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OPPORTUNITIES FOR MULTIMODAL TRANSPORT DEVELOPMENT TO PROMOTE A SUSTAINABLE ENVIRONMENT

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Abstract. The rapidly growing global production and trade increase the demand for transport and logistics, leading to the establishment of increasingly more new companies providing these services. This also results in a much larger number of vehicles, which is not always a positive thing. Excessive vehicle traffic leads to an increase in environmental pollution, noise and traffic accidents, which have a highly negative impact on society and, more specifically, on human health. The negative impact on the environment has been increasing, and therefore representatives of national politics, the transport and logistics sectors should be alarmed and take action to reduce the environmental pollution. The development of the transport system should be carefully planned and geared towards achieving green and sustainable transport. In order to create a sustainable freight transport network, certain alternatives that could help to stop or at least reduce the process of environmental pollution should be pursued. One of such alternatives is the use of multimodal transport, which involves several different modes of transport for transporting one freight. This both distributes and reduces the burden on the currently dominant road transport mode, which contributes significantly to environmental pollution and is not sufficiently sustainable.

Keywords: creating a sustainable environment, intermodal interaction, multimodal transport development.

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Introduction

According to the European Commission, "multimodal transport" describes the use of various modes (or means) of transport during the same journey. This concept concerns both freight and passenger transport (European Commission, 2018). To serve future mobility needs, physical infrastructure, transport systems, traffic management, operational processes, and information systems will be seamlessly integrated (OECD, 2020).

When fully implemented, the multimodal transportation network should decrease road congestion and climate impact, making the whole sector safer and more cost-efficient. Ultimately, multimodality is expected to help creating a sustainable, integrated transport system ((European Commission, 2018).

When it comes to door-to-door (D2D) travel, it is frequently studied from different points of view. Researchers have explored different angles of D2D travel. Some focused on the purpose of the trip (Tłoczyński et al., 2022), while others concentrated on population density, regional accessibility, the walkability index, and network density, among other aspects (Lee, 2022).

European countries envision connecting different parts of the continent through a sustainable multimodal transport system that seamlessly joins all modes of travel (Bagamanova et al., 2022). Such a multimodal travel network requires efficient and convenient planning and governance services. Therefore, the development of Mobility as a Service (MaaS) depends on creating conditions that will enable the innovation of mobility services, integrating competitors' banners, thus creating a sharing economy and its associated benefits and providing a framework for developing and financing appropriate transport infrastructure (Martinčević et al., 2022).

The transport and logistics sector is of particular importance to countries, both vitally and economically, as it accounts for a large share of their gross domestic product and provides their populations and businesses with the goods they need and want (Wang et al., 2021).

As an example, Lin (2019) analyses the case of a Swedish trading company that uses multimodal transport to import goods from China and distribute them to the Scandinavian and European markets. In this case, consignments from manufacturers in China are collected by small trucks, delivered to collection centres, where the goods are transferred to large trucks and transported to consolidation centres, where the consignments are further loaded into containerised transport units. This system of collection, transhipment and transport to the loading centres reduces the risk of traffic congestion and environmental

pollution. Shipments stacked in containers at the consolidation centres are transported by lorries to loading terminals at the seaport, where they are loaded onto ships and transported to their destination. On arrival of the cargo ship, the containers are transferred to rail transport for carriage to an intermodal terminal and warehouse. At this terminal, the cargo is loaded to road vehicles for last-mile delivery to the required trading points (Lin, 2019).

According to Lomotko et al. (2023), when studying intermodal transport, the use of multimodal transport for the transport of dangerous goods has a positive impact on the environmental impact compared to the delivery of such goods by individual vehicles. The study found that reducing the share of single-modal road transport and replacing it with multimodal transport, such as rail, sea and river transport, can improve environmental performance of large volumes of dangerous goods, reducing the number of flights involved in the transport of goods and minimising the harmful environmental impact (Lomotko et al., 2023).

According to Datsii et al. (2021), multimodal transport is important for an effective transition to a climate-neutral economy. Investing in the development of multimodal transport can help countries to achieve high sustainability ratings, which will help to attract investment and increase consumer confidence.

It is important to highlight the risks associated with multimodal transport. According to Karavaeva and Lavrenteva (2021), the use of multimodal transport can lead to delays and damage to goods. The authors argue that these risks arise from a large number of different actors involved in the freight transport process. This has implications for the complexity of calculations and planning.

