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SUSTAINABLE INNOVATIONS TO RAISE QUALITY 5.0 IN THE TRANSPORT AND LOGISTICS COMPLEX: INTERNATIONAL EXPERIENCE AND MANAGERIAL PERSPECTIVE

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A B S T R A C T

The perspectives on the sustainable development of the transport and logistics complex include the need to minimise the environmental impact and increase social needs satisfaction.

Transport and logistics are the main components of the country's socioeconomic development (Sumbal et al., 2023). The key to success in the logistics sector lies in cooperation between humans and machines.

Sustainable transport in logistics involves implementing practices and technologies that substantially reduce the environmental impact of transport and distribution activities. Sustainable transport aims to minimise greenhouse gas emissions, reduce air and water pollution, and optimise resource use. Integration of innovations and sustainable development is important for the optimisation of logistic operations and the growth of effectiveness and support of companies in achieving the Sustainable Development Goals. A successful transition to more sustainable logistics requires such approaches as the integration of eco-friendly technologies, an increase in renewable energy use, and the promotion of digital solutions to raise effectiveness.

Technological progress, combined with the development of environmental awareness and regulatory requirements, stimulates the fundamental evolution in this sector. Quality 5.0 in the transport and logistics sector combines leading technologies, such as artificial intelligence, machine learning, and blockchain, with an approach that is oriented towards humans and sustainable development. The new approach puts emphasis on cooperation between humans and machines to create more effective and sustainable supply chains. Quick technological changes and the increasing needs of consumers are the main drivers of digital transformation. Logistics and transport companies have to accelerate the implementation of models that are based on data analysis, to use new market opportunities to the largest extent.

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1. INTRODUCTION

Logistics is a term that is widely used to describe the transportation and storing and processing of products during their movement from the raw materials sources, through the production system to the final point of sales or consumption.

Transport infrastructure has a decisive role in the economic development of regions and cities, with different types of transport having their pros and cons (Ngcobo et al. 2024).

Over the recent years, against the background of increasing concern of the public and government due to the state of the environment, the company have been facing increasing pressure regarding the reduction of the impact of their logistic operations on the environment. According to the International Transport Forum, logistics accounts for almost 8% of the world's greenhouse gas emissions. This impact is different from the position of the range of external effects and distances at which the negative impact is felt. The focus on sustainable development stimulates innovations, for companies seek new solutions to reduce their influence on the environment. These innovations are beneficial for the environment and can ensure a competitive advantage in the market, which is concerned with sustainable development. It is important to invest in R&D to develop innovative solutions, which are effective and economically profitable at the same time.

The goal of the sustainable development of transport is to reduce the negative impact on the environment and support society's needs for mobility in such a way as not to worsen the needs of future generations (Etukudoh et al., 2024). At present, among the strategies of sustainable development management, the primary role belongs to the strategy of human resources development management based on corporate social responsibility. Achievement of sustainable development is possible only by a group of like-minded individuals and only in case of completion of optimal (in the achievement of the Sustainable Development Goals) business processes.

Logistics and quality management are general processes of the organisation of production at companies. They are aimed at raising the effectiveness of the use of the available material, financial, information, and human resources in the supply chain. Quality determines which products and services must be produced according to the demands and standards and consumers. Logistics determines how the necessary levels of production, organisation of processes, and expenditures are achieved. The basis of the development of the transport and logistics complex is the need for close interaction with almost all sectors that produce goods and services and the possibility for quick adaptation to possible changes in the sector.

Though the types of services, which are required in the sector, change very often, they are also diversified due to the digitalisation of industrial processes. At present, Industry 5.0 technologies are integrated into the transport and logistics complex.

Transformation in the direction of sustainable transport requires integrated approaches, which unify many interested parties around common goals. These approaches must contribute to the comprehensive and complex analysis of different dimensions, including risks and vulnerability and the influence on the environment, which can help with systemic identification and development of integrated solutions.

