Advanced Logistic Systems – Theory and Practice, Vol. 19, No. 2 (2025), pp. 41-52.
https://doi.org/10.32971/als.2025.010

SUSTAINABLE LOGISTICS: GREEN SOLUTIONS, TECHNOLOGIES AND CHALLENGES IN THE SERVICE OF INDUSTRIAL EFFICIENCY

SZABOLCS SZENTESI[1] – GÁBOR NAGY[2] – DÁNIEL KISS-SIMON[3],

Abstract: *This study explores the development opportunities of sustainable logistics systems, with a particular focus on environmentally friendly technologies and green solutions that enhance industrial efficiency. It provides a detailed overview of innovative technologies applicable in transportation and supply chain processes, emphasizing their impact on energy efficiency, cost optimization, and environmental load reduction. The analysis covers key Industry 4.0 tools, including the integration of IoT and artificial intelligence into logistics, as well as the applicability of alternative fuels and emission reduction strategies. The aim of the study is to formulate strategic guidelines and practical recommendations for integrating sustainability at all levels of logistics systems, thereby promoting both environmentally and economically efficient operations.*

Keywords: *sustainable logistics, green technologies, Industry 4.0, energy efficiency, environmental impact, digitalization, artificial intelligence*

1. INTRODUCTION

The primary aim of our study is to explore the development opportunities of sustainable logistics systems, with special attention to eco-friendly technologies and green logistics solutions that enhance industrial efficiency. Environmental sustainability has become a crucial factor in supply chain management today, as companies and logistics service providers increasingly strive to reduce their ecological footprint and comply with tightening environmental regulations. Our study provides a detailed presentation of green logistics technologies applicable to transportation processes, and their effects on improving resource efficiency, optimizing costs, and reducing environmental impacts. We believe that achieving sustainable industrial logistics is a complex challenge that requires an integrated approach and close cooperation among suppliers, production processes, and distribution system actors.

We specifically examine technological innovations that enhance energy efficiency, solutions that serve emission reduction, and the applicability of transportation systems based on alternative fuels. We also analyse the role of digitalization, especially the integration of IoT (Internet of Things) and artificial intelligence into logistics processes, which can significantly contribute to reducing fuel consumption and greenhouse gas emissions. Industry 4.0 technologies – such as smart sensor networks, real-time data collection systems, and automated predictive maintenance solutions – enable continuous monitoring and optimization of manufacturing and logistics infrastructures. In logistics practice, these tools support real-time tracking of shipments, improved inventory management efficiency, and control of environmental parameters (e.g., temperature, humidity), which is particularly important for sensitive goods.

[1] senior lecturer University of Miskolc, Institute of Logistics, Hungary
szabolcs.szentesi@uni-miskolc.hu
[2] senior lecturer, University of Miskolc, Institute of Logistics, Hungary
gabor.nagy4@uni-miskolc.hu
[3] BSc student, University of Miskolc, Institute of Logistics, Hungary
daniel.kiss.simon@student.uni-miskolc.hu

Our work not only presents current application examples but also makes recommendations for future development directions. We pay particular attention to how sustainability can become a strategic element of logistics systems and corporate operations. Our research provides concrete proposals for the cost-effective integration of environmental objectives at all levels of logistics planning, operation, and feedback. Our goal is to contribute to the widespread industrial adoption of green logistics solutions, supporting the reduction of ecological footprint, improvement of economic performance, and long-term enhancement of corporate competitiveness.

2. Green Solutions and Efficiency Improvement in Transportation and Industry

Green solutions and increasing industrial efficiency are becoming urgent challenges in addressing global environmental issues such as climate change and pollution. The industrial sector plays a key role in shaping sustainable production and consumption, making it essential for companies to adopt environmentally friendly technologies and practices. The principles of sustainable development not only carry environmental but also economic benefits: optimized resource use, waste reduction, and the integration of renewable energies contribute to increased competitiveness. Automation, IoT, and other technological innovations are crucial in achieving sustainability goals while also offering cost savings and new market opportunities. The scientific community has conducted numerous studies in the fields of green logistics, sustainable supply chain management, and innovative industrial practices, shedding light on long-term benefits, some of which I would like to present.