Li and Sun (2022) state that multimodal transport has an important impact on national economies. The study showed that multimodal transport could reduce transport costs and carbon emissions. This means that transporting freight by different modes can have a positive impact on the development of a sustainable environment.

Road transport makes an important contribution to the social and economic growth of countries. According to Bazaras and Vasilis Vasiliauskas (2012), some modes of transport are trying to displace others in certain freight transport sectors. Wiśnicki and Dyrda (2016) state that road transportation also has the advantage of providing a wide range of services, ensuring safety and flexibility. Although road transport offers the best mobility, its reliability and speed can be compromised by high traffic congestion (Kelle, 2019). When it comes to rail transport, Pietrzak O. and Pietrzak K. (2019) say that this mode of transport has the advantage of being able to transport heavy-weight

homogeneous goods over long distances, which is one of its main advantages, as rail transport can carry a much larger number of orders at once. Rail transport is also environmentally friendly. However, it also has a number of disadvantages, for example, it cannot offer door-to-door freight transport, which road transport can do. Rail transport is also often characterised by low flexibility and poor quality of service.

The authors of the analysed scientific articles give different definitions of multimodal transport (Table 1), providing insights into what is most important in this freight carriage process. According to Guo et al. (2021), multimodal transport is a process that combines two or more modes of transport to carry a single freight. Multimodal transport has the advantages of low transport costs, low energy consumption and high efficiency, which is why this mode of freight transport is becoming increasingly popular worldwide (Tadić et al., 2021). Authors states that terminals, which represent the location of storage and transhipment of multimodal transport units between different transport modes, play an important role in the development of multimodal transport. According to Tawfik and Limbourg (2019), multimodal transport can be defined as a chain of transport services that links the original consignor to the final consignee, where the shipment is in the same transport vessel, usually a container, simply transferring it to a different mode of transport. According to Archetti et al. (2021), the evolution of unimodal transport

Table 1. Definition of multimodal transport (compiled by the authors)

Author, year	Definition
Guo et al. (2021)	Multimodal transport is a process that combines two or more modes of transport-to-transport a single load.
Tadić et al. (2021)	Multimodal transport is defined as the movement of goods within a single loading unit using two or more modes of transport, changing the vehicle only.
Archetti et al. (2021)	Multimodal transport can be defined as a chain of transport services linking the original consignor to the final consignee, where the consignment is in the same transport vessel, usually a container, simply transferring it to a different mode of transport.
Archetti et al. (2021)	Multimodal transport can be defined as a chain of transport services linking the original consignor to the final consignee, where the consignment is in the same transport vessel, usually a container, simply transferring it to a different mode of transport.
Yang (2021)	Multimodal transport is a complex transport system consisting of a land transport and a water transport subsystem.
Baykasoğlu and Subulan (2016)	Freight carriage in a single intermodal unit using consistent modes of transport, i.e. road, rail, and maritime.

into multimodal transport is mandatory, as the growth in the number of goods transported each year around the world has increased the interest in the use of operational research methodologies for proper management of a multimodal transport system. According to Yang (2021), multimodal transport is a complex transport system consisting of a land transport and a water transport subsystem. Baykasoğlu and Subulan (2016) define multimodal transport as the transportation of freight in a single intermodal unit using sequential modes of transport, namely, road, rail, and maritime transport.

Although there is a considerable amount of research on logistics and transport network planning, i.e. the selection of the mode of transport, route planning, the selection of the location of loading and transhipment hubs, and the location of terminals, researchers claim that there still is a shortage of research on the design of the identified freight transport network issues.

Identification of issues relating to the development of sustainable environment in freight transportation and possible solutions

In freight transport, which is an integral part of international trade, participants in the process calculate the financial costs of transport, but often overlook one of the major problems of nowadays and the past, which is environmental pollution. According to Mostert et al. (2017) but it also contributes to air pollution which, in turn, affects human health. These negative impacts generate additional costs for society that are not necessarily taken into account in public transportation policies and in private transportation decisions of companies and individuals. This leads to inefficient transportation systems where the social equilibrium is not reached. Intermodal transport is promoted by the European Commission to reduce these negative externalities. The objective of this paper is to analyze at a strategic level the effect on modal split between road, intermodal rail and intermodal inland waterway transport of several economic or environmental policies. An intermodal allocation model is applied to the Belgian case in order to identify the modal split changes between the single minimization of costs (operational or health-related external, the activities involved in the freight transport process have a high external cost, and this cost is related to environmental pollution in particular. The growing concern for human health in the context of climate change has also led to increased attention to the sustainability of the transport sector (Holguín-Veras and Sánchez-Díaz, 2016). Marrero et al. (2021) notes that the current average air temperature has risen by up to 2 °C, which is a very serious problem that could lead the world to a catastrophe if it is

