management	*v*	*v*
Sypply chain reorganization		*v*
Environmental control	*v*	
Green packaging	*v*	*v*
Vehicle use	*v*	*v*
Environmental training and information	*v*	*v*

Source: own research based on Chamari Pamoshika Jayarathna & Duzgun Agdas & Les Dawes, 2023. "Exploring sustainable logistics practices toward a circular economy: A value creation perspective," Business Strategy and the Environment, Wiley Blackwell, vol. 32(1), p. 706.

These practices are directly connected to economic performance [20]. For instance, cutting energy usage by shifting models, adopting eco-friendly driving habits, using alternative energy sources, and effectively managing fleets can lead to cost savings. While initially requiring greater financial investment, the implementation of sustainable practices can enhance long-term financial performance by offering cost-effective services that attract more customers, potentially expanding market size, sales, and profitability [21]. Additionally, companies anticipate gaining a competitive edge through the adoption of environmentally friendly practices.

3. SUSTAINABLE LOGISTICS AND SUPPLY CHAINS

Although sustainability, "green" practices, and environmental concerns are relatively recent developments in the logistics and supply chain management field, early research in the 1990s focused on transportation processes throughout a product's lifecycle, with an emphasis on manufacturer activities and reverse logistics. The three primary themes in sustainable logistics and supply chain management are: reverse logistics, emissions assessment, and the implementation of environmentally friendly practices in logistical activities and supply chains [22].

3.1 Reverse logistics

While not a new concept, reverse logistics, involving the return, recovery, and recycling of products, has been in practice for decades. It is becoming increasingly important in the field of logistics and supply chain management, especially with the rise of omnichannel e-commerce and the challenges posed by retail returns. Reverse logistics is defined as "(…) the process of planning, implementing, and controlling the efficient, 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 recapturing value or proper disposal" (Figure 6). [23].

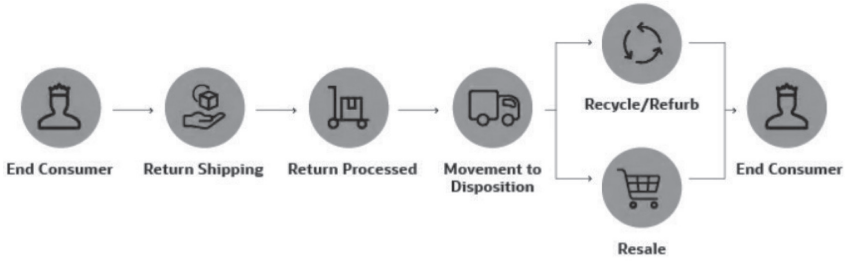

Fig. 6. Reverse logistics supply chain
Source: https://www.netsuite.com/portal/resource/articles/inventory-management/reverse-logistics.shtml (access: 29.02.2026).

Companies worldwide are adapting their waste management strategies, with a significant focus on the supply chain. The 5Rs of reverse logistics - returns, reselling, repairs, repackaging, and recycling - play a crucial role in this initiative. To measure progress and success, organizations use metrics for each of these options.

3.2 The incorporation of eco-friendly practices in logistics operations and supply chains

The push for sustainability in logistics and supply chains involves making these operations environmentally friendly and efficient, with a key emphasis on reducing carbon emissions throughout the entire supply chain. The World Economic Forum proposed that the responsibility for promoting sustainability in the supply chain should be shared among logistics and transport service providers, shippers and buyers who use these services, and government and non-government policymakers.

Green logistics practices should be applied in the following areas:

- Transportation - To drive efficiency and sustainability, logistics and transport service providers should embrace new technologies, fuels, and processes that offer a strong economic rationale. They should conduct network assessments of large closed networks to streamline hierarchies and nodal structures, integrate optimization efforts across various networks, encourage collaboration among multiple shippers and carriers, and transition to environmentally friendly modes of transport within their operations [24].
- Sourcing, product and packaging design - Shippers and buyers need to assess the carbon footprint of a product by considering factors like the carbon content of raw materials, production process emissions, supply chain length and speed, and carbon impact during product use. They should establish standards and goals for reducing packaging weight and waste, and collaborate with other industries to standardize modular transit packaging materials [24].
- Administrative issues - Logistics and transport service providers should include carbon offsetting options in their range of services for both their operations and customers. Policymakers should collaborate with these providers to establish consistent carbon measurement and reporting guidelines, create a transparent carbon trading system, reassess tax structures to align with sustainability goals, and promote wider adoption of carbon labeling. Furthermore, efforts should be made to incorporate the true cost of carbon into energy tariffs for all regions and transportation modes [24].

CONCLUSIONS

Logistics has a huge impact on the global economy, but also on everyday life. Education in the field of green logistics and the circular economy and the promotion of this type of economy among entrepreneurs is currently key. The growing amount of waste is becoming a serious problem around the world. Implementing sustainable logistics and the circular economy is a difficult task for entrepreneurs.

In conclusion, the article emphasizes the critical role of the logistics sector in global trade and economic growth, while acknowledging the significant environmental impacts associated with its rapid expansion. To address these challenges and achieve sustainable development in logistics, a comprehensive approach that considers both environmental and economic efficiency is necessary. By highlighting the need for reducing emissions, minimizing waste generation, and conserving resources, the article underscores the importance of incorporating sustainable practices in

logistics operations. Additionally, the economic benefits of sustainable logistics, such as cost savings, improved resource management, and increased competitiveness in the global market, further support the argument for integrating sustainability into the industry. Ultimately, the article aims to identify solutions and strategies that can contribute to achieving economic efficiency and reducing the environmental impact of logistics operations, emphasizing the pivotal role of logistics in attaining sustainable development goals through environmentally friendly practices and a holistic approach to efficiency.

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