Alan McKinnon and his co-authors provide a comprehensive overview of improving the sustainability of the logistics sector, particularly focusing on reducing the environmental impacts of transportation and storage systems. The book analyses how to mitigate the harmful emissions of logistics processes while maintaining service levels and efficiency. The authors examine a variety of challenges and opportunities, including emission reduction, energy efficiency, and alternative fuels. In the early chapters, the book introduces the environmental impact of logistics activities, showing the level of carbon dioxide emissions and the main sources of environmental burdens in the industry. The subsequent sections provide a detailed analysis of individual logistics links: transportation routes, warehousing, inventory management, and waste management, focusing on their sustainability aspects.

The authors specifically address the significance of route optimization, which helps reduce fuel consumption by decreasing transportation distances. Additionally, they analyse sustainable packaging methods and eco-friendly materials that can reduce waste and the ecological footprint of logistics activities. The authors emphasize the role of innovation in increasing logistics sustainability, such as the use of drones and electric vehicles for transportation. They also discuss the use of alternative fuels, with particular attention to biofuels and hydrogen, which have the potential to reduce carbon dioxide emissions. The authors highlight the role of data-driven technologies such as GPS and IoT in optimizing logistics processes, as well as the use of artificial intelligence for forecasting and enhancing efficiency. Special attention is given to governmental regulations and incentives that could support the spread of green logistics solutions and help companies achieve sustainability goals. The authors also stress the role of consumer demand and social responsibility, which are increasingly putting pressure on companies to implement environmentally friendly solutions. Finally, the authors provide practical examples from different companies that

successfully apply green logistics solutions, offering inspiration to readers. With its comprehensive and practical approach, the book is a valuable resource for those wishing to incorporate sustainability aspects into their logistics processes. DHL, FedEx, and UPS sustainability reports provide illustrative examples of how these leading logistics companies strive for environmentally friendly operations and reduce their ecological footprint [1].

The logistics sector, which consumes a massive amount of energy, generates significant carbon dioxide emissions. These companies are working to mitigate these effects by applying various green technologies and strategies. The sustainability programs outlined in each company's reports address the use of alternative fuels, the optimization of transportation routes, and the search for sustainable packaging solutions.

DHL's report highlights the GoGreen program, which aims to make the company carbon-neutral by 2050. To achieve this, DHL has introduced alternative-powered vehicles, such as electric and hybrid vehicles, especially along urban transport routes (Fig. 1). Additionally, GPS-based route planning allows vehicles to follow the most efficient routes, reducing fuel consumption and harmful emissions. DHL also applies sustainable packaging solutions, minimizing waste and reducing the environmental impact of logistics activities. Following circular economy principles, they encourage their partners and customers to use recyclable materials, contributing to strengthening sustainability at the industry level [2].

Figure 1. DHL Electric Delivery Vehicles [3]

FedEx has also developed numerous strategies to reduce its environmental impact, with the most notable being the FedEx Fuel Sense program. The goal of this program is to optimize fuel use in both air and ground operations, saving significant amounts of energy. The company is continuously expanding its electric and hybrid vehicle fleet, which ensures greater energy efficiency, especially in urban traffic. In addition, energy-efficient aircraft used in air transport help reduce carbon dioxide emissions.

FedEx is also making further efforts to deploy and utilize renewable energy sources, such as solar energy for the operation of certain package distribution centres (Fig. 2). These

measures collectively represent significant progress toward achieving the company's sustainability goals [5].

Figure 2: FedEx Delivery Aircraft [4]

UPS aims to meet its green objectives through carbon-neutral shipping and the introduction of environmentally friendly packaging. One of the company's most important programs is the Orion route planning system, which uses artificial intelligence to minimize fuel consumption. The system, which operates with advanced algorithms, can optimize vehicle routes, considering traffic data and the sequence of individual shipments. Additionally, UPS offers customers the option of carbon-neutral shipping, enabling them to offset emissions through the purchase of carbon credits. The company places significant emphasis on the sustainability of packaging as well: it uses materials that are recyclable or easily biodegradable, significantly reducing packaging waste [6].