not reduced. Changing mobility patterns, i.e. improving public transport and promoting multimodality, is important, but the main objectives should focus on promoting technological change. Urrutia-Pereira et al. (2021) state that the use of fossil fuels is the main cause of climate change caused by human activities. In addition to air pollution, the development of a sustainable environment is hampered by the never-ending problems of vehicle noise. According to Shah et al. (2021), noise is a sound that exceeds permissible, undesirable limits and causes serious damage to human health. Utriainen et al. (2018) say that the targets set by the European Union to significantly reduce the number of fatalities and serious injuries have not been fully met, but various preventive measures are being taken to reduce or absolutely eliminate the number of deaths and injuries and to prevent road accidents, creating sustainability on the roads.

The use of multimodal transport results in lower transport costs and is a more environmentally friendly way of transporting freight (Trnka et al., 2021). The lack of sustainability in freight transport is still an unsolved problem. In order to achieve sustainable mobility, various alternatives have been proposed, and as López-Navarro (2014)there is widespread consensus about the notable, yet simultaneously growing, negative environmental impacts generated by the transportation sector. Experts working in a number of different fields consider the current situation to be unsustainable and possible measures to reduce emissions and foster sustainability are being encouraged. The European Commission has highlighted the need to shift away from unimodal road transport toward a greater use of intermodal transport through, for example, motorways of the sea, in light of the evidence that the former makes a significant contribution to increased CO_2 emissions. However, although there is a general perception that sea transport is environmentally preferable to road transport, recent studies are beginning to question this assumption. Moreover, little research has been conducted to quantify environmental aspects and incorporate them into the decision-making processes involved in the modal shift. This study first reviews the existing literature to examine the extent to which environmental aspects are relevant in the modal choice in the case of short sea shipping and motorways of the sea. Related to this, the study also evaluates the role that different agents may play in making decisions about choice of mode, taking into consideration environmental aspects. Secondly, we use the values the European Commission provides to calculate external costs for the Marco Polo freight transport project proposals (call 2013 states, the use of alternative, less harmful or completely environmentally friendly fuels is such a measure that could help to manage harmful environmental impact of transport. According to

Tamannaei et al. (2021) economic, and social sustainability dimensions are concerned. Governments usually improve sustainability dimensions in freight transportation by imposing taxes on transportation systems. Therefore, they should extend their knowledge on interactions between sustainability dimensions and how their interventions affect each dimension. In this regard, we analyze competition between two freight transportation systems in the context of government intervention. These systems include road and intermodal road–rail transportation modes, where the latter is regarded as an environmentally sustainable mode. A sequential game is addressed to analyze the duopoly competition. In the upper level, a government, as a Stackelberg leader, imposes taxes on fuel usage based on environmental, economic, and social concerns. In the lower level, a Nash game is developed to analyze price competition in the transportation market. Our analyses reveal that: (a, in order to accelerate sustainability in the freight transport process and to ensure a friendly, healthy and safe environment for the society, transport policies of countries must be controlled.

Applying advanced technologies in multimodal transport

The concept of multimodal transport is gaining ground in both freight and passenger transport. According to Hosseini and Al Khaled (2021), the selection and development of the infrastructure of a multimodal transport network is crucial taking into account the key elements of the network in order to ensure the resilience of the whole network. Altuntaş Vural et al. (2020) says that modern technologies such as Intelligent Transport Systems (ITS) have a huge positive impact on the efficiency of the transport network, traffic safety, reducing congestion and improving environmental sustainability. Blockchain, which is a distributed database system that archives various transactions together with other relevant information and manages all data, can be identified as one of the most effective technologies. According to Nofer (2017), this technology benefits the intermodal transport network by improving data traceability and speed. The tool allows the necessary data to be transmitted quickly, even to participants in the freight transport network on different continents. Major players in the logistics and container transport process are investing in the development of these technologies and platforms, seeing the full benefits. According to the scientific literature, all these advanced technologies and automation can facilitate the process of transporting freight, especially transshipment between different modes of transport. The Internet of Things (IoT) is also an effective technology. Some of the advanced IoT solutions for multimodal transport include Radio Frequency

Identification Technology (RFID) and Sensor System. These technologies have intelligent functions for detection, localisation and identification, which make them very useful in solving flow optimisation and freight management and control problems. Hofmann and Rüsch (2017) state that these advanced technologies, which mark the fourth industrial revolution, not only have a positive impact on transport and logistics, but also on the production process. Thus, assessing the logistics and production in combination, they can be seen to benefit the entire supply chain and the global exchange process.

