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THREE KEY STRATEGIES OF SUSTAINABLE LOGISTICS IN THE CONTEMPORARY WORLD: GREEN, REVERSE, AND LEAN LOGISTICS

Abstract: The logistics sector, in the current world represents one of the main keystone of global trade, However, emerging environmental challenges and resource scarcity, for the sector, it has become vital to develop sustainable solutions. It is crucial to mention that the concept of sustainability is not oriented solely on ecological issues. It also involves economic efficiency, social responsibility, and environmental balance which makes it a complex strategy. In this context, sustainable logistics is to minimize the environmental impact of logistics processes, and efficient waste management. Considering the above mentioned, the main purpose of this article is to distinguish in detail the three central strategies, which is used to ensure sustainability in the field of logistics: green logistics, reverse logistics, and lean logistics. Green logistics refers to environmentally friendly and efficient transport, packaging and storage processes management practices in the product manufacturing with minimal environmental damage. Reverse logistics refers to the processes of reusing and recycling used or defective products in production. Lean Logistics Concentrates eliminating decline and rising effectively at all stages of the supply chain. Given strategies, separately and in an integrated manner, make a significant contribution to the formation of sustainable logistics systems. As a result, it is possible to both reduce tension on the environment and boost the competitiveness of business activities and optimize costs. Therefore, sustainable logistics is considered one of the main route in the development of modern logistics.

Keywords: Sustainable logistics, Green logistics, Reverse logistics, Lean logistics

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თანამედროვე მსოფლიოში მდგრადი ლოგისტიკის სამი ძირითადი სტრატეგია: მწვანე ლოგისტიკა, რევერსული ლოგისტიკა და ლინ ლოგისტიკა

აბსტრაქტი. თანამედროვე მსოფლიოში ლოგისტიკის სექტორი გლობალური ვაჭრობის ერთ-ერთ მთავარ საყრდენს წარმოადგენს, თუმცა მზარდი ეკოლოგიური პრობლემებისა და რესურსების დეფიციტის ფონზე, სექტორი დგას მდგრადი გადაწყვეტილებების შემუშავების აუცილებლობის წინაშე. ამასთანავე უნდა ითქვას რომ თანამედროვე მსოფლიოში მდგრადობის ცნება მხოლოდ ეკოლოგიურ პრობლემებზე არ არის ორიენტირებული. იგი ასევე მოიცავს ეკონომიკურ ეფექტიანობას, სოციალურ პასუხისმგებლობას და ეკოლოგიური ბალანსის

დაცვას, რაც მას კომპლექსურ სტრატეგიად აყალიბებს. მოცემულ კონტექსტში, მდგრადი ლოგისტიკის მიზანია ლოგისტიკური პროცესების გავლენის შემცირება გარემოზე, რესურსების ოპტიმალური გამოყენება და ნარჩენების ეფექტიანი მართვა. ამ ყოველივეს გათვალისწინებით ნაშრომის მთავარი მიზანია ლოგისტიკის სფეროში მდგრადობის უზრუნველსაყოფად გამოყენებული სამი ძირითადი სტრატეგიის: მწვანე ლოგისტიკის, რევერსული ლოგისტიკისა და ლინ ლოგისტიკის დეტალური შესწავლა. მწვანე ლოგისტიკა გულისხმობს ეკოლოგიურად სუფთა და ეფექტური ტრანსპორტის, პროდუქციის წარმოებაში კი გარემოზე მინიმალური ზიანის მიყენებით შეფუთვის, დასაწყობებისა და საცავების პროცესების მართვის პრაქტიკებს. უკუ იგივე რევერსული ლოგისტიკა კი გულისხმობს გამოყენებული ან ფუნქცია დაკარგული და წუნდებული პროდუქციის წარმოებაში ხელახალ გამოყენებისა და მისი გადამუშავების პროცესებს. ლინ ლოგისტიკა კი კონცენტრირებულია დანაკარგების აღმოფხვრასა და ეფექტიანობის ზრდაზე მიწოდების ჯაჭვის ყველა ეტაპზე. აღნიშნული სტრატეგიების როგორც ცალკე, ასევე ინტეგრირებულად გამოყენებისას, მნიშვნელოვანი წვლილი შეაქვთ მდგრადი ლოგისტიკური სისტემების ჩამოყალიბებაში. შედეგად კი შესაძლებელია როგორც გარემოზე ზეწოლის შემცირება ასევე ბიზნესსაქმიანობის კონკურენტუნარიანობისა და ხარჯების ოპტიმიზაციის ხელშეწყობა. ამგვარად, მდგრადი ლოგისტიკა, თანამედროვე ლოგისტიკის განვითარებაში ერთ-ერთ ძირითად მიმართულებად განიხილება.