Now companies face difficult logistic problems. Growth of supply volumes, lack of drivers, and fuel price fluctuations require technological solutions that raise effectiveness and improve results. A synergy of logistics and technologies is a sign of a smart era, in which companies use technologies, including robots, cloud computing, and the Internet of Things, to obtain, compare, and analyse data.

The objective of this paper is to elaborate on sustainable innovations which are to raise Quality 5.0 in the transport and logistics sector. This topic is disclosed by the example of international experience and from the position of management aspects.

2. LITERATURE REVIEW

Niewiadomski and Merkisz-Guranowska (2024) presented a strategy for the sustainable production of parts and components for agricultural transport. The authors focused on the minimisation of production costs and waste formation after production and offered an optimisation model for the selection of resources and use of waste after production to achieve economic and environmental savings. The proposed approach minimises production costs and reduces waste formation after production, achieving economic effectiveness and environmental sustainability.

Sun et al. (2023) presented the key segments that contribute to the creation of a digital twin of reverse logistics, which can support decision-making in a complex and uncertain environment, and presented a systemic conceptual basis for a digital twin of reverse logistics to fill literature gaps.

Audonin et al. (2020) considered modern transport and logistics projects, railroad and maritime, in Eurasia and disclosed the trends of air transport development. The authors focused on such projects' influence on the economic growth of the region's countries and international processes and demonstrated the impact of logistic projects on the national economy.

Villar et al. (2023) used a systemic analysis of literature to study the influence of Industry 5.0 on the sector of supply chain research and ensured a comprehensive understanding of the key concepts, technologies, and trends, which determine supply chain 5.0. The scholars demonstrated the advantages of this new paradigm for organisations and contributed to the value of the supply chain management sector, describing the potential of supply chain 5.0 and emphasising the importance of integrating sustainable practices and principles of human-centric design into the supply chain.

Shamsuddoha et al. (2025) dwelt on the role of forecasting the key components of Transportation 5.0 in a sustainable transport system and considered the cause-and-effect model within modelling the systemic dynamics to solve the issues of sustainable development and movement towards sustainable development in the context of Transportation 5.0. Transportation 5.0 is a change in paradigm in favour of sustainable mobility. It will allow solving the problem of transport's increasing influence on the environment and will provide practical means to raise operational effectiveness and environmental sustainability with the help of green technologies.

Ngcobo et al. (2024) assessed the problems of implementing the principles of sustainable development in the transport infrastructure of South Africa and emphasised the necessity for expansion and modernisation of the transport and logistics complex given the growth of population and an increase in economic activities. This research showed the importance of improving coordination between stakeholders, including public authorities, the private sector, and the community.

Khayari and Kassim (2019) provided insights into the level of service quality in the aviation sector, given the expected level of passenger services and effectiveness of services, stating that improvement of quality is a factor contributing to the differentiation of services and competitiveness in the aviation sector.

Sultanova (2021) examined the specifics of financial flow management at railroad transport, including the classification of financial flows of Uzbek Railways JSC, consolidated budgeting, and tax flow management. According to Nicoletti and Appolloni (2024), a green approach and Logistics 5.0 are important steps towards sustainable development, innovations, and entrepreneurship. By agreeing logistical operations with the criteria of sustainable development, logistics organisations can achieve substantial environmental advantages, raising operational effectiveness. The scholars studied the problems of implementing AI algorithms, such as initial investments, compliance with regulatory demands, and technological integration.

Hsu et al. (2024) stated that Industry 5.0 can facilitate the transition to smart logistics with the help of thirteen interconnected factors. The transformation potential of the leading technologies of Industry 5.0, including the Internet of Things, artificial intelligence, Big Data, and other innovations, has a positive effect on the development and improvement of smart logistics. These technologies play an important role in the optimisation of the logistics system and an increase in its effectiveness.
Schmidt and Schmidt (2019) presented the role of packaging in logistic processes: transportation, storing, loading, and packaging, with special emphasis on sustainable development. According to the scholars, the development of environmental thinking is very important, while handling packaging is the initial stage of this thinking. All interested parties, including companies and consumers, must develop based on environmental awareness.