Opportunities for multimodal transport development

The growing international production and trade volumes have also been increasing the extent of and demand for transport services, which is why the transport sector is expanding and its participants are constantly looking for new, efficient, innovative, and especially sustainable solutions for the performance of their activities (Jarašūnienė & Čižiūnienė, 2021). With expanding geographical scope of consumers and producers, as well as the participants in the logistics chain, sustainable freight transport is becoming a significant challenge that could be overcome through synergies between different transport modes. According to Nitsche (2021), developing countries have little expertise and knowledge of multimodal transport development, but are trying to focus on improving infrastructure and gradually moving towards the implementation of this transport system, which is not only more cost-effective, helps to reduce transport costs, but also contributes to a sustainable global environment. Yin et al. (2021) states that a multimodal transport network can optimise the distribution of transport costs and promote integrated and coordinated regional development. In the opinion of Ge et al. (2020), multimodal transport could be a substitute for price promotion policies. Jacobsson et al. (2017) resources and activities conclude that one of the most significant barriers to the development of intermodal transport is the lack of technological innovation, as the process involves many different actors interacting at ports and terminals, and the financial and time costs of operation at these terminals need to be kept to a minimum in order to achieve an efficient loading and transshipment process. According to Harris et al. (2015), advanced technologies have a huge potential to manage processes efficiently and reliably in real time, and can act like the nervous system of the entire multimodal transport system, responding quickly and efficiently to a wide range of unexpected situations during the transportation of freight. Giuffrida et al. (2021) the rise in fuel prices, the risk of drivers' shortage, and the new legal

developments limiting the hours of service on frequently congested roads, developing efficient and effective intermodal freight transport networks is becoming an increasingly important success factor for companies to manage their supply chains. However, many factors hinder the smooth implementation of intermodal systems, such as the high number of operators to be involved, the duplication of handling activities and transit times at the intersection of each transport mode, and the lack of information sharing among the different transport modes and companies. To overcome such barriers, Intelligent Communication Systems (ICS identifies lack of communication between different transport modes and difficulties in the monitoring and control of processes as one of the main challenges to the full implementation of multimodal transport. According to Jarašūnienė and Čižiūnienė (2021), the efficient interaction of different modes of transport depends more on the technological and physical flows and components of freight movements, but the integration of information systems is also crucial. In their research paper, the authors give the communication process between maritime and rail transport, i.e., information sharing, as an example. The rail and maritime transport modes use different information systems, which creates obstacles to proper management of the freight transport process and the interaction between the two modes. As a solution to the problem, a model (Figure 1) for the creation

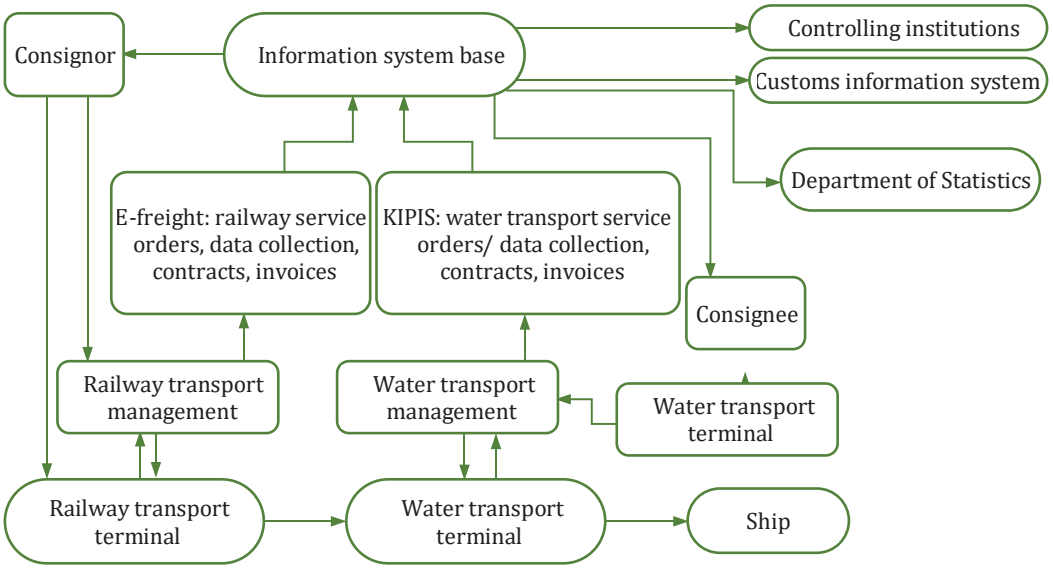


Figure 1. A model for interoperability between maritime and rail transport information systems (Jarašūnienė & Čižiūnienė, 2021)