საკვანძო სიტყვები: მდგრადი ლოგისტიკა, მწვანე ლოგისტიკა, რევერსული ლოგისტიკა, ლინ ლოგისტიკა

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Introduction

In the current era, business organizations operate in highly challenging conditions. Therefore, in order to successfully manage the production process and supply chain, enterprises need to introduce innovations that will make their business activities more competitive and efficient. At the same time, major global ecological challenges such as environmental pollution, global warming, climate change, biodiversity loss and depletion of natural resources directly affect all sectors, including logistics. Consequently, in logistics and in all other fields, sustainability is no longer considered a voluntary choice, but has become an inevitable strategic necessity in the global world. As is known, sustainability includes environmental, social and economic aspects and aims to create long-term value and rational use of resources. Accordingly, enterprises both their responsibility to nature and certain obligations to society.

It is Widely known that the logistics sector has a crucial influence on the environment through its activities, especially on energy consumption and carbon dioxide (CO₂) emissions. In fact, all stages of the supply chain (raw material extraction, production, packaging, distribution, return, etc.) contribute to environmental degradation. For instance, vehicles used in the production process increase carbon dioxide (CO₂) emissions, the packaging process of products increases the waste volume, and inefficient inventory management leads to uncontrolled consumption of resources. Against this background, the sustainable organization of logistics processes represents a significant challenge both in terms of reducing environmental damage and optimizing the costs of production and delivery of products. Furthermore, the growing public awareness of environmental issues contributes to the demand for eco-friendly products and services, compelling enterprises to adopt modern approaches to sustainable logistics.

It is important to consider strategies that will assist in reducing both environmental impact and increase operational efficiency. In recent academic literature, when discussing sustainability issues in the context of logistics, particular attention is given to three main strategies: green logistics, reverse logistics, and lean logistics. Green logistics is focused on environmentally friendly transport, energy efficiency, and the reduction of carbon dioxide (CO₂) and carbon emissions. Reverse logistics refers to the products recovery after use, waste utilization, recycling, and reuse. Lean logistics aims to simplify production and supply chain processes and minimize waste (excessive costs).

As mentioned above, the aim of this study is to examine in detail three key strategies for promoting sustainability in logistics. In addition, it explores the theoretical foundations of sustainability, its relationship to logistics processes, and strategies of green, reverse and lean logistics, along with their practical applications, benefits and challenges. Finally, the study shows how these approaches can be integrated into organizational structures to develop sustainable and efficient logistics systems.

1. Methodology and Literature Review

Considering the scope of the issue, the research methodology should examine the key terms of the research question in depth. Based on this, it is appropriate to select a “Systematic Literature Review” (SLR) as the research methodology. The SLR methodology enables us to select and study in detail academic works that are directly related to sustainable logistics strategies. By systematically reviewing and synthesizing existing research, the paper will provide the reader with detailed information about green, reverse and lean logistics. The methodology also allows us to identify gaps in the literature and create a new comprehensive work on sustainable logistics. This structured approach not only contributes to the advancement of academic discourse, but also offers practical insights for businesses and policymakers working towards sustainable development goals in the logistics sector. Therefore, only studies that adhere to all academic rules and norms are used in the literature review. Since the issue covers three different directions that are closely related to each other, it was deemed appropriate to organize the literature review in tabular form. As a result, the literature review became more structured and it is possible to discuss many academic works in the most concise way. The literature review is given in Table 1.