Trstenjak et al. (2022) develop a model based on the system of decision support for Logistics 5.0 (including such aspects as green storage, green transport, green packaging, infrastructure, and organisation, as well as human resources.

3. RESULTS

The main specific feature of Logistics 5.0 is its approach to the harmonious integration of human intellect and technologies. Instead of simple automatization of processes, it creates an environment in which employees and machines supplement each other. For example, robots can perform routine tasks in storage, while humans focus on strategic planning and interaction with customers.

Sustainable development in the transport and logistics complex is not just adaptation to regulatory demands but also numerous opportunities: from the reduction of CO_2 emissions and growth of economic effectiveness to support of innovations and increase in competitiveness. Companies that make their processes sustainable at early stages receive important long-term advantages and minimise their risks.

Sustainable logistics offer additional advantages, which are often omitted. Employees can enjoy a better working environment, knowing that their company contributes to the planet's development. Customers value companies that take care of the environment. This also helps form a positive image of the brand, which also might bring more clients.

Table 1. Top 10 sustainable companies in transport and logistics

	Company	Employees	Revenue (2024), $/€ billion
1.	Amazon (USA)	798,000	$637.95
2.	DHL Group (Germany)	504,000	€84.18
3.	UPS (USA)	377,000	$91.07
4.	FedEx (USA)	374,000	$87.39
5.	IKEA (Ingka Group) (Netherlands)	231,000	€45.1
6.	A.P. Moller – Maersk (Denmark)	83,500	$55.5
7.	XPO Logistics (USA)	38,000	$7.7
8.	Evri (UK)	31,700	$1.3
9.	DPD / Geopost (France)	57,000	€15.8
10.	Brambles (Australia)	12,000	$6.54

Source: Compiled by the authors based on Birch (2024) and CompaniesMarketcap.com (2025)

According to Darley (2025), the top 10 sustainable fleets are FedEx (USA), XPO Logistics (USA), Amazon (USA), Walmart (USA), PepsiCo (USA), UPS (USA), DHL (Germany), IKEA (Netherlands), Schneider Electric (France), and Siemens (Germany).

The key technologies that allow improving the speed, safety, reliability, and sustainable development in the transport and logistics complex include GSP and real-time tracking, drones and unmanned aerial vehicles, blockchain, the Internet of Things, electric transport means, artificial intelligence, machine learning, and mobile apps. The aspects of the transport sector where artificial intelligence demonstrates large prospects include more complex optimisation of routing and planning, autonomous trucks and storage robots, predictive technical maintenance of transport vehicles, and chatbots for customer support which imitate human behaviour.

Traditional diesel trucks have a large carbon footprint. They were effective for transporting loads with lower exploitation costs, compared to petrol trucks, but their emissions are rather harmful. Transition to trucks with electric engines will allow for a substantial reduction of emissions, helping companies to better control their budgets and expenditures, without dependence on international oil markets and the negative consequences of dependence on fossil fuels.

The growth of the number of automatized trucks offers numerous advantages for the sector of freight transportation and logistics. One of the main advantages is saving costs, for these trucks optimise fuel efficiency, reduce driver fatigue, and minimise the need for operators. This is especially important in the context of the global lack of drivers.

Sustainable development has become a priority for many companies, and artificial intelligence plays a key role in this sector. Optimising operations, artificial intelligence allows reducing energy consumption and CO2 emissions. It also allows for constant control of energy efficiency along the entire supply chain, offering operational improvements which reduce the influence on the environment. One of the most important results of using artificial intelligence and robots is the automatization of storage. Mobile and collaborative robots accelerate the configuration, sorting, and processing of products. These robots work alongside human operators, reducing physical burden and raising operational effectiveness. Leading logistics companies use a new generation of robots (cobots), which are safer and smarter and can work with humans. Logistica companies utilise the integration of information flow through software to manage supply chains, packaging, materials processing, storing, and management of returned goods.