The sustainability reports of these three major companies clearly demonstrate that for companies operating in the logistics sector, environmental protection and the reduction of carbon footprints are of paramount importance. The active involvement of leading logistics providers in green innovations sets examples that can be followed by other industries. All three companies face similar challenges and, though using different tools, are developing their services with the same goal: to ensure efficiency, reduce emissions, and meet the societal and industry expectations for sustainability with eco-friendly technological innovations. The lesson from these reports is that sustainability and efficiency are not only compatible but can mutually reinforce each other, creating long-term value for the logistics industry.

Black (2010) primarily deals with the sustainability challenges of transportation and their possible solutions. The authors provide a comprehensive analysis of the environmental impacts of transportation systems, including carbon dioxide emissions and other pollutants. The book emphasizes that the transportation sector is responsible for a significant portion of global carbon dioxide emissions, which makes finding more sustainable solutions urgent. The authors also introduce the concept of sustainable transportation, which encompasses the

balance between economic, social, and environmental considerations. The book suggests various solutions, such as the use of renewable energy sources, the spread of electric vehicles, and the development of public transportation. Additionally, it highlights the importance of urban planning, which plays a key role in reducing transportation demand and facilitating sustainable solutions. The study thoroughly discusses environmental impacts and outlines the measures that policymakers and industry players must take to achieve sustainability goals. The book also provides insights into the innovations and technologies that can be applied in transportation systems to increase efficiency. Furthermore, it emphasizes the importance of transitioning between transportation modes, such as promoting walking, cycling, and public transportation. The book pays special attention to the sustainability of transportation infrastructure, which is essential for implementing green transportation solutions. It analyses transportation policies and offers recommendations that can help cities and regions build sustainable transportation systems. The authors highlight that sustainability is not only about environmental considerations but also about promoting social justice and economic competitiveness [7].

3. SUSTAINABILITY PRINCIPLES IN LOGISTICS

Sustainability principles today play a crucial role in logistics, as global environmental challenges demand the implementation of green and efficient solutions. The optimization of logistics processes aims not only to reduce costs but also to mitigate environmental impacts. Resource efficiency, waste reduction, and energy conservation all contribute to sustainable operations, which have now become expectations from both economic and social responsibility perspectives. Prioritizing local resources and choosing alternative modes of transport across the supply chain can reduce emissions. Digital technologies – such as automation and big data – enable further refinement of planning and operations. Therefore, sustainability is not just a trend, but a strategic advantage and the foundation for the future of logistics. This is addressed in numerous research studies.

Grant and his co-authors discuss sustainability in logistics and supply chain management. The book addresses the principles of sustainability and their practical implementation, with a particular focus on environmental, social, and economic aspects. The authors emphasize that sustainability is not just a trend but a fundamental requirement in the modern business world. The book presents the connection between green logistics and sustainable supply chain management, highlighting that both aim to minimize environmental impacts. In addition to theoretical frameworks, the book also includes practical case studies that illustrate the success of sustainability initiatives. The authors place special emphasis on optimizing logistics processes, which creates opportunities to reduce costs and increase efficiency. Among the sustainable logistics practices mentioned are green transportation, waste management, and energy efficiency. The book emphasizes the role of technological innovations, such as IoT and big data, in promoting sustainability. The authors also point out that companies must treat sustainability as a strategic aspect to create a competitive advantage. Applying sustainability principles is important at every stage of the supply chain, from suppliers to end-users. The book guides the reader through the latest research findings and practices that serve the development of sustainable logistics. Moreover, the authors highlight the business benefits of sustainability measures, such as improving brand reputation. The case studies in the book cover a wide range, spanning different industries and companies. The book provides not only a scientific but also a practical guide for companies

looking to integrate sustainability into their logistics strategies. The authors also emphasize the importance of corporate social responsibility, encouraging companies to actively contribute to the development of their communities. Overall, the book offers a comprehensive overview of sustainability principles in logistics and provides practical guidance for successful implementation [8].

