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Environmental Challenges and Innovations in the Asia-Europe Rail Transport Corridors in the Context of the ESG Concept

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Abstract: The aim of the publication is to assess the significance of contemporary environmental challenges that shape strategies and expectations towards long-distance rail freight transport, as well as to present solutions aimed at reducing the environmental pressure of this mode of transport.

The proposed objective and the subject of the analysis indicate that the basic research method used for the purposes of this article should be a literature review, including primarily documents that define objectives in the field of environmental protection and confrontation with programs and projects implemented in railway companies involved in the organization of long-distance rail transport on the Asia-Europe-Asia routes. The study is based on selected, detailed case studies. A marketing concept for sustainable transport development is also presented.

It has been shown that innovative technologies and growing consumers' environmental demands are increasingly responsible for the development of the modern economy. New technologies and solutions not only become part of the attractiveness and competitiveness of transport logistics chains, but also contribute to reducing their environmental impact, thanks to application of the concept of sustainable marketing.

The subject of rail freight traffic between Asia and Europe is analyzed in the paper in the specific context of the ESG concept, with a valuable contribution of the unique materials of various railway entities, including the Organization for Co-Operation between Railways, illustrating state-of-the-art environmental solutions in Eurasian transport corridors.

Keywords: eco-innovation; rail transport; transport corridors; sustainable development.

JEL Classification: L92; M31; Q56.

Introduction

Modern transport and logistics industry is undergoing dynamic changes due to the continuous development of new information and digital technologies. On the one hand, this transformation is based on the use of advanced technologies intended to fundamentally change the ways and methods of managing operational activities and customer service, and on the other hand, it is based on adjusting to changing expectations, requirements and regulations (Pieriegud 2016, 12). In this context, worldwide trends are becoming one of the key drivers of development. These trends are global in their scale, shaping the development strategies of companies, economic sectors, entire countries and international organizations. In the case of transportation as part of global supply chains, one of the key challenges is climate and environmental policy, which is reflected in the ESG concept.

The ESG (Environmental, Social, and Governance) concept provides organizations with a framework to assess the sustainability of their operations and evaluate their impact on the planet, people, societies and profits. The ESG environmental aspect is focused on reducing the negative impact of production and other activities on the environment. This includes reducing energy consumption, waste management, greenhouse gas emissions

and related practices. Companies must openly report their environmental practices to maintain transparency and prove their compliance with ESG standards. The transportation sector is a significant polluter, but at the same time it provides services to other sectors of the economy. Therefore it must both increase its efficiency and reduce its impact on the environment. Sustainability is becoming the main feature of transport development in terms of environmental friendliness, which means minimizing negative impact on the environment, as well as preventing and eliminating the effects of transport-related environmental hazards (Pawłowska 2013, 205). This is also reflected in society's expectations of marketing activities.

The aim of this paper is to assess the significance of contemporary environmental challenges that affect strategies and expectations for long-distance rail freight transport, as well as to present solutions aimed at reducing the environmental impact of this mode of transport. What makes this research novel and important is its holistic approach to solving the heterogenous challenges of Eurasian rail traffic. Especially noteworthy is integrating environmental issues directly with practical technical and operational strategies implemented in various Eurasian countries. By identifying how innovation can help overcome continental-scale obstacles, this work contributes meaningfully not only to railway transport expertise but also to the broader, urgent objectives of sustainable development, economic cohesion and climate action across continents.

1. Research Background

When it comes to environmental trends in the rail freight market, it must be noted that he European Union's transport policy has long emphasized the need to transfer as much long-distance freight as possible to rail. Postulates on this matter can be found in a number of documents related to transportation development, including the European Union Strategy for Sustainable Development, which is detailed in the White Paper "European Transport Policy for 2010: Time to Decide"[1] (European Commission 2001), in the White Paper "Roadmap to a Single European Transport Area – Towards a Competitive and Resource-Efficient Transport System" (European Commission 2011), as well as the latest Sustainable and Smart Mobility Strategy (European Commission 2020) and the "Fit for 55" package that implement the latest proposals of the European Green Deal of 2020. All of the documents mentioned emphasize the necessity of reconciling the growing demand for transportation services with the decreasing availability of resources and environmental restrictions. They point to the necessity of changes in the sectoral distribution, limiting the level of external costs and the dominance of road transport, counteracting congestion and reducing the negative pressure of the sector on the environment and public health. An integral part of this is also the demand for a significant increase in the share of rail transport in the transport market, specifically for freight traffic that involves routes exceeding 300 km. When analyzing international climate policy issues in a broader context, it can be seen that the European Union, which aspires to be a leader in the global fight against climate change, is simultaneously implementing its own and external commitments that result, among other things, from the ratification of the Paris Agreement (United Nations 2015)[2]. The document, which will operationalize the provisions of the Kyoto Protocol[3], is considered to be "the first-ever universal, legally binding climate agreement" (Czepiel 2021). The aforementioned documents include tools for implementing a global environmental policy, such as increasing the use of renewable energy sources, eliminating tax incentives in greenhouse gas-emitting sectors, and, in the case of transport, the need for measures to reduce greenhouse gas emissions and the need to develop low-carbon means of transport while reducing road traffic. Table 1 shows an example of the proposed changes in European transportation.

[1] Both the document issued by the European Commission following the June 2001 summit and the immediately preceding White Paper of 2001 set a new direction for the Community's transport policy, resulting in numerous program documents and executive acts adopted by the Member States.

[2] Almost 190 countries have signed the Paris Agreement. It was ratified in 2016 with the participation of 55 countries that generate 55% of global greenhouse gas emissions.

[3] The Kyoto Protocol to the United Nations Framework Convention on Climate Change (2008) is a document from 1997 that was finally ratified and entered into force in 2005. It is considered one of the main international agreements in which the task of improving the quality of the environment and combating climate change is defined in a concrete, unambiguous and effective way. Thus, this protocol lays the foundation for the contemporary way of thinking about reducing carbon dioxide emissions as the main cause of global warming.