The main components of Quality 5.0 in the transport and logistics sector include effectiveness and optimisation, sustainable development, human well-being, green logistics, safety and ergonomics, productiveness, decision-making, quality of services, confidentiality and cyber security, and artificial intelligence.

Integration of IoT technologies and sensor systems is the most important factor in the transformation of logistic operations. These innovations allow for real-time data collection from physical objects and environment, which provides unprecedented opportunities for analysis and management of supply chains. IoT sensors, built-in transport means, cargo, and storage facilities, allow recording a wide range of indicators, e.g., temperature, humidity, and location and movement of goods. Due to these data, logistic companies can track the state and location of cargo at all stages of supply. The integration of these technologies also improves the management of the transport fleet and dynamic planning of routes. Real-time data on the road situation allow for quick correction of routes in view of traffic, which contributes to timely delivery of cargo, optimisation of fuel consumption, and reduction of CO2 emissions. Analytical data, received with the help of the IoT and sensor technologies, enables logistic companies to make justified decisions, raise operational effectiveness, improve the level of customer services, and support innovations.

The transport and logistics complex is a sphere demonstrating high-tech results in the conditions of increasing competition and growth of expectations from various segments of customers. During the COVID-19 pandemic, the sustainability of this sector's companies underwent a stress test, which led to transformations in the market structure of the main sectors. Actors who were able to ensure their sustainability during challenges and unpredictable events achieved the growth of their competitive positions (including in international markets). Certain subjects, being unable to cope with the new threats, led to failures in transport and logistics chains of supply and were forced to leave the market. A large effect on supporting the competitiveness of the companies of the transport and logistics complex in international is made by sustainable technological innovations, which ensure the implementation of management decisions.

Sustainable innovations are a tool for raising Quality 5.0 in the activities of the sector's companies at the national and international markets. Leadership in this sphere is demonstrated mainly by large companies which have access to financing of sustainable innovations (including technology).

It is possible to distinguish a range of sustainable innovations in the transport and logistics sector that are connected with alternative fuel and transport (Cavallaro, 2025; Lee et al., 2024):
1) Ships with a hybrid fuel system, which are alternatives to regular transport vessels which account for a large amount of greenhouse gas emissions into the atmosphere. The sector of cargo shipping accounted for 218,5 m tons of carbon in 2021; in 2024, this indicator equalled 240,6 m tons of carbon (growth of 10.11 %) (Stausbøll, 2025). Hybrid cargo ships have fuel systems that allow combining non-renewable sources of fuel and electric energy from solar and wind energy (stored in batteries).
The main advantages of these hybrid ships are as follows:
- Possibility of raising profitability of companies which provide services of cargo transportation with the use of hybrid ships. Since prices for batteries working from wind and solar energy tend to go down companies using them for the energy transition and/or applying combined types of fuel (clean fuel or fossil fuel) can reduce expenses and ensure their profit. Ships' hybrid fuel systems (container ships using 50 % gas and 50 % renewable electric energy) allow for a 50 % reduction of consumed fuel. Hybrid fuel systems at ships, which use 50 % diesel fuel and 50 % electric energy from renewable sources), allow for 15-25 % reduction of consumed fuel. There are also types of engines in which the alternative energy source or non-renewable fuel dominates in the fuel system, as per the exploitations terms. Three types of fuel can be used in hybrid fuel systems of ships. In the case of a fuel system that uses clean fuel elements, renewable electric energy (produced from wind and solar energy), and energy produced by the generator fed by non-renewable fuel, an 11.6 % decrease in greenhouse gas emissions can be achieved compared to emissions from the generator engine system. A fuel system based on a battery, which uses clean energy, and a generator engine system, allows reaching 5.1 % reduction of greenhouse gas emissions compared to regular fuel systems with a generator engine system (Lee et al., 2024);
- Possibility to reduce the transportation companies' expenditures for fines for methane and greenhouse gas emissions. Hybrid fuel systems on ships allow for a decrease in total greenhouse gas emissions of 15 % (methane – 20 %). This is the established threshold limit for the reduction of negative climate influence during transportation companies' transition to ships' sustainable hybrid fuel systems. Legislation in many countries and international unions contains norms on administrative regulation of greenhouse gas emissions from ships entering ports. This is also true for the EU. According to the requirements of the EU Emissions Trading System, ships with 5,000+ t displacement entering the ports of the EU member states must purchase EU quotas for CO emissions (Thurman, 2025). One quota accounts for coverage of 1 ton of CO2 emissions per year. Companies with lower volumes of emissions can sell excessive quotas;
- Possibility to reduce climate footprint, due to a decrease in greenhouse gas emissions. In this case, environmentally oriented activities, connected with the reduction of greenhouse gas emissions, could attract investments. International transport companies dealing with sea freight services can ensure the growth of foreign investments – if they provide materials on green accounting and business plans with exhaustive information on well-balanced sustainable development and effective managerial perspectives;
- Possibility to ensure uninterrupted provision of services of international cargo shipping in the conditions of fuel supply problems. Most hybrid fuel systems can work also only on renewable energy, which predetermines high demand for their energy security in the conditions of risks and challenges in this sector.
2) Synthetic fuel, which is produced from renewable energy and captured CO2 (Cavallaro, 2025). This type of fuel contributes to the reduction of CO2 emissions in the logistics sector and the functioning of international transport companies. It is produced based on the synthesis of biomass energy, wind energy, and solar energy. Production and generation of this fuel are perspectives due to various climate and economic opportunities in this direction. One of the important advantages of this fuel is the possibility to use it in the conditions of the existing fuel systems. Another important aspect of the transition to this type of fuel is its environmental friendliness. All sources of synthetic fuel do not produce greenhouse gas emissions. Accordingly, companies that produce it contribute to the improvement of climate indicators at the national and international levels. Recently, large players in the fuel and energy market (ExxonMobil, Fuels Global, Highly Innovative and Porcgy) invested $1 billion in synthetic fuel