Sezen and Çankaya discuss the theoretical framework and practical applications of green supply chain management. The authors highlight that environmental sustainability has become a core element of modern business practice, and it is essential for companies to establish a sustainable supply chain. The book reviews the concept of green supply chains, which focuses on minimizing environmental impacts at every stage of the supply chain, from raw material sourcing to manufacturing and final distribution. The authors present the role of green logistics in supply chain management and how sustainability principles can be integrated into various logistics processes. The case studies included in the book show examples of how green solutions were applied in different industries and the benefits achieved as a result. Sustainability practices include waste management, recycling, and increasing energy efficiency, all of which contribute to reducing environmental burdens. The authors emphasize the importance of technological innovations, such as IoT and automation, in green supply chain management. The book also mentions the role of collaboration and partnerships between companies, as these can help achieve sustainability goals. The authors point out that green supply chain management is not only about environmental benefits but also offers business advantages, such as cost reduction and increased competitiveness. The book also discusses the significance of green procurement policies that support the selection of sustainable products and services. Green supply chain management offers an integrated approach that considers environmental, social, and economic aspects. The authors also emphasize that successful future business strategies cannot be separated from sustainability. Through the theoretical frameworks and practical solutions presented in the book, readers can understand how to effectively apply green supply chain management to create competitive advantages. Overall, the publication provides a comprehensive guide to the theory and practice of green supply chain management and highlights the significance of sustainability in the future business world [9].

Based on the literature presented above, sustainable logistics is significant not only from an environmental perspective but also from economic and strategic points of view. Through eco-conscious transportation, automated technologies, and resource efficiency, logistics systems become not only more sustainable but also more competitive. The intersection of sustainability and innovation opens new horizons for industrial operations, where environmental protection and economic benefits go hand in hand.

4. GREEN SOLUTIONS IN TRANSPORTATION

The application of green transportation solutions is one of the most important logistical responses to the challenges posed by climate change and sustainability requirements. Traditional transportation systems' high emissions and energy consumption significantly contribute to the increase in greenhouse gases. In contrast, sustainable transportation aims to reduce the environmental footprint while maintaining the efficiency of the supply chain. The rise of electric and hybrid vehicles is becoming increasingly common, as they are not only environmentally friendly but also enable more cost-effective long-term operation.

Key elements of sustainable logistics include rail and water transport, which, with their lower emissions, can move larger volumes of goods. The railway plays a key role in energy-efficient transportation. The application of multimodal systems, which combine multiple modes of transport, also promotes environmentally friendly and efficient transportation.

Digital technologies – such as IoT-based tracking, data-driven route planning, and real-time traffic analysis – enable the optimization of transportation, reducing fuel consumption and time losses. Intelligent systems mitigate emissions during peak hours through better timing. Additionally, eco-friendly packaging – such as recyclable or compostable materials – further reduces the ecological burden and costs. Sustainable warehouse operations (e.g., energy-efficient lighting, temperature regulation) also contribute to the green logistics chain.

Environmentally conscious operations are now not only a requirement but also a market advantage. Companies that follow sustainability principles can gain a competitive edge, improve their image while comply with regulations. Green transportation not only protects the environment but also contributes to the long-term sustainability of the logistics sector. Numerous studies are underway on this topic, offering new approaches to green transportation.

"Banister and his co-author discuss the environmental impacts of modern transportation systems and the possibilities for managing them. The focus of the book is to demonstrate how transportation can become sustainable, considering economic, social, and environmental aspects. Banister provides a detailed analysis of how transportation contributes to carbon dioxide emissions, greenhouse gas production, and global warming…" – The author emphasizes the importance of transforming technological, social behaviours, infrastructure, and urbanization. He highlights the role of multimodal systems, route optimization, and public transportation, while seeing the sustainability of urban transportation as achievable through comprehensive interventions. The book discusses the relationship between transportation and the environment in a readable yet professionally grounded manner, especially focusing on aspects relevant to logistics [10].

"Psaraftis focuses on integrating sustainability into freight logistics, emphasizing the urgent need for environmentally conscious practices in the industry… The goal of the book is to show how to balance economic viability and ecological responsibility…" – The author presents practical strategies for green logistics, such as using alternative fuels, optimizing routes, and integrating technological solutions like telematics and automation. Analysing political and regulatory frameworks is also an important element of the work, which offers a practical and systemic approach for decision-makers and industry players [11].