Table 1. Schedule of planned changes in European transportation

Task	Time frame
– 30 million emission-free passenger cars and 80 million emission-free trucks, – 100 climate-neutral cities, – climate-neutral travel using public transportation for distances up to 500 km, – doubling of long-distance and freight rail traffic, – equalization of competitive conditions for road, rail and inland waterway transport, – full digitization of information in logistics chains, – significant share of automation in transport operations, – full availability of integrated ticketing systems, – providing access to the basic elements of the Trans-European Transport Network (TEN-T), – introducing emission-free maritime vessels,	overall by 2030
– market launch of emission-free airplanes,	2035
– emission-free cars, delivery vans and buses, – new emission-free trucks, – doubling of rail freight traffic, tripling of high-speed rail traffic, – 50% increase in inland waterway and short-sea shipping, – linking transportation charges and external costs, – providing access to the complete Trans-European Transport Network (TEN-T).	overall by 2050

Source: Zych-Lewandowska *et al.* (2021, 15).

Regarding the subject of this analysis, it is worth noting that the Paris Agreement is based on international cooperation, which focuses on the joint implementation of agreed environmental goals through the support of richer countries for developing countries. In terms of transport, this means cooperation in organizing low-carbon logistics chains and coordinating solutions to ensure maximum efficiency – not only in individual countries, but also along the existing transport corridors. The European Green Deal prioritizes research, development and innovation, as well as other aspects, such as the circular economy, zero pollution and sustainable transportation (cf. *e.g.* Piotrowski 2021). Table 2 shows the environmental challenges associated with the circular economy. In 2019, transportation accounted for approximately 25% of greenhouse gas emissions in the EU, with road transportation being responsible for more than 70% of these emissions and air travel for almost 15%. In Poland, the share of transport emissions in the entire economy was lower and amounted to 17%, including over 92% for road transport and almost 5% for air transport[4].

Table 2. Environmental challenges for a modern circular economy

Today Inefficient production and unreasonable consumption	10-30-year perspective Resources demand increase, mining development	After 2040 Danger for the ecosystems, the future generations
• 35% of the materials that circulate in the economy are used for the manufacturing of short-term consumption products • current pace of the resource mining and processing causes loss of 90% of the biodiversity and 50% of the increase of greenhouse gases • 1/3 of all food products become garbage • 460 $ bn/year – the value of clothes thrown out despite of its usability retained • 8,9% only of the materials are recycled.	• 75% of the infrastructure to be developed by 2050 does not yet exist • a two-fold increase of the resources mining and usage thereof in the period from 2017 to 2050 • a five-fold increase of the middle class in the ATR area by 2030, total 5,6 bn of the middle class representative in the world • 68% of the world population live in the towns by 2050 • 43 metropolises with population of 10 mil people by 2030.	• resources shortage at the planet for the well-being of 9,9 bn world population (2050), the rundown of the resources being vital for production, • the 1,9-3.0 C° increase of global temperature by 2030-2060 will cause mass scale natural disasters, • 70% increase of waste volume by 2050 – devastating for human health and climate.

Source: Kudryavtseva 2022.

[4] Transport was the second most polluting sector of the Polish economy (see Maj, Miniszewski and Rabiega 2022, 6). According to Lewandowska's assessment (cf. Ołdak 2021), taking into account air pollution, climate change and noise, rail freight traffic generates annual costs of around PLN 0.35 billion. This means that it is 75 times less harmful than freight transport by road.

In this context, it has to be noted that the implementation of ESG strategies in transportation and logistics can bring benefits not only to the environment and society, but also to the business sector. These benefits may include (cf. Miziński 2024): an increase in operational efficiency and cost reduction; improvement of reputation and customer loyalty; increase in innovativeness and competitiveness; easier access to financing and support from public and private institutions.

2. Research Methodology

The proposed objective and subject of the analysis indicate that the basic method of research carried out for the purposes of this paper should be a review of the literature, primarily documents that define environmental protection objectives, as well as a comparison of these objectives with the programs and projects implemented in railway companies involved in the organization of long-distance rail transport on the Asia-Europe-Asia routes. The study, based on selected, thoroughly analyzed examples, makes it possible to examine the practical implementation of environmental requirements addressed to the rail transport sector and to assess the extent to which trends and results of activities followed in European policy are also reflected outside its borders. Because of the broad geographical scope, the analysis of source materials comprises international documents that represent obligations undertaken at the trans-European and global level, including materials from the United Nations Economic Commission for Europe (UNECE), Organization for Co-Operation between Railways (OSJD) and International Union of Railways (UIC). In this respect, the suggested approach to the relationship between transport policy and environmental policy has a practical dimension. Based on a specific sectoral example, this makes it possible to identify the dependencies and differences between the measures implemented in the European Union and in other countries. Also, since intermodal[5] transport dominates rail traffic in the Eurasian area, a synthetic marketing concept for this type of transport will be outlined.

3. Environmental Measures in Eurasian Transport Corridors

One way to meet general environmental demands is to transfer long-distance freight transportation to rail transport via international transport corridors[6]. on a global scale, there are hardly any routes where they can compete with sea or air transportation. Environmental pressure as well as the digitalization of transport operations are becoming key challenges for the transformation of rail transportation in Eastern European and Asian countries. This is because the situation is different in non-EU countries. Most of them pursue their own innovation and environmental policies, coordinating them through bilateral cooperation. To illustrate this phenomenon, it is worth looking at a few specific examples implemented in the countries involved in the so-called New Silk Road (Jakóbowski, Popławski and Kaczmarski 2018; see also Figure 1). The first few of them involve the starting point of the New Silk Road, which is China. China is a country that until recently built its economic power on the intensive exploitation of environmental resources and that is now paying increasing attention to the limitations in this area. In the 21st century, the issue of environmental protection is clearly increasing in importance. Regulations, standards and guidelines in this area are becoming more restrictive, and there is also growing pressure to increase environmental management requirements in both infrastructure investments and the organization and operation of the transportation system. The combination of trends that determine the development of long-distance rail freight traffic on the one hand, and the expected gradual increase in the competitiveness of this form of transport, on the other hand, results in the need for technological development and innovation aimed at reducing the environmental impact of this sector (see OSJD 2025a). In the individual countries involved in economic exchange, it has a different nature and advancement level.