production (Janaki et al., 2024). Its growth is expected; this is due to a possible increase in administrative fines for CO2 emissions from the use of non-renewable energy sources. By 2026, 550 million litres of synthetic fuel are expected to be produced. The companies aim at the effectiveness of management solutions in the sphere of energy transition. Synthetic fuel acquires mass character for these companies. This will increase their international competitiveness and sales revenues. Customers' transition in the sector of transport and logistics to the use of synthetic fuel ensures the reduction of CO2 emissions and an increase in profitability.

The modern methods of improving transport and logistics activities are a multifunctional tool during the organisation and management of logistic processes and services of the transport and logistics systems. Methods and means of transport and logistics business change over time, which is very important in the conditions of a global market. The methods of logistics are means of influencing the object for the purpose of effective resolution of logistic tasks at the company. Each of the applied methods has its advantages. The main advantages include assessment of the level of quality at the company, identification of weaknesses, and the possibility to obtain a complex indicator of quality from the position of consumer and employee.

4. DISCUSSION

The influence of transport and logistics on climate change has become increasingly vivid in recent years. This is partly because increased control over pollution and improvement of traffic safety mitigated other environmental problems, and because new scientific research showed that global warming poses a larger and more direct threat than was believed in the past. The transport and logistics complex, which contributes to global CO2 emissions, faces the task of rethinking its processes and further transformation.

Transition to sustainable development of transport is a transformation process, which goes beyond technological progress. It requires a comprehensive approach, including the development of infrastructure, technological innovations, political interference, and changes in behaviour (Etukudoh et al., 2024).

Management of logistics plays a decisive role in business operations, especially in such sectors as production, retail, and e-commerce, where timely and effective delivery is of utmost importance for the satisfaction and preservation of clients. Transport companies can achieve high effectiveness, reliability, and strategic planning due to the methods of machine learning, such as deep learning, optimisation, simulation, and predictive modelling.

Quality 5.0 conforms to the current and future challenges of internal logistics and industrial supply chains. It is based on research, innovations, and technological development, which allow companies to change their internal logistics and move forward, raising operational effectiveness and competitiveness and taking care of humans and the planet.