of an efficient shared maritime and rail information system that reduces the cost of freight transport for an inadequate and inefficient information dissemination was proposed.

The model focuses on the development of a single electronic freight transport document for all modes of transport involved. The idea behind the development of the model is to allow all those involved in the freight transport process to monitor the status of the freight, its departure and arrival times in real time to be able to coordinate work schedules. Such information collection and sharing base makes it much quicker and easier to access the information needed, as it is collected in real time and in one place. According to Kumar and Anbanandam (2019), proper multimodal transport infrastructure can improve global supply chain connectivity, economic and regional development. When choosing the location of a terminal, the environment where it is to be built must be considered. Often, some vehicles cannot reach a terminal due to its inappropriate location, which slows down the multimodal transport process.

The scientific issues addressed in this paper reflect the most pressing problems related to the negative impact of the transport sector on humanity, i.e., environmental pollution. In order to promote a sustainable environment, it is proposed to develop and use multimodal transport, i.e., to combine different modes of transport to carry a single load, thus shifting a larger part of the freight volumes from road transport to other modes of transport. Multimodal transport is in this context a means of tackling the global problems of environmental pollution. However, in order for this measure to work, it should take into account aspects that help to improve the interaction between different modes of transport. In this context, information technology and infrastructure must be a major focus.

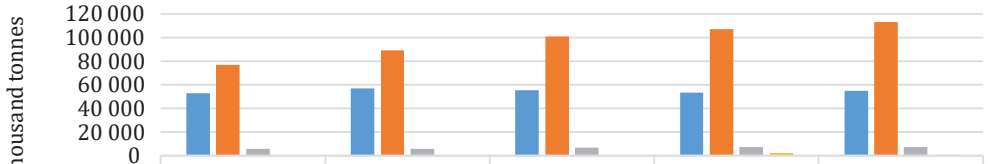
1. Research methodology

The performed analysis of the scientific literature allows concluding that the development of multimodal transport may be one of the solutions to reduce the negative environmental impact of the transport sector. Road transport has the greatest negative impact on the environment and accounts for the largest share of freight transport turnover. In view of these results, multimodal transport is identified as one of the solutions to this global problem. Scientific sources of literature suggest that using multimodal transport in freight transportation is a way of shifting the bulk of freight transported by road to other modes of transport and, thus, contributing to the development of a sustainable environment.

1.1. Analysis of the distribution of freight transport volumes between different transport modes

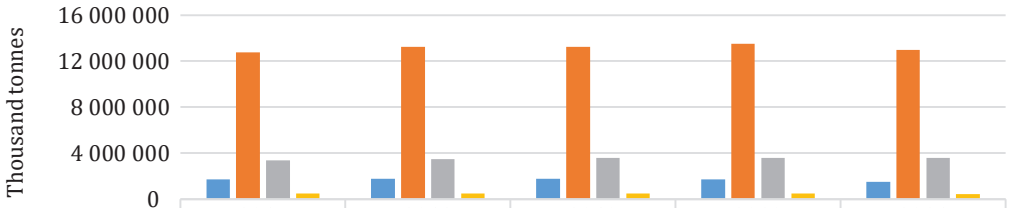
An analysis of statistical data was conducted in the first stage of the study. During the analysis, data showing the distribution of freight transport volumes between different modes of transport in Lithuania were collected. The diagram below illustrates the summarised data (Figure 2).