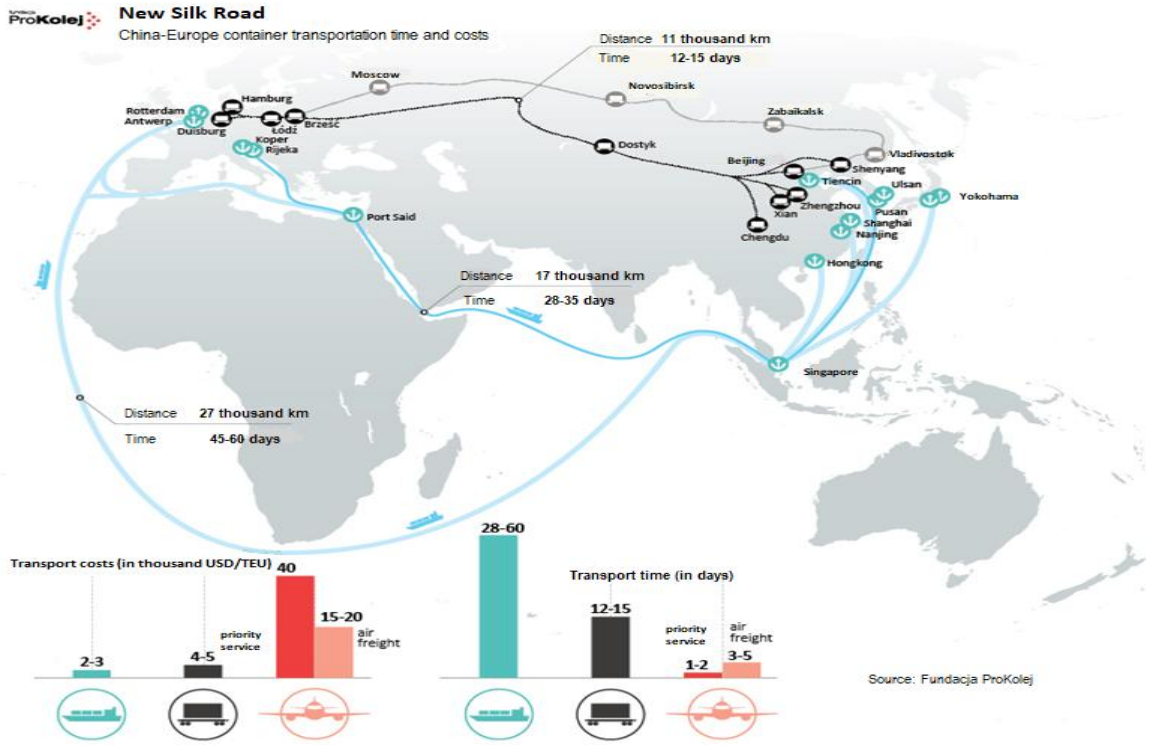
The importance of the individual railway systems in Eurasian traffic is illustrated in Figure 2. Environmental solutions cover the entire transportation system, from new power technologies, such as hydrogen fuel cell engines, to new rolling stock designs and innovations in infrastructure construction. The modernization of infrastructure and rolling stock in Eurasian transport corridors, and especially purchasing new vehicles, are increasingly subject to environmental criteria. The Organization for Co-Operation between Railways (OSJD) is a valuable source of information on initiatives in this area (see eg. relevant articles in the *OSJD Bulletin* Nos.

[5] In 2024, rail freight traffic from China to Europe reached over 330,000 TEUs and increased by over 131% compared to 2023, of which traffic from China to Poland reached over 192,000 TEUs (see Stefaniak 2025 and European Rail Alliance data).

[6] An international corridor is part of a national or international transport system which is used to transfer sufficient passenger and freight flows between geographical regions. It includes the infrastructure facilities and means of transport of all transportation modes presented in this corridor, as well as all technical, organizational and legal conditions for the implementation of this transportation (Engelhardt 2018, 85).

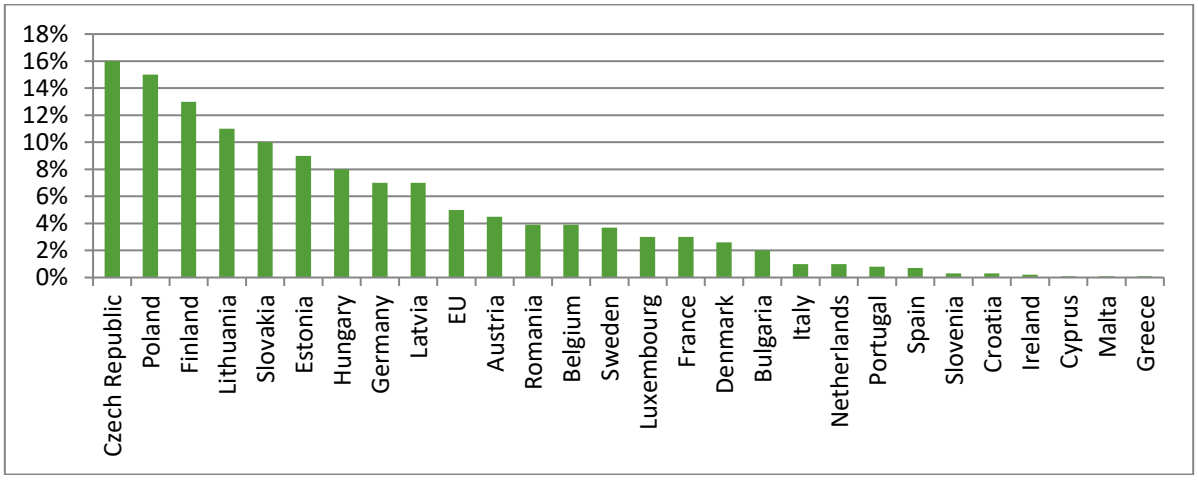
5/2022 and 1/2025). OJSD member companies are paying increasing attention to this issue in their development and investment strategies in Eurasian transport corridors.

Figure 1. New Silk Road – China-Europe container transportation time and costs



Source: ProKolej Foundation 2020.

Figure 2. Railway share in the import volume from China to the EU-countries



Source: Piechociński 2022.

Examples of such measures, which are not always well-known in Europe, include selected initiatives undertaken by *e.g.* the Chinese and Azerbaijani railways that operate on the Silk Road Railway, which are briefly described in the further part of the study.