5. CONCLUSION

More and more companies nowadays pay attention to environmental sustainability. The use of electric transport, optimisation of routes, and implementation of sustainable packaging are some of the solutions that allow reducing the carbon footprint in the transport and logistics complex. In the modern world, sustainable technologies are not only an ethical necessity but a competitive advantage.

The modern approach to logistics is based on the principles of an eco-friendly and human-oriented approach, which goes beyond operational effectiveness and includes environmental and social resilience. Thus, practices of CO2 emission reduction and optimisation of resource use are applied. Digital technologies contribute to the development of multimodal transport systems and foster the implementation of innovations. They create a market potential for cooperative and automatized transport, which leads to the creation of new jobs.

Successful transition to the future of logistics requires rethinking and transformation of the existing systems and processes. Transition to logistics that is oriented towards sustainable development offers numerous advantages. However, this is accompanied by many challenges. Companies must not only rethink the existing structures and processes but also overcome complex barriers. The trend for sustainable development in transport is a fundamental transformation, which rethinks the foundations of the transport and logistics sector. This change of the paradigm reacts to a range of critical factors, which go beyond regulatory pressure or market trends.

The implementation of artificial intelligence and robots can transform the sectors of logistics and supply chains. Since demand for quicker and more effective operations grows these technologies are a fundamental solution for ensuring competitiveness, sustainable development, and innovations. The modern transport and logistics sector is in the process of deep innovative transformation, caused by the quick development of technologies and the necessity for adaptation to increasing market demands. While companies used to apply reactive strategies in the past, modern trends demonstrate a transition to innovations-oriented management, which ensures long-term growth, improvement of effectiveness, and resilience to changes. The key drivers of this evolution are artificial intelligence, automatization, digitalization, and cloud technologies, which form a new reality of transport logistics.

References:

Audonin, A., Turginbayeva, A., Askerov, A., & Yergobek, D. (2020). Modern economic and logistical trends in Eurasia: How do new trans-Eurasian mega-projects influent to national economic growth. In *E3S Web of Conferences* (Vol. 159, p. 06009). EDP Sciences.

Birch, K. (2024). Top 10: Sustainable Transport and Logistics Companies. Sustainability Magazine. Retrieved from https://sustainabilitymag.com/supply-chain-sustainability/top-10-sustainable-transport-and-logistics-companies

Cavallaro, U. (2025). Green Logistics: The Transition to Innovative, Ecological and Sustainable Transport Technologies. Retrieved from https://www.forbes.com/councils/forbesbusinessdevelopmentcouncil/2025/01/02/green-logistics-the-transition-to-innovative-ecological-and-sustainable-transport-technologies/

CompaniesMarketcap.com (2025). Top publicly traded transportation companies by revenue. Retrieved from companiesmarketcap.com/transportation/largest-transportation-companies-by-revenue/

Darley, J. (2025). Top 10: Sustainable Fleets. EV Magazine. Retrieved from https://evmagazine.com/top10/top-10-sustainable-fleets

Etukudoh, E. A., Adefemi, A., Ilojianya, V. I., Umoh, A. A., Ibekwe, K. I., & Nwokediegwu, Z. Q. S. (2024). A review of sustainable transportation solutions: Innovations, challenges, and future directions. *World Journal of Advanced Research and Reviews, 21*, 1440–1452. doi: 10.30574/wjarr.2024.21.1.0173

Hsu, C.-H., Cai, X.-Q., Zhang, T.-Y., & Ji, Y.-L. (2024). Smart Logistics Facing Industry 5.0: Research on Key Enablers and Strategic Roadmap. *Sustainability, 16*(21), 9183. https://doi.org/10.3390/su16219183

Khayari, S., & Kassim, N. (2019). Service Quality: Gap in Air Transportation. *Proceedings on Engineering Sciences, 1*(2), 321-334. doi: 10.24874/PES01.02.029