Based on the above, the greening of transportation logistics is not only an environmental necessity but also a strategic and economic requirement. Environmentally friendly technologies, alternative fuels, intelligent systems, and digitalization together enable the alignment of industrial efficiency and sustainability. The following chapters provide a more detailed presentation of these solutions.

5. TOOLS AND TECHNOLOGIES

Modern companies aim to achieve a balance between sustainability and economic efficiency through technological tools. Digital solutions, such as big data and the Internet of Things (IoT), play a key role as they enable real-time data collection and analysis. IoT devices – such as sensors and GPS trackers – assist in route optimization, reducing fuel consumption and CO_2 emissions [12].

An essential element of green logistics is the use of environmentally friendly vehicles (e.g., electric, hybrid), which operate with lower emissions and reduced operating costs. Regenerative braking increases energy efficiency [11]. Automated systems (e.g., robotic warehousing) speed up processes, reduce errors, and lower energy consumption [13].

Waste management and recycling offer cost savings and environmental benefits: companies can reduce raw material usage through processing equipment [14]. Green procurement and sustainable material use support corporate environmental goals [12]. Biodegradable and recyclable packaging, as well as minimalist solutions, reduce waste and shipping volume.

Integrating green technologies serves both environmental protection and economic performance. Sustainability now provides a competitive edge and strengthens corporate social responsibility.

5.1. Industry 4.0 Technologies in Logistics

Industry 4.0 is based on automated, networked systems where devices sense, communicate, and make decisions. The goal of data-driven manufacturing is to maximize efficiency and decentralize operations [15].

- **Big Data**: Managing vast structured and unstructured datasets – behaviour analysis, simulations, industrial process planning [16].
- **Artificial Intelligence (AI)**: Machines perform tasks requiring human intelligence – such as learning and decision-making [17].
- **M2M (Machine to Machine)**: Direct data exchange between machines without human intervention – wired or wireless connection (IoT) [18].
- **IoT (Internet of Things)**: Networked smart devices for data collection and control – used in industries like manufacturing, agriculture, and transportation [19].
- **V2V (Vehicle to Vehicle)**: Information exchange between vehicles – location, speed, direction, accident prevention [20].

5.2. Logistics 4.0 – Digital and Networked Logistics Systems

Logistics 4.0 integrates digitalization, cloud-based systems, and networked collaboration into logistics processes. Its task is to coordinate and optimize the entire supply chain [21]. When logistics can be integrated into the supply chain at an earlier stage, just-in-time production can be optimized. On the other hand, carriers expect greater planning security, better fleet utilization, and shorter waiting times at loading points. The goal is low per-unit costs and fast turnaround times for customized production.

6. MATHEMATICAL MODELLING IN SUSTAINABLE LOGISTICS

6.1. CO_2 Emissions Calculation for Diesel and Electric Vehicles

One of the main objectives of sustainable logistics is reducing carbon dioxide (CO_2) emissions. The difference between diesel and electric vehicles can be clearly demonstrated by estimating annual CO_2 emissions. The following simple model can be used to calculate the yearly emissions of a vehicle:

$$CO_2 = D \times C \times E \tag{1}$$

where:

- **D** – daily distance travelled (km),
- **C** – fuel consumption (l/km),
- **E** – CO_2 emission per litre of diesel fuel (on average 2.63 kg/l).

Using the above formula, the following example can be calculated: daily distance of 100 km, fuel consumption of 0.3 l/km, 250 working days/year: **Annual CO_2 = 100 × 0.3 × 2.63 × 250 = 19,725 kg.**

6.2. The Role of Route Optimization in Sustainability, Cost-Benefit Analysis of Green Investments

Optimizing transportation can save a significant amount of fuel and, consequently, CO_2. The most well-known route optimization algorithm is Dijkstra's algorithm, which calculates the shortest path from one node to others. In practice, modern route planning software applies this algorithm combined with real-time traffic data, increasing energy efficiency.

The return on investment of sustainable technologies – such as electric vehicles – can also be evaluated financially using the Net Present Value (NPV) method:

$$NPV = \Sigma (B_t - C_t) / (1 + r)^t \quad (2)$$

where:

- B_t – annual savings [EUR],
- C_t – annual cost [EUR],
- **r** – discount rate,
- **t** – year of the period.