3.1. Case Studies: China

For more than a decade, the Chinese railways have been paying special attention to environmental standards and are increasingly taking into account the impact of investment and transport activities on the environment (CRRC 2024, OSJD 2025a). On a corporate level, this is achieved by such solutions as an environmental management system based on advanced management methods – including environmental management of railway construction projects, environmentally friendly technologies and techniques in railway construction, as

well as intelligent environmental information management systems (Zhang 2022). The design and construction of railway lines are based on external legal acts defining standards and rules, as well as on internal regulations. Several solutions are also provided by technology – including innovations used to reduce and eliminate negative phenomena resulting from railway operations and infrastructure investments. The most interesting solutions that combine operational needs with environmental requirements include a line construction system based on LVT[7] (ballastless track), ecological sleepers[8] and the use of photocatalytic concrete[9] in engineering structures. In terms of geographical location, in turn, examples of environmental projects can be provided that relate to particularly valuable natural areas. These examples will be discussed below.

3.1.1. Whooper Swan Protection Project

The first example of an investment that respects particularly sensitive ecosystems is the road and rail bridge over the Yellow River. It was built in Jiangxi Province, in the autonomous region of Inner Mongolia, to serve the Haolebaoji-Ji'an connection. The railway line crosses the Yellow River National Wildlife Refuge and passes just 470 meters from Lake Tsanglong. It is one of the main habitats of rare water birds, mainly whooper swans. According to classifications, this species is categorized as a second-class protected animal. To reduce the impact of noise and light on whooper swans, flexible ballast seals are used in the operation of the bridge, which reduces the noise level of passing trains by 2-3 decibels. In addition, a 2.5-meter-high light barrier has been installed on both sides of the bridge to block the train headlights in the habitat area (Zhang 2022). An evaluation of both solutions shows that despite the commissioning of the investment, the number of swans on both sides of the bridge has remained at the same level as in previous years, and their habitat has not been degraded.

3.1.2. Crested Ibis Protection Project

Another example of a solution aimed at protecting birds is the Xi'an-Chengdu railway line, which crosses the national nature reserve of the crested ibis in Shaanxi Province, near the city of Hanzhong. In order to protect the animals from the negative impact of rail traffic, detailed studies and simulations were carried out before the investment was implemented, aimed at selecting solutions to protect the numerous colonies of rare birds in this area. As a result, a 4-meter-high safety net and reflective warning elements were installed on both sides of the line (Wangshu 2017). Here, too, the effectiveness of the solution was confirmed by monitoring after the line was put into operation, as no collisions between protected birds and trains were recorded during operation, and thus train traffic did not affect the habitat of the ibis population.

3.1.3. Giant Panda Protection Project

The Chengdu-Lanzhou railway is a third example of a railway investment in an environmentally sensitive area. One section of the line crosses the Qianfo mountain range. This area is part of the Baodingou nature reserve and is home to many rare species, including the giant panda[10]. The railroad route uses a long tunnel with a reduced level on this section. Due to the fact that the entrances to the facility are at 1,100 and 1,800 meters above sea level, respectively, the railroad infrastructure does not interfere with the higher parts of the mountains, which are subject to protection. Therefore, it does not pose a threat to giant pandas, which feed in bamboo communities at an altitude of over 2,000 meters above sea level. Scientific research and monitoring of the panda population confirm the effectiveness of the solution adopted already at the design stage of the new railway line. The measures taken to avoid the habitats during both the construction and operation of the connection minimized the impact on the panda population (Wan 2022, Xinhua 2021).

3.1.4. Bird Paradise Protection Project

Bird Paradise is a small island with a bird colony in Jiangmen, Guangdong Province. The central point of the island is a 300-year-old tree on the banks of the Tianm River, which is home to around 96 species of heron, with a total population of over 30,000 birds. It is also one of the most famous bird watching spots in China. The Shenzhen-Maoming railway line was built just 300 meters from this spot. To reduce the impact of train noise on

[7] The LVT surface consists of concrete reinforced elements placed on elastic pads, covered with rubber sheaths and set on a concrete subgrade. This design dampens vibrations and thus reduces noise and environmental impact.

[8] Green sleepers are modern, recyclable composite sleepers made of technical sulfur. Their carbon footprint is 40% lower compared to the production of classic concrete sleepers, and their service life amounts to 40-50 years.

[9] Photocatalytic concrete owes its properties to the use of cement containing titanium dioxide particles, which initiate reactions with oxygen molecules through UV absorption. It is also used to reduce noise.

[10] Currently, there are 42 wild giant pandas living in the reserve.

the birds, the world's first fully enclosed high-speed rail sound barrier with a height of 2,036 meters was installed. To protect birds from the train headlights, 5-meter-long shading panels were installed at both ends of the noise barrier to completely block the light from night trains. More about sustainable transport measures and goals to be achieved in Chinese transportation can be found in the study by the Chinese Academy of Transportation Sciences (China Academy of Transportation Sciences 2023, 67-71).

Overall, China is trying to remodel its energy consumption in the face of significant pressure to decarbonize the country's energy- and emission-intensive industries such as transportation, steel and cement. The government is ordering more solar power to reduce emissions from the energy sector, which is the country's largest emitter of greenhouse gases due to its dependence on coal. According to forecasts (cf. *e.g.* Economist Intelligence 2023), coal consumption will peak in 2026 and then decline steadily. Even if coal power remains indispensable in the short term, it should be seen as an indicator of larger global changes in the long term.

3.2. Case Studies: Other Countries

The UN Sustainable Development Goals in the field of environmental protection are part of the development strategy of railway companies in various countries. The implementation of the environmental strategy by 2030 is intended to contribute to improving the economic efficiency, investment attractiveness and competitiveness of rail transport and to promote the railway as an environmentally and socially responsible sector (see UNECE 2021a, UNECE 2021b, UIC 2021).

3.1.5. Russian Federation

The project to protect Lake Baikal is a practical example of the use of digital technologies. In 2020, the development of the first version of the module for monitoring and controlling the environment in the natural territory of Lake Baikal during the construction and reconstruction of infrastructure facilities, the so-called Baikal-M module, was completed The purpose of the project is to protect the valuable natural ecosystems during the construction of the Baikal-Amur Mainline and the Trans-Siberian Railway (RZD OJSC 2021). The project, which is based on environmental monitoring, is highly complex and includes environmental protection and fire safety components. Everything is supervised by an informational and analytical platform that can record images and collect, process and analyze data on the state of the environment. An environmental passport is created for each construction site, containing detailed information on the situation before the investment, measurements of current parameters and possible compensation measures. The procedures for soil sampling and monitoring of the parameters of the atmosphere, water and individual ecosystem components are standardized. In 2021, in order to organize the transfer of data from the Baikal-M module to information systems, an appropriate agreement on the exchange of information in electronic form was concluded between the interested partners and the railway. In order to increase the automation of the monitoring process, two mobile stations and a pilot project for permanent environmental stations in the natural area of Lake Baikal with a function for direct transmission of measurement results to the EC ACS OPB system were put into operation in 2021 (RZD OJSC 2022).