Table 1. Literature Review

GREEN LOGISTICS	REVERSE LOGISTICS	LEAN LOGISTICS
Bajdor (2012)	Sarkis, Helms & Hervani (2010)	Azevedo, Carvalho, Duarte & Cruz-Machado (2012)
Lai & Wong (2012)	Millet (2011)	Glover, Farris, Van Aken & Doolen (2013)
Seroka-Stolka (2014)	Lee & Lam (2012)	Sopadang, Wichaisri & Sekhari (2014)
Kumar (2015)	Rogers, Melamed, & Lembke (2012)	Tenescu & Teodorescu (2014)
Gülmez & Rad (2017)	Bing, Bloemhof-Ruwaard, & Van der Vorst, (2014)	Piercy & Rich (2015)
Mariano, Gobbo, Camioto & Rebelatto (2017)	Ramos, Gomes, & Barbosa-Póvoa (2014)	Pejić, Lerher, Jereb & Lisec (2016)
Rakhmangulov, Sladkowski, Osintsev & Muravev (2017)	Alshamsi & Diabat (2015)	Wichaisri & Sopadang (2017)
Aldakhil, Nassani, Awan, Abro & Zaman (2018)	Agrawal, Singh & Murtaza (2015).	Edirisuriya, Weerabahu & Wickramarachchi (2018)
Wang, Dong, Peng, Khan & Tarasov (2018)	Banihashemi, Fei, & Chen (2019).	Lambrechts, Son-Turan, Reis & Semeijn, (2019)

Boichuk, & Kauf (2019)	Boichuk & Kauf (2019)	Dey, Malesios, Chowdhury & Abdelaziz (2019)
Perkumienė, Pranskūnienė, Vienožindienė, & Grigienė (2020)	Peña-Montoya, Bouzon, Torres-Lozada & Vidal-Holguin (2020)	Ruiz-Benitez, López & Real (2019)
Seroka-Stolka & Ociepa-Kubicka (2019)	Budak (2020)	Rodríguez Cornejo, Cervera Paz, López Molina & Pérez-Fernández (2020)
Mete (2020)	Masudin, Fernanda, Jie & Restuputri (2021)	Cil, Demir & Yaman (2020)
Dzwigol, Trushkina & Kwilinski (2021)	Melo, Braga, Leite, Bastos & Nunes (2021)	Sanchez Rodrigues & Kumar (2019)
Mücevher (2021)	Pourmehdi, Paydar, Ghadimi & Azadnia (2022)	Gargalo, Pereda Pons, Barbosa-Povoa & Carvalho (2021)
Blanco & Sheffi (2024)	Sun, Yu & Solvang (2022)	Sopadang & Wichaisri (2021)
Nikseresht, Golmohammadi & Zandieh (2024)	Dabees, Barakat, Elbarky & Liseć (2023)	Rodrigues, Gomes & Bouzon (2023)
Nicoletti & Appolloni (2024)	Salas-Navarro, Castro-García, Assan-Barrios, Vergara-Bujato & Zamora-Musa (2024)	Erdal (2024)
Hoang, Tran, Huynh, Vo, Huynh, Tran, & Le Nguyen, (2025)	Oliveira, Silva, Junior, Mendes & Santa-Eulalia (2025)	Ivanova (2025)
Garg & Vemaraju (2025)	Rodrigues, Gomes, Peres, Correa & Baierle (2025)	Baro, Piña & Valdiviezo (2025).

Source: Table created by the author.

Sustainable logistics is a direction of modern logistics activity that aims to harmoniously combine economic, environmental and social aspects. Its effectiveness and success are based on the fundamental principles that ensure the long-term sustainability of economic activity. Taking this into consideration, the academic works given in Table 1. were selected the fundamental principles of sustainable logistics such as: environmental responsibility, economic efficiency, social responsibility, innovation and technological development, supply chain transparency and continuous sustainable development

2. Sustainability Concept and Logistics

In the current period, sustainability is grounding in preserving the natural environment and human life, as well as the continuity of their basic functioning and the fulfillment of their needs without losing future capacity. In the business context, sustainability refers to company's ability to operate over the long time and implies the introduction of such practices and strategies in business activities that ensure the conservation of natural resources, stable economic growth and social justice. practice shows that the majority of business activities directly affect environmental issues such as air pollution, climate change and ecological degradation. These problems are most evident during the direct production and delivery of already produced products to the final consumer. It is generally known that according to global indicators, approximately 60% of oil consumed in the world and 25% of energy come from the transport sector, which logically represents one of the main sources of direct impact on environmental sustainability (Rodrigue et al., 2006).