It is important to note that an investment is worthwhile if the NPV is positive.

There are also simple Excel-based models. In one Excel simulation, we modelled two types of routes. The results showed that a 12% reduction in route length led to a 14% reduction in fuel consumption, resulting in 2 tons of annual CO_2 savings for five vehicles. Logistics simulations — such as Plant Simulation or Arena — enable the analysis and optimization of complex systems, thereby supporting sustainable operations.

6.3. Energy Efficiency Indicator in Logistics

Logistics efficiency can also be measured with quantitative indicators, such as the ratio of transported mass to energy consumption:

$$\eta = M_T / E_C \quad (3)$$

where:

- M_T – Total transported mass (kg),
- E_C – Energy consumed (kWh).

This indicator is particularly important for electric and alternative fuel vehicles, where energy efficiency is a key competitive factor.

7. CORPORATE SOCIAL RESPONSIBILITY (CSR) IN SUSTAINABLE LOGISTICS

CSR is becoming an increasingly influential factor in logistics, as companies now assume not only economic but also social and environmental responsibilities. CSR activities in logistics can be divided into three main areas:

- **Environmental CSR**: emission reduction, sustainable packaging, use of alternative fuels.
- **Social CSR**: employee well-being, education, equal opportunities.
- **Economic CSR**: ethical sourcing, support for local partners, operational transparency.

These initiatives contribute to competitiveness, brand building, customer loyalty, and employee retention. Successful programs include the support of public transport, environmental education, carbon-neutral options, and involvement of local communities.

Challenges of Sustainable Logistics
Implementation may face technological, economic, and societal barriers. IoT-related security risks, high investment costs, and concerns over job displacement due to automation can hinder progress. Therefore, sustainability is not only a technical but also an organizational and cultural challenge.

Green Strategies and Future Outlook
Leading logistics companies – such as DHL, FedEx, and UPS – employ alternative vehicles, route optimization, and sustainable packaging to varying extents. The logistics of the future will be shaped by green hydrogen, autonomous vehicles, carbon credits, and digital twins. By 2035, systems based on real-time communication and automated decision-making using renewable energy are expected to become widespread.

CSR in Procurement Logistics
CSR is also important in procurement decisions: companies prefer partners who comply with labour and environmental standards. "Green procurement" supports local economies, reduces transportation distances, and improves supply chain resilience.

Digital CSR Solutions
Digitalization enables real-time monitoring of CSR aspects. Sensor networks, cloud systems, blockchain, and AI assist in measuring sustainability performance. Predictive analytics enable early risk detection. Digital CSR supports the preparation of ESG reports and strengthens transparency.

8. SUMMARY

The aim of this study was to explore the synergy between sustainability and digitalization in the development of logistics systems. Special attention was given to environmentally friendly technologies, Industry 4.0 tools, and the application of corporate social responsibility (CSR) in logistics. Green logistics solutions – such as alternative fuel vehicles, energy-efficient packaging, route optimization, and recycling – simultaneously promote environmental sustainability and economic efficiency.

The application of big data, IoT, artificial intelligence, and predictive algorithms enables real-time control and process optimization. CSR is not only a branding tool but has become a strategic component of logistics operations. Concrete forms of environmental, social, and economic responsibility – such as carbon-neutral transport, support for employee well-being and ethical sourcing – greatly contribute to long-term competitiveness. However, implementing sustainability remains a complex challenge: high technological investment costs, data security risks, and the need for societal mindset shifts may slow the transition. These obstacles are especially significant for small and medium-sized enterprises. The future of logistics is expected to be digitalized, autonomous, and zero-emission, where systems communicate in real-time and decisions are made by automated processes. Digital CSR solutions – such as blockchain-based records and ESG audits – will redefine transparency and accountability. In summary, sustainable and responsible logistics is not merely a trend but an operational necessity. Companies must integrate technological innovations with social and environmental expectations to build long-term viable and competitive systems.

REFERENCES

[1] McKinnon, A., Browne, M., Whiteing, A. & Piecyk, M. (Eds.). (2015). *Green logistics: Improving the environmental sustainability of logistics.* Kogan Page Publishers.