3.1.6. Projects in Azerbaijan[11]

In the current geopolitical situation, the Trans-Caspian International Transport Route (TITR) is an alternative to long-distance rail corridors through the Russian Federation and Belarus[12]. The World Bank (World Bank 2023) sees significant opportunities for the development of this corridor by 2030 as an alternative to China-Europe rail freight transport, which was confirmed at the 2024 UN conference in Baku (cf. Antonowicz 2025, 1-7). The initiator and supporter of this route is the Azerbaijani Railways. The activities of the Azerbaijani Railways in the field of the broadly understood green energy concept are vital and significant for the entire corridor. Particular attention is paid to energy issues, including, above all, the acquisition of energy from renewable sources. Consequently, specific measures are being taken to ensure that renewable green energy is actually used. To this end, the Garadagh solar power plant project with a capacity of 230 MW has been initiated[13]. The green energy

[11] The example is based on Shurganova 2022.

[12] The corridor was created in 2013 as part of the 2nd International Transport and Logistics Business Forum "New Silk Road" in Astana. The agreement to establish the Coordination Committee for the development of the Trans-Caspian International Transport Route was signed by Kazakhstan Temir Zholy, Azerbaijani Railways and Georgian Railways.

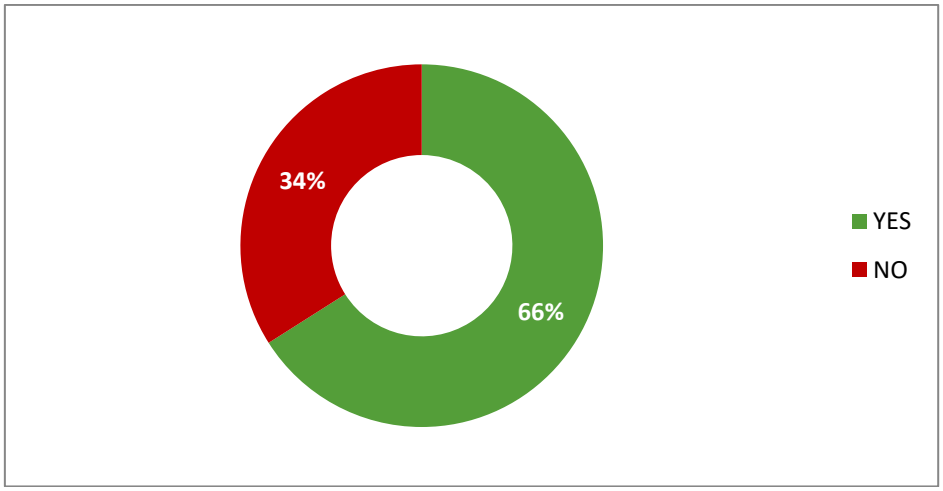
[13] For example, in 2022, the Azerbaijani Railways signed a memorandum with Masdar, a company from the United Arab Emirates, in the field of renewable energy and energy efficiency. Its aim is to explore the possibilities of using renewable energy sources (solar and wind energy) in the railway sector and to prepare a comprehensive energy efficiency program.

policy is reflected in practical measures in the railway infrastructure sector. The Republic of Azerbaijan is paving the way for a greener future by introducing renewable energies in its railway industry. The Azerbaijani Railways are working on the use of renewable energies. For the technical inspection and repair of AC locomotives to promote green energy and reduce carbon emissions, more than 650 solar panels were installed in the newly built locomotive depots in Bilajar and Ganja, which generated 79,000 kilowatt-hours of electricity and saved more than 8,000 cubic meters of natural gas. The Azerbaijani Railways take all necessary measures to avoid environmental damage during the construction of railway lines. In every new project, ESG principles are analyzed and applied in the most effective way. Since 2023, the Azerbaijani Railways have been a member of the UN Global Compact and are guided by the principles of environmental protection, social responsibility and transparent management (ESG) in their activities (OSJD 2025b, 10-11). The Azerbaijani Railways as an organization aim to attract young employees through organized events, raising their awareness of the Sustainable Development Goals in the context of Azerbaijan's socio-economic development by 2030.

4. An Outline of a Marketing Concept for Intermodal Transportation via Rail Transport Corridors

Intermodal transportation[14], due to the multitude of actors involved in the process, requires the adoption of a customer-oriented and relationship-based marketing philosophy. If, for example, we understand marketing as the process of planning and implementing ideas, pricing, distributing and promoting ideas, goods and services to create an exchange that meets the goals of an individual, company, society and the state (Kotler 2005, 8), then the idea of developing and promoting intermodal transport is undoubtedly socially significant from a marketing point of view. Marketing science has developed the concepts of green marketing or social marketing, and in the modern sense, the concept of sustainable marketing. Social marketing means applying marketing principles and techniques to influence a target audience to voluntarily adopt, reject, modify, or discontinue certain behavior for the good of individuals, groups, or society as a whole (Kotler 2005, 26). This is aimed at improving the quality of life, for example by influencing decision-makers to protect the environment. This also applies to the development of the idea of intermodal transport with the participation of railways as an environmentally friendly means of transport within the concept of ESG and sustainable development. All the more so because – as shown by research conducted on emissions in intermodal transport – when asked about taking measures to reduce emissions, the majority of the entities surveyed respond positively, as shown in Figure 3.

Figure 3. Implementation of measures to reduce emissions in intermodal transportation



Source: Jemiołek *et al.* 2022.