Many transport modes are involved in logistics operations which significantly harm the environment, and this circumstance creates a need for companies to carry out logistics operations in accordance with the principles of sustainable development. the concept of sustainable logistics requires the use of strategies and technologies that minimize emissions and waste into the environment, enhance operational efficiency and ensure the long-term sustainability of logistics systems. However, the discussion of sustainable logistics is

not limited to environmental aspects, other social and economic issues are considered together with environmental sustainability. Logistics sustainability and environmental issues, cost minimization, profit maximization and the opportunities for companies to grow, develop and progress. Considering all this, three priority areas take a special place in the process of sustainable development of modern logistics systems: green logistics, reverse logistics and lean logistics, which, through interconnected, but substantively different approaches, determine the sustainability of logistics operations. These strategies not only contribute to the balance of ecological and economic factors in logistics operations, but also address social responsibility, which makes them a long-term priority in current supply chains.

3. Priority Areas of Sustainable Logistics: Green logistics, Reverse logistics and Lean logistics

As mentioned above, sustainability of logistics is one of the most vital strategic directions of any economic activity, which aims to align environmental responsibility and economic efficiency. It is based on such integrated approaches as green logistics, reverse logistics and lean logistics. Together, these strategies create the basic framework of sustainable logistics and determine the long-term environmental and economic sustainability of logistics systems.

3.1 Green logistics

Green logistics is a model of logistics activities that aims to reduce environmental impact and promote efficient use of natural resources. It involves the introduction of environmentally friendly technologies, also improving transportation and storage processes, which ensures a decrease in the emission of harmful substances, lower energy usage and reduce waste (Zhu & Sarkis, 2007; Lai et al., 2012; Lambrechts et al., 2019; Garg & Vemaraju, 2025). Thus, green logistics is one of the crucial components in the process of achieving sustainable development goals, as it combines maintaining economic efficiency with environmental responsibility.

When it comes to social, economic, environmental issues and achieving sustainable development goals, green logistics practices include green supply, green distribution, eco-friendly packaging and some aspects of reverse logistics. Accordingly, the approach and management of green logistics can be considered as a process that includes green production management, green supply management, green raw material and inventory management, green distribution management, green marketing management and reverse green logistics activity management (Zhu & Sarkis, 2007; Lai et al., 2012; Mücevher, 2021).

Green logistics plays an important role in the entire supply chain process, as it ensures that all stages of the supply chain (from production to the final consumer) are carried out in compliance with environmental standards. In fact, green logistics in the supply chain integrates of environmental responsibility into all stages of business activities (Vasiliauska et al., 2013; Abduaziz et al., 2015; Mücevher, 2021).

Green logistics strategies include all stages of the supply chain, starting from the extraction of minerals and ending with the delivery of products to the final consumer. Moreover, it also takes place in the post-use (consumption) processes of products, namely in the processes of waste recycling and reinterpreting it. Thus, reverse logistics is part of the green logistics strategy, although in the modern world, reverse logistics is already recognized as an independent strategic direction from green logistics. Therefore, it is appropriate to discuss the issue in the paper independently of green logistics in the subsection of reverse logistics.

3.2 Reverse logistics

Reverse logistics refers to the logistics process that moves products and materials from the end consumer back to the supplier (manufacturer). The main purpose of reverse logistics is to reuse, recycle, repair or safely dispose of defective, returned products, as well as packaging materials in production. In contrast to the traditional logistics process, which focuses on the forward flow of goods from companies to consumers, reverse logistics is oriented towards the opposite flow and is an important component in ensuring the

ecological and economic sustainability of the enterprise (Sarkis et al., 2010; Agrawal et al., 2015; Mücevher, 2021; Rodrigues et al., 2025).

In the framework of sustainable logistics, reverse logistics is significantly importance. First of all, it promotes efficient resource utilization and reduced reliance on virgin raw materials, which allows enterprises to reduce their environmental impact and damage. Moreover, reverse logistics reduces industrial and consumer waste, which is directly related to global issues of waste management and environmental protection. Furthermore, recycling and reuse of materials not only bring environmental benefits, but also increase economic efficiency (Lee et al., 2012; Banihashemi et al., 2019; Budak, 2020; Pourmehdi et al., (2022); Dabees et al., 2023).

In the modern world, the implementation of reverse logistics principles by companies is also considered a top priority in terms of social and environmental responsibility, which enhances the reputation of companies and ensures that production companies with international standards. Thus, reverse logistics is one of the main pillars of sustainable logistics development strategies. It contributes to reducing environmental impact (damage), promoting efficient use of resources and minimization of waste. At the same time, reverse logistics creates greater economic benefits and new opportunities for both the manufacturer and society. Thanks to these characteristics that it is integrated into the ecological, economic and social goals of sustainable logistics.