In order to assess the distribution of freight volumes between the different modes of transport in Lithuania, a five-year period (2017–2021) was chosen for data collection. Figure 2 shows that freight volumes between different modes of transport are spread over a fairly wide range. The data collected reveals that road transport is the dominant mode of freight transport, accounting for the largest volume of freight transported. Railway transport ranks second; however, the figures



	2017	2018	2019	2020	2021
Railway transport	52 638.2	56 775.7	55 209.2	53 429.7	54 682.8
Road transport	76 979.6	89 104.8	100 802.2	107 041.6	113 134.6
Maritime transport	5887.6	5790.9	6644.4	7376.5	7289.5
Air transport	390.6	324.9	350	2118.5	830.5

Figure 2. Distribution of freight transport volumes between different modes of transport in Lithuania in 2017–2021 (data from Statistics Lithuania)



	2017	2018	2019	2020	2021
Railway transport	1 741 890	1 762 800	1 764 462	1 734 994	1 535 061
Road transport	12 796 811	13 241 840	13 230 394	13 527 022	13 005 137
Maritime transport	3 376 704	3 476 076	3 584 537	3 587 258	3 598 974
Air transport	490 996	481 382	479 043	493 613	421 925

Figure 3. Distribution of freight transport volumes between different modes of transport in Europe in 2016–2021 (Eurostat data)

show that this mode of freight transport is significantly inferior to road transport. Maritime and air transport carry the smallest volumes of freight.

Distribution of freight transport volumes between modes of transport in Europe

In order to assess the distribution of freight volumes between the different modes of transport at the European level, data were collected for a five-year period (2016–2020). Summarised data are presented in the diagram below (Figure 3).

The conducted analysis of statistical data on the distribution of freight transport volumes between different modes of transport in Europe shows that, in terms of the volumes transported, road transport has the largest share of the transport market. The comparison with the previous data on the distribution of freight volumes in the Lithuanian transport market reveals that, at the European level, road transport carries several times more freight than rail or maritime transport. The data also show that air transport accounts for the lowest volume of freight.

1.2. Research process and methodology

In order to study the Lithuanian and European transport markets, the dominant modes of freight transport and the need and opportunities for the development of multimodal transport in order to promote the development of a sustainable environment, the method of survey of Lithuanian transport companies and their representatives and an expert evaluation method were used, calculating coefficients of significance of the factors affecting the development of multimodal transport.

Quantitative research method

Given that the research aims to explore the opportunities for the development of multimodal transport to promote a sustainable environment and to find out the demand for this mode of freight transport, the focus was placed on representatives of the transport industry, i.e. companies and their employees. A quantitative research method was chosen to this end. According to Kardelis (2002), a quantitative research searches for external signs of a phenomenon, extracting various indicators that can be quantified and measured. Quantitative research is more structured and planned, as the research methods and data measurement tools are usually constructed before the research. A questionnaire survey method was chosen for this research.

Research population and sample. Answers of 104 respondents were received during the survey. The research population was all Lithuanian transport companies, the size of the population – 4252 legal entities. To calculate the reliability of the conducted research, the Equation (1) was used:

$$n = \frac{1}{\Delta^2 + \frac{1}{N}}, \tag{1}$$

where n – sample size; N – population size; Δ^2 – margin of error.

$$104 = \frac{1}{\Delta^2 + \frac{1}{4252}},$$

$$104\Delta^2 = 1 - \frac{104}{4252},$$

$$\Delta^2 = 0.00938;\ \Delta \approx 0.097 = 9.7\%.$$

The Equation (1) was used to calculate the reliability of the survey, which was 9.7% at the probability of 95%.

1.3. Analysis and summary of research results

An analysis of transport companies selected according to certain criteria was conducted using the survey research method. First of all, it was found that the majority of the companies surveyed, i.e., 80.9%, focused their activities on the European Union market, while the remaining 19.1% worked with the CIS countries only. Almost half of the companies surveyed (45.2%) used road transport to transport their goods, fewer (22.9%) used rail transport and 16.9% used maritime transport. These results show that road transport is still the dominant mode for freight transportation and the highest volume of this type of transportation is in the territory of the European Union Member States in particular.

When it comes to multimodal transport being studied, 95.2% of the respondents indicated in the questionnaire that they were familiar with this concept and the mode of transport of goods, which allows concluding that both business and the general public have an interest in this area of transport. The results of the question asked in the questionnaire on the level of development of multimodal transport in the country show that 44.2% of respondents think that the multimodal transport network is only partly developed across Lithuania, fewer respondents (33.7%) think that it is not developed and the smallest share (22.1%) of respondents say that the multimodal transport network in Lithuania is well developed.