Lee, J. I., Cha, S. W., & Yi, H. S. (2024). CO2 emissions of fuel-cell battery hybrid system for large ships. *International Journal of Green Energy, 22*(1), 1–8. https://doi.org/10.1080/15435075.2024.2401955

Ngcobo, N., Akinradewo, O., & Mokoena, P. (2024). Challenges to sustainable transport infrastructure integration in Johannesburg, South Africa. *Journal of Sustainable Development of Transport and Logistics, 9*(2), 92–108. https://doi.org/10.14254/jsdtl.2024.9-2.7

Nicoletti, B., & Appolloni, A. (2024). Green logistics 5.0: A review of sustainability-oriented innovation with foundation models in logistics. *European Journal of Innovation Management, 27*(9), 542–561. https://doi.org/10.1108/EJIM-07-2024-0787

Niewiadomski, P., & Merkisz-Guranowska, A. (2024). Sustainable production strategies in agricultural transport: Balancing economic efficiency and environmental impact. *Journal of Sustainable Development of Transport and Logistics, 9*(1), 30-39. doi: 10.14254/jsdtl.2024.9-1.3

Schmidt, S., & Schmidt, B. (2019). The role of packaging in logistics processes: Impact on sustainable logistics in the food sector. *Proceedings on Engineering Sciences, 1*(2), 235–246. doi: 10.24874/PES01.02.020

Shamsuddoha, M., Kashem, M. A., & Nasir, T. (2025). A Review of Transportation 5.0: Advancing Sustainable Mobility through Intelligent Technology and Renewable Energy. *Future Transportation, 5*(1), 8. https://doi.org/10.3390/futuretransp5010008

Janaki, S. T., Madheswaran, D. K., Naresh, G., & Praveenkumar, T. (2024). Beyond fossil: the synthetic fuel surge for a green-energy resurgence. *Clean Energy, 8*(5), 1-19. https://doi.org/10.1093/ce/zkae050

Stausbøll, E. (2025). Record-breaking carbon emissions in ocean container shipping: here's what shippers need to know. Retrieved from https://www.xeneta.com/blog/record-breaking-carbon-emissions-in-ocean-container-shipping-heres-what-shippers-need-to-know

Sultanova, S. M. (2021). Improvement of financial flow management of a railway transport enterprise. *Turkish Online Journal of Qualitative Inquiry, 12*(6), 7117–7121. Retrieved from tojqi.net/index.php/journal/article/view/2993/1994

Sumbal, M. S., Ahmed, W., Shahzeb, H., & Chan, F. (2023). Sustainable Technology Strategies for Transportation and Logistics Challenges: An Implementation Feasibility Study. *Sustainability, 15*(21), 15224. https://doi.org/10.3390/su152115224

Sun, X., Yu, H., Solvang, W.D. (2023). A Digital Reverse Logistics Twin for Improving Sustainability in Industry 5.0. In: Alfnes, E., Romsdal, A., Strandhagen, J.O., von Cieminski, G., Romero, D. (eds) Advances in Production Management Systems. Production Management Systems for Responsible Manufacturing, Service, and Logistics Futures. APMS 2023. IFIP Advances in Information and Communication Technology, vol 690. Springer, Cham. https://doi.org/10.1007/978-3-031-43666-6_19

Thurman, A. (2025). Hybrid ships: a surprising reason they are such an excellent idea. Retrieved from https://www.wartsila.com/insights/article/hybrid-ships-a-surprising-reason-they-are-such-an-excellent-idea

Trstenjak, M., Opetuk, T., Đukić, G., & Cajner, H. (2022). Logistics 5.0 Implementation Model Based on Decision Support Systems. *Sustainability*, *14*(11), 6514. https://doi.org/10.3390/su14116514

Villar, A., Paladini, S., & Buckley, O. (2023, July). Towards supply chain 5.0: redesigning supply chains as resilient, sustainable, and human-centric systems in a post-pandemic world. In *Operations Research Forum* (Vol. 4, No. 3, p. 60). Cham: Springer International Publishing. https://doi.org/10.1007/s43069-023-00234-3

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