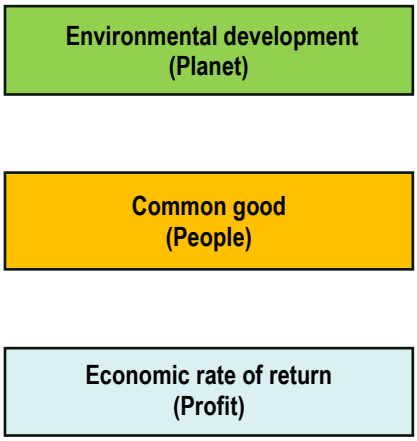
A closer look at the survey results shows that the majority of the companies surveyed are taking measures to reduce CO_2 emissions. Among this group of respondents, the most popular measure for the green transformation was increasing fuel efficiency. There was visible interest in introducing electric or hydrogen-powered vehicles to the fleet. About 14% of the respondents opted for introducing an alternative mode of transportation to their business profile. The respondents considered investments in training on how to reduce CO_2 emissions to be of great importance. Additionally, barriers to pro-emission activities in the form of a lack of

[14] Multimodal transportation carried out using an intermodal transportation unit, *e.g.* a container, piggyback trailer, swap body; transportation of goods using two or more modes of transportation in the same loading unit or road vehicle without reloading the cargo itself when changing modes of transportation. See Aspayeva *et al.* 2024, 307.

sufficient funds for pro-environmental investments should be noted. An important innovative solution was the development of the concept of road trains in the European Union (Jemiołek *et al.*2022).

The aforementioned concept of sustainable development combines innovation and economic progress with environmental protection and is reflected in consumer trends and marketing, *i.e.* the concept of sustainable marketing based on three basic pillars, which are shown in Figure 4. Most modern companies in transportation chains work in networks, relying heavily on partnerships with other companies. Networking is a feature of intermodal transportation, through which various links participate in the supply chain, which in the course of their operation add value to the service provided, acting in relation to each other as both supplier and customer. When it comes to marketing, service companies nowadays focus not only on customers but also on employees and, more broadly, on various stakeholders interested in an efficient solution to the problem of transportation and product delivery to the customer. The main stakeholder is society as a whole and its well-being reflected in the environment in which people live. Armstrong and Kotler (Armstrong and Kotler 2012, 331) point out a far-reaching understanding of the service-profit value chain. This chain links the profit-making potential of companies with employee satisfaction, customer satisfaction and society.

Figure 4. Pillars of the sustainable marketing concept



Source: Albrecht, Green and Hoffman 2024, 682.

This concept consists of five main links and is in line with the idea of creating a service in intermodal transport. These include:

- internal quality of service created by employees;
- satisfaction and productivity of service employees;
- higher value of service and value creation for the customer;
- customer satisfaction and loyalty;
- proper profit level and company growth, related to good performance of a service company thanks to the integration of activities, *e.g.* organizational or pricing, and the existence of sustainable marketing of an interactive nature.

Interactive marketing means that the quality of service largely depends on the quality of the relations and interactions between the seller, service provider and buyer during service provision. In service marketing, the quality of the service depends not only on the service provider, but also on the quality of the service delivery process itself. This is even more important in intermodal transport services, where various links are involved in the service delivery process, and their performance quality determines the quality of the final service. As part of the integration process, in which, for example, the operator takes over the organization and management of the transport process from the customer, a partnership is necessary in the creation of the service offer. The approach taken by the intermodal transport operator should therefore take the form of an active (partnership-based) attitude, involving the search for mutual and equivalent benefits. This attitude assumes that the intermodal transport operator treats the purchaser of the transport service, the recipient and the subcontractors (carriers) as customers and partners, and that integration with them brings mutual benefits and synergy effects, *e.g.* high quality of service and brand awareness. Customers are willing to choose brands that support the principles of sustainable development, and rail transport is one of the most environmentally efficient, as shown in Table 3 below.

Table 3. Share of the selected transportation sector in greenhouse gas emissions in 2022

Transport type	Share in % EU-27	Share in % in Poland
Road transport	73.19%	93.94%
Water transport	14.23%	1.22%
Air transport	11.77%	4.18%
Rail transport	0.33%	0.42%
other	0.49%	0.25%

Source: UTK 2024.

The important point about this concept is that the intermodal transport operator must treat clients, suppliers and intermediaries as partners in creating and guaranteeing value for the customer. The buyer benefits can be defined in terms of the value offered by companies and organizations to the buyer and to society. The role of marketing is to create this value, which promotes customer satisfaction and loyalty and the achievement of the service provider's desired results, *i.e.* long-term profits. Customers who understand the ESG concept make marketing an interactive form of engaging customers in social initiatives for the benefit of the environment, and marketing communication highlights the importance of the social aspect in companies' activities (Kotler *et al.* 2024). It is important to realize that the implementation of an intermodal transport service is a dynamic business process that integrates marketing and logistics processes, and therefore managing this process inevitably requires the integration of various links, forms and levels of activity, marketing and logistics instruments. As a result, a variety of values are created for the customer. These include utility values, *e.g.* purpose, location; communication values, *e.g.* information values; experience values, economic values, *e.g.* the relationship between price and the value perceived by the customer. In this process-oriented creation of basic values, the customer who uses intermodal transportation considers:

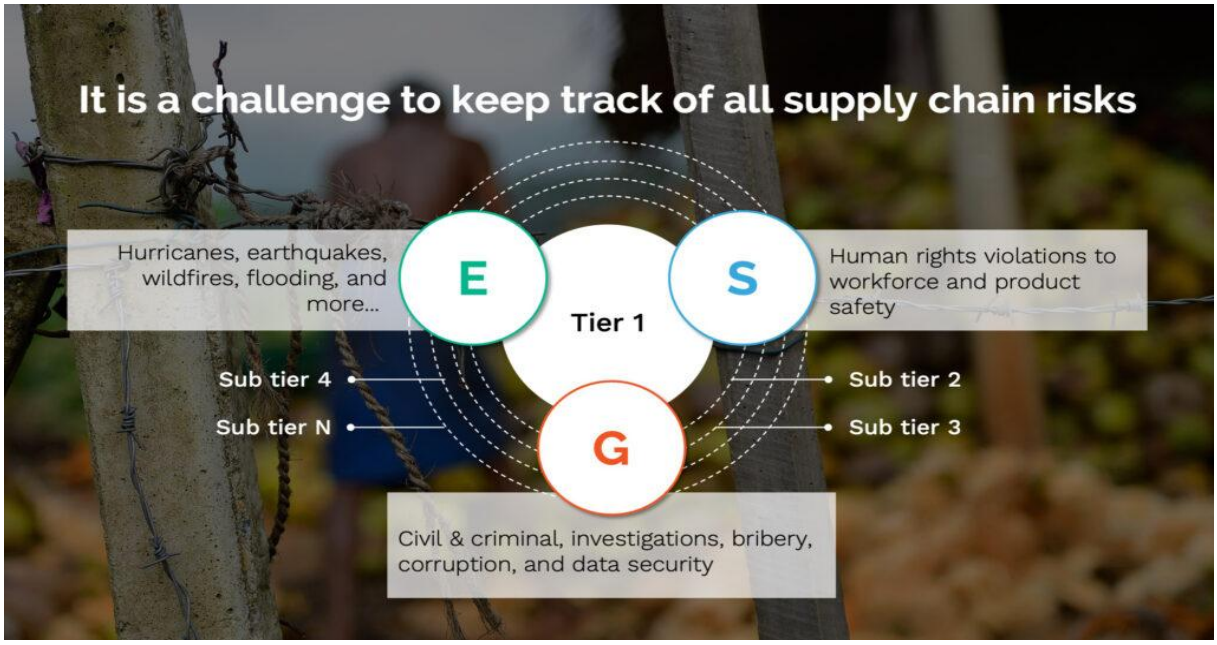
- marketing activities in terms of cost, benefits, communication, availability;
- transport and logistics activities in terms of *e.g.* customer service, the supplier's ability to respond to customer requirements, transparency of activities;
- relationships in terms of experiences resulting from contacts, experiences from interactions with a given entity, brand, service, environmental protection activities.

Hammer (cf. Bąkowski 2010, 5) confirms this reasoning and states that customer value is created by the processes that are the essence of transportation. From the economic perspective, customer value is inextricably related to price and is of a utility value (Christopher and Peck 2003, 56). Since most modern companies work in a networked manner, relying heavily on partnerships with other companies, a kind of marketing network of value creation is created (Armstrong and Kotler 2012, 95-96). In terms of sustainable marketing, the network includes the company with its employees, service providers, agents, partners, customers, and more broadly – society and other stakeholders who care about the social aspect of running a business. Managing the process of creating value for the customer by the intermodal transport operator means that the operator effectively meets the needs of the customer and other entities that constitute the value network. Value is the difference between the observed benefits that result from, for example, the properties of the service offered, such as its completeness, execution time, reliability, and the observed costs, such as the transaction costs associated with the service purchase costs (service price for the entire transportation route) or, for example, risks associated with uncertainty about the consequences of decisions made or unforeseen events during the execution of a service order. Identifying sustainability risks is a good ESG practice. Nowadays, companies are taking more responsibility than ever for their supply chains to assure stakeholders that they are applying relevant practices, thus reducing risks. See Figure 5.

Therefore, as part of an organized process and methodology of actions, it will be possible to manage this area of operation as well. The marketing concept in the value creation process in intermodal transport for the operator and the customer means that:

- when choosing a service provider, the buyer chooses the company that offers the highest value;
- the buyer is guided by the possibility of satisfying their needs, most often the economic ones, *e.g.* cost reduction;
- the buyer is guided by the belief that it is more profitable to build long-term relationships with customers, which creates trust and loyalty among customers who, as a result, continue to use the company's services (Doyle 2003, 85).

Figure 5. ESG-related supply chain risks include human rights issues and key business operation activity



Source: Everstream Team 2023.

Intermodal transport is, in fact, about providing a comprehensive solution to the customer's problems related to the flow of a specific product in a cargo unit from point A to point B. Therefore, by effectively solving the customer's problems, the intermodal transport operator also creates value in the form of, for example, a base of customers who use its services. The above reasoning is reflected by the theory that one of the most effective ways to build a stable position in the market is to create customer loyalty by providing them with the value they expect (Smyczek 2012, 21). It is therefore essential to develop an appropriate strategy for delivering value. The impact of ESG on modern marketing strategies for delivering value is therefore multidimensional and includes (cf. Kotler *et al.* 2024):

- economic benefits of sustainable marketing;
- building customer trust through transparent communication;
- creating value by engaging in solving social issues;
- creating and putting social innovation measures into practice.

In conclusion, it should be noted that meeting the challenges of sustainable development through relevant marketing strategies that take into account the management of environmental, social and corporate governance factors is gaining importance in the company's supply chain.

5. Research Results

The transportation services market is a driving force for innovation in the economy. The need for innovation applies to the entire transportation system in its individual branches and forms of transportation (cf. Antonowicz 2014). Innovation in transport means introducing new solutions or processes for any changes that contribute to increasing not only the economic, technical and technological, but also environmental efficiency of transport systems (Merta-Olejniczuk 2014, 39). One of the key instruments for reducing the environmental impact of rail freight transport is therefore innovation and new technologies (Niedzielski 2013). Global economic progress and the creative potential of the railway generate new relationships, products and services. External expectations and requirements – including those presented in Table 2 – therefore become not only part of optimization or performance improvement, but also part of adapting to the environment. This is also the case in rail freight transport, where solutions involving modern technologies become an element of creating new operational models and market strategies, playing a key role at all stages of the transport process, from planning, through investment implementation, management and execution of business processes, asset maintenance, work organization, to the arrangement of contact with contractors (Antonowicz and Majewski 2022, 142). The potential for innovation in long-distance rail transport makes it possible to overcome traditional barriers to the exchange of information, the supervision of operations throughout the logistics chain and the ongoing coordination of international transport (OSJD/UNESCAP 2022). New products and services offered by freight forwarders, carriers and service providers

must meet global expectations for high environmental standards, as shown in the case studies from China, Russia and Azerbaijan. Concern for the environment extends to defining the offer, optimizing the use of resources, the selection and configuration of rolling stock, supervision and monitoring of train traffic, as well as reporting. The resulting environmental value is shared by all participants in the transportation process, including not only companies but also their partners on the border services and the administration side of individual countries, as well as end customers. The ESG environmental aspect influences marketing, transforming marketing strategies towards informing the public about their environmental activities.

6. Discussions

The authors of the paper present the relevant environmental issues related to long-distance rail freight traffic along the Eurasian corridors, showing how the sector is reacting to the sustainability demands. The paper offers valuable insights into the environmental policies and practices that bring change in the rail freight industry, including innovative sustainable technologies, marketing strategies and regulations. A thorough literature review and case studies concerning leading railway operators and international organizations show how new technologies and evolving consumer expectations influence the logistics sector and contribute to reducing the ecological impact of freight transport.