The survey then provided for factors determining the use of intermodal interoperability in freight transport. The results of the responses to this question show that the highest share of respondents (28.6%) say that the main factor in favour of multimodal freight transport is the reduction of environmental pollution, while a similar share of respondents (26.4%) indicate lower transport costs and faster and easier border crossing procedures as key factors. The smallest share (18.6%) point out that the main factor for interoperability between different modes of transport for the carriage of a single load is improved traffic safety. The results suggest that all four of these factors have a fairly strong influence on the freight transport process. It is safe to say that shifting freight transport volumes from one mode of transport, such as road transport, to several modes of transport can improve both the economic and the social environment and maintain and increase the sustainability of the transport sector. Next question addressed the use of multimodal transport as a means to promote a sustainable environment. According to the responses, 97.1% of respondents believe that the use of multimodal transport can improve environmental sustainability. There was also a question about the advantage of multimodal transport over single vehicles, such as road vehicles, in improving road safety. The results of this question show that a vast majority (84.6%) of respondents believe that multimodal transport is superior to single modes of transport for increasing road safety. It was also important to find out factors determining the choice of mode of freight transport. The data showed that the cost of transport was considered to be the most important factor, with 31 respondents indicating this aspect. The second most important factor was the speed of transport, followed by safety and transport flexibility, which was distinguished as the fourth most important factor by the respondents. These results reveal that a majority of companies assessed the quality of the transport process services in terms of price and speed of performance. The results show that sustainability of transport services is the least considered aspect. Thus, it can be concluded that the price and the speed of the service still determine the method of freight transportation. Although scientific literature and studies by responsible health authorities suggest that the issue of sustainability in the transport sector is very important and needs to be addressed, a vast majority of transport operators still do not take sufficient account of the existing problems.

These results reveal that the largest share of the respondents (34.1%) considers infrastructure and its development to be the most important aspect, while 24.1% of the respondents believe that the means of information transmission are important for proper development of a multimodal transport network. Terminals and loading stations that are properly arranged to receive, trans-ship, and prepare freight are

considered an important aspect of the multimodal transport network. The respondents surveyed also consider human capital qualifications and competences to be of high importance, as it is difficult to properly manage and control a process which involves a significant number of different actors.

The last question of the survey was related to the assessment of the potential for developing multimodal transport. Almost all respondents (91.3%) believe that the development of a multimodal transport network in both Lithuania and Europe is the way to go in light of future prospects. Based on these survey results and considering that one of the global issues is negative environmental impact of the transport sector, multimodal transport can be concluded to have sufficient potential and can be used as a tool to promote the creation of a sustainable environment and a sustainable supply chain.

Having analysed and structured the results of the survey, it was found that a majority of respondents had a positive attitude towards the integration of multimodal transport and saw prospects for its development.

1.4. Qualitative research method

In order to obtain more accurate answers about the potential of multimodal transport to promote the development of a sustainable environment, an expert evaluation study was conducted (Tidikis, 2003). A qualitative research method was chosen to assess the potential of multimodal transport to promote the development of a sustainable environment. In the study, each expert was asked to rate the potential of multimodal transport to promote the development of a sustainable environment on a scale of 1 to 5. Before making evaluations, the experts were presented with the findings and the main problems related to the development of multimodal transport that emerged from the analysis of scientific literature. The results of the experts' evaluations were analysed. The chosen qualitative evaluation method was used to substantiate the scientific literature and to find out which factors were the most important in the development of multimodal transport.

Research sample. The sample for qualitative research is not usually defined, so eight experts were chosen to be interviewed in the context of the problem being analysed. The experts were selected for the research on the basis of their degree of qualification, experience in the field of transport and logistics and their competence in assessing the multimodal transport process.

The experts were interviewed using a structured questionnaire where they rated the importance of each of the identified problematic

factors for the development of multimodal transport according to the given criteria.

1.5. Analysis of the determination of the significance of the criteria

The experts rated the significance of each criterion on a scale of 1 to 100. The analysis reveals which factor is the most important for the development of a multimodal transport network.

Problem factors for the development of a multimodal transport network include:

- Lack of terminals and other infrastructure elements;
- Lack of adoption of advanced technologies;
- Project requiring high investment;
- Insufficient state support and involvement;
- Mistrust of participants in the transport sector in the new alternative.

In order to calculate the significance of the criteria, experts' scoring of the criteria had to be obtained. Scoring of the criteria by separate experts (in total) is presented below. The next step was to calculate the significance of the criteria using the formula below:

$$\text{Significance of the criteria} = \frac{\text{Total}}{800}. \quad (2)$$

These calculations show which criterion is the most and least important according to the experts, and Tables 2 and 3 illustrate the results thereof.