[2] DHL: *Our sustainability approach*. Retrieved from https://group.dhl.com/en/sustainability/sustainability-roadmap.html (2025.05.05.)

[3] Logisztikai hírek. *E-Transit furgonokkal duplázza meg elektromos flottáját Budapesten a DHL.* Retrieved from https://logisztikaihirek.hu/e-transit-furgonokkal-duplazza-meg-elektromos-flottajat-budapesten-a-dhl/ (2025.05.05.)

[4] 3BLMedia: *Every Drop Counts at FedEx.* Retrieved from https://www.3blmedia.com/news/every-drop-counts-fedex

[5] Fedex: *Our three-part initiative to advance environmental stewardship*. Retrieved from https://www.fedex.com/en-us/sustainability.html (2025.05.05.)

[6] UPS: *Sustainability*. Retrieved from https://about.ups.com/us/en/our-impact/sustainability.html

[7] Black, W. R. (2010). *Sustainable transportation: problems and solutions*. Guilford Press.

[8] Grant, D. B., Wong, C. Y. & Trautrims, A. (2017). *Sustainable logistics and supply chain management: principles and practices for sustainable operations and management*. Kogan Page Publishers.

[9] Sezen, B. & Çankaya, S. Y. (2018). Green Supply Chain Management Theory and Practices. In I. Management Association (Ed.), *Operations and Service Management: Concepts, Methodologies, Tools, and Applications* (pp. 118-141). IGI Global Scientific Publishing.. https://doi.org/10.4018/978-1-5225-3909-4.ch006

[10] Hickman, R. & Banister, D. (2019). Transport and the environment. In *A Research Agenda for Transport Policy* (pp. 25-33). Edward Elgar Publishing. https://doi.org/10.4337/9781788970204.00011

[11] Psaraftis, H.N. (ed.) (2016) *Green Transportation Logistics: The Quest for Win-Win Solutions*. Cham: Springer International Publishing (International Series in Operations, https://doi.org/10.1007/978-3-319-17175-3

[12] Manners-Bell, J. & Lyon, K. (2019) *The logistics and supply chain innovation handbook: disruptive technologies and new business models*. 1st Edition. New York: Kogan Page Ltd.

[13] Chopra, S. & Meindl, P. (2016). *Supply chain management: Strategy, Planning, and Operation*. Global edition. Pearson. Boston

[14] Seuring, S. & Gold, S. (2013). Sustainability management beyond corporate boundaries: from stakeholders to performance. *Journal of cleaner production*, **56**, 1-6, https://doi.org/10.1016/j.jclepro.2012.11.033

[15] Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of cleaner production*, **252**, 119869. https://doi.org/10.1016/j.jclepro.2019.119869

[16] Khan, M., Wu, X., Xu, X. & Dou, W. (2017, May). Big data challenges and opportunities in the hype of Industry 4.0. In *2017 IEEE International Conference on Communications (ICC),* 1-6, https://doi.org/10.1109/ICC.2017.7996801

[17] Krantz, S., Rao, A. S. S. & Rao, C. R. (2023). *Artificial intelligence*. Elsevier Academic Press.

[18] Verma, P. K., Verma, R., Prakash, A., Agrawal, A., Naik, K., Tripathi, R., Alsabaan, M, Khalifa, T., Abdelkader, T. & Abogharaf, A. (2016). Machine-to-Machine (M2M) communications: A survey. *Journal of Network and Computer Applications*, **66**, 83-105, https://doi.org/10.1016/j.jnca.2016.02.016

[19] Madakam, S., Ramaswamy, R. & Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications*, **3**(5), 164-173, https://doi.org/10.4236/jcc.2015.35021

[20] Demba, A. & Möller, D. P. (2018). Vehicle-to-vehicle communication technology. In *2018 IEEE international conference on electro/information technology* (EIT), 0459-0464, https://doi.org/10.1109/EIT.2018.8500189

[21] Winkelhaus, S. & Grosse, E. H. (2020). Logistics 4.0: a systematic review towards a new logistics system. *International Journal of Production Research*, **58**(1), 18-43, https://doi.org/10.1080/00207543.2019.1612964