What is particularly noteworthy as regards this paper is the application of Environmental, Social, and Governance (ESG) principles to Eurasian rail freight traffic, which offers a fresh perspective on how sustainability frameworks can be successfully incorporated into global transport systems. The paper's findings broaden general understanding of the role of railway transport in the issue of global sustainability, thus providing a practical roadmap for those railway operators and decision-makers that aim to reduce their environmental footprints.

The study's value also lies in the fact that it can be a source of information for further studies on sustainable logistics, new transport technologies and industry policies. Thanks to highlighting progressive environmental practices in international rail freight corridors, the paper can serve as a basis for further research that can make an impact on environmental management in the transport sector, which proves it to be a significant contribution to the academic literature and practical applications in the development of sustainable transport.

Conclusions

Innovative technologies and consumers' growing environmental awareness are increasingly responsible for the development of the modern economy. New technologies and solutions not only make transport and logistics chains more attractive and competitive, but also help to reduce their environmental impact. In the case of rail transportation, they play a particularly important role. The multitude of companies, entities, regulations and rules that need to be integrated in order to prepare long-distance international transportation is unprecedented in this industry. Eurasian transportation requires overcoming barriers such as very diverse technical, legal, cultural, linguistic and political conditions. National borders create barriers in the form of different track gauges, signaling and power supply systems, organizational structures, business models and the application of the ESG concept. Large railway companies, which enjoy a great deal of autonomy but are usually limited to one country, find it difficult to adapt to these challenges. Innovation is therefore one of the key opportunities for overcoming barriers in this area. The examples described show how environmentally friendly innovations and increasingly advanced technologies are creating completely new perspectives for the development of environmentally friendly rail transportation, while at the same time reducing the impact of railways on the environment. They add value to the long-distance rail service and promote network solutions based on transport corridors that go beyond the scale of individual companies, countries and infrastructure networks, creating value for a number of societies and countries located along the transport corridors. Although the level of integration and the dynamics of the processes are not yet comprehensive on an international scale, it is expected that the initiatives will gradually gain international significance and ensure not only optimal service parameters along entire transport corridors, but also the lowest possible ecological footprint of cargo transported between Asia and Europe.

Credit Authorship Contribution Statement

Mirosław Antonowicz: author of the article concept, author of the text, researcher responsible for collecting source data, data analyst.
Jakub Majewski: author of the text, data analyst, editor of the final version and conclusions.

Declaration of Competing Interest

The authors declare that they have no known financial conflicts of interest or personal relationships that could influence the work described in this article.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they did not use generative artificial intelligence or artificial intelligence-assisted technologies in the preparation of this work.

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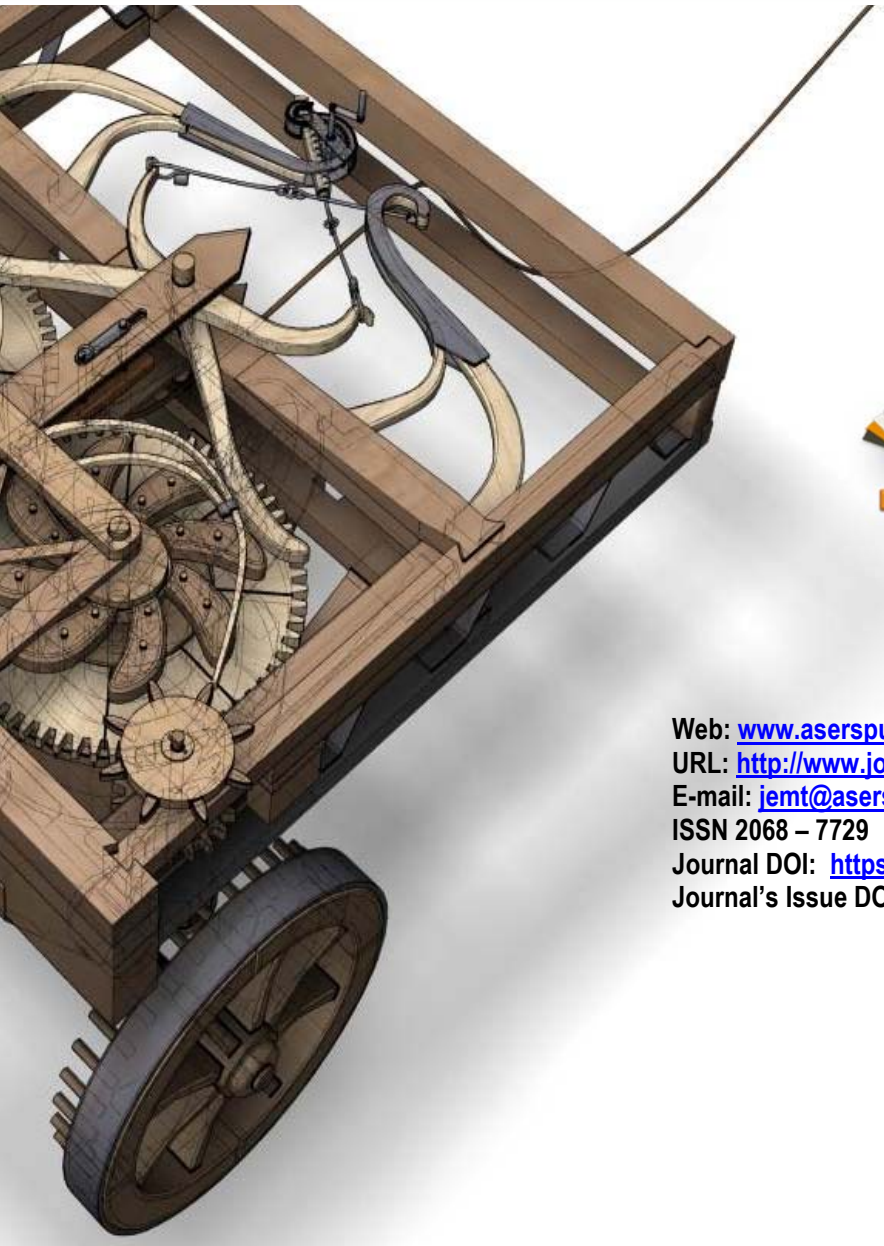

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