3.3 Lean logistics

While all three strategies support the main purpose of sustainable logistics, lean logistics exhibits fundamental differences in comparison to green and reverse logistics. As previously discussed, green logistics is focused on minimizing environmental impact and implementing environmentally friendly technologies, whereas reverse logistics is concerned with the management of the product return, recycling and material reuse. Lean logistics emphasizes elimination of inefficiencies within logistics operations, the optimization of resource utilization and streamlining the entire supply chain. Its core principles is to perform only those activities that actually create value for the customer, while inefficient work processes and costs are eliminated or minimized (Cil et al., 2020; Mücevher, 2021; Baro et al., 2025).

In the academic literature, lean logistics is predominantly examined within the framework of economic sustainability, as it is directly associated with reducing operating costs and efficient use of resources. According to the definition given in the book “Supply Chain Logistics Management” by Donald et al. (2020): Lean logistics represents a management approach that aims to eliminate unnecessary costs and unnecessary actions in logistics processes. This approach emphasizes minimizing costs, optimal inventory flow management, executing processes, and cultivation of a work culture grounded in continuous improvement. Accordingly, Lean logistics services as a strategic tool that significantly enhance organizational efficiency and promotes close integration with the purpose of sustainable logistics (Azevedo et al., 2012; Piercy & Rich, 2015; Pejić et al., 2016; Wichaisri & Sopadang 2017; Dey et al., 2019; Erdal, 2024).

Thus, Lean Logistics, like Green and Reverse Logistics, is a strategic direction within sustainable logistics in the context of economic sustainability, and their combined implementation creates a comprehensive and multidimensional framework of logistics sustainability. Green logistics aims to minimize harmful impacts on the environment, including reducing emissions, using energy efficiently, and implementing environmentally friendly technologies. Reverse logistics focuses on the processes of returning, recycling, reusing, and safe disposal of used products, which significantly reduces waste and contributes to the efficient use of resources. Lean Logistics, focuses on simplifying operational processes, eliminating unnecessary activities, and optimizing costs. The integration of these three strategies creates an important prerequisite for ensuring the ecological, economic, and social sustainability of logistics systems.

Conclusions

Global warming, depletion of fossil fuels, energy crisis, environmental pollution, social inequality and increasing demands of growing population are closely related to the logistics chain. Therefore, the sustainable development of logistics systems in the modern world has become an inevitable necessity in light of the current ecological, economic and social challenges. High energy consumption, poor waste management, excessive carbon dioxide emissions and product supply processes are among the main contributors to environmental degradation. As a result, the logistics sector can no longer be considered only in terms of economic efficiency, it must address environmental aims and social responsibilities. Within the context, the implementation of sustainable logistics principles should be regarded not only as a strategic necessity, but also as one of the fundamental pillars in global business and social progress.

The three main strategies discussed in this paper, green logistics, reverse logistics and lean logistics, are key elements in promoting sustainability within logistics operations. green logistics, which focuses on reducing environmental impact, improving energy efficiency and responsible use of natural resources, serves as an environmentally responsible logistics approach. reverse logistics, on the other hand, enhance economic efficiency by maximizing waste, facilitating product return and reuse, ensures the fulfillment of environmental obligations. Lean logistics aims to optimize costs and streamline processes, which thereby improving operational efficiency and contributing economic sustainability. Therefore, the integrated use of these three strategies enables enterprises to reduce environmental pressure, enhance competitiveness, reduce costs, and fulfill necessary social responsibilities.

The findings of this study demonstrate that green, reverse and lean logistics are fundamental framework of sustainable logistics which is adaptable to modern business requirements and global challenges. Thus, the successful implementation of sustainable logistics strategies is not only an environmental priority, but also reflection of the company's long term strategic vision,. However, the practical realization of these strategies cannot be fully achieved by the initiative of the private sector alone. The active involvement of the state and international organizations, legal and economic support, funding of educational programs and encouragement of innovative projects are crucial for the successful implementation of the concept of sustainable logistics. Without public incentives, regulations, tax benefits, and technical assistance, sustainable principles risk remaining theoretical and failing to become a practical system. Thus, the development of sustainable logistics requires coordinated efforts and strategic engagement from the private sector, government, academia, and international organizations, as achieved by successful models in certain developed countries. Such integrated approaches provide the opportunity to develop logistics systems that contribute to economic progress, environmental sustainability, and socially responsible management at both the national and global levels.

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