Table 2. Calculating the significance of the criteria

Criterion	Experts								Total	Significance
	1	2	3	4	5	6	7	8		
Lack of terminals and other infrastructure elements	30	35	20	35	20	40	10	15	205	0.26
Lack of adoption of advanced technologies	40	35	35	35	45	20	50	35	295	0.37
The project requires significant investment	10	20	30	15	5	10	20	35	145	0.18
Insufficient state support and involvement	15	5	5	15	15	10	20	5	90	0.11
Mistrust of participants in the transport sector in the new alternative	5	5	10	0	15	20	0	10	65	0.08

Table 3. Determining the significance of the criteria

Criteria	Ranking in terms of significance
Lack of terminals and other infrastructure elements	2
Lack of adoption of advanced technologies	1
The project requires significant investment	3
Insufficient state support and involvement	4
Mistrust of participants in the transport sector in the new alternative	5

In summary, it was determined that the most significant factor interfering with the development of multimodal transport was the lack of adoption of advanced technologies, which led to problems with information dissemination and the incompatibility of the different actors in the freight transport process. The lack of terminals and other infrastructure elements is an equally important criterion. Experts believe that the development of a multimodal transport system is a complex project which requires significant investment, so this factor also has a strong influence on its development. The least important criterion is the lack of confidence of participants in the transport sector in the new alternative.

2. Results

The performed analysis of the scientific literature reveals that the growing number of vehicles, traffic intensity and freight transport volumes are becoming an increasing challenge for a sustainable and environmentally friendly environment, revealing the key global issues such as environmental pollution, vehicle noise and congestion. Thus, the aim is to search for new ways and alternatives to tackle these problems and promote sustainability. Researchers have identified multimodal freight transport as one of the most effective means. This alternative makes it possible to shift a greater proportion of freight volumes to less polluting means of transport, since studies have shown that road transport is the main contributor to the environmental pollution caused by the transport sector. The analysis of statistical data has shown that road transport has the largest share of the transport market. Road transport accounts for several times more freight than rail or maritime transport. In order to find out the reasons for this statistic and the possibilities of shifting a larger share of freight from road to other modes

of transport and of exploiting synergies between the different modes of transport, a survey and an expert evaluation study were conducted.

The conducted research shows that road transport is the main mode of transport used by the surveyed transport service providers. The respondents positively evaluated the alternative of multimodal transport. It was found that the use of intermodal interoperability to carry a single load required consideration of the improvement of infrastructure, information management and transmission facilities. The lack of adoption of advanced technologies was identified as the most significant factor, with the shortage of terminals and other infrastructure elements being an equally important criterion. It was also found that the development of multimodal transport is a complex project which required significant investment; thus, the availability of funding ha to be taken into consideration.

A multimodal transport development model has been created to address the identified problems in the transport sector in terms of environmental pollution and to ensure a sustainable, environmentally friendly and efficient transport and logistics service environment (Figure 4).

The presented multimodal transport development model highlights the main factors – technological progress, terminals and infrastructure – that affect the potential of this mode of freight transport. These factors are closely related to the process of developing multimodal transport to foster the development of a sustainable environment. Technological progress and the improvement of terminals and infrastructure would have a positive impact on the country's economic performance and the society. Ultimately, it would lead to a reduction in environmental pollution, improved public health indicators, a more sustainable, greener environment for the transport sector, improved economic performance of countries, a reduction of costs associated with freight transport, as well as optimisation and efficiency of freight transport processes.

It is also important to note that technological progress and the development of terminals and infrastructure are the main factors related to the development of multimodal transport, which have been identified through the analysis of scientific literature and research. The development of terminals and infrastructure would contribute to better transport links, as well as to the creation of new jobs and the efficiency of freight handling processes. The introduction and application of advanced technologies would improve the dissemination of information, help to combine different modes of transport in a single freight transport process and contribute to efficient, rapid and innovative freight carriage solutions. All this is important for the development of a multimodal

transport network that can be used as a tool in pursuit of the sustainable environment development.

Financial support and involvement of countries, adoption of new legislation on transport-related pollution, cooperation between countries, the design and development of new strategies and projects on the interaction between different modes of transport, as well as the development of new computer systems that bring together the different modes of transport, using such advanced technologies as Blockchain, cloud logistics, or the Internet of Things, are essential for the achievement of these goals. The creation and modernisation of terminals that are accessible to all modes of transport involved in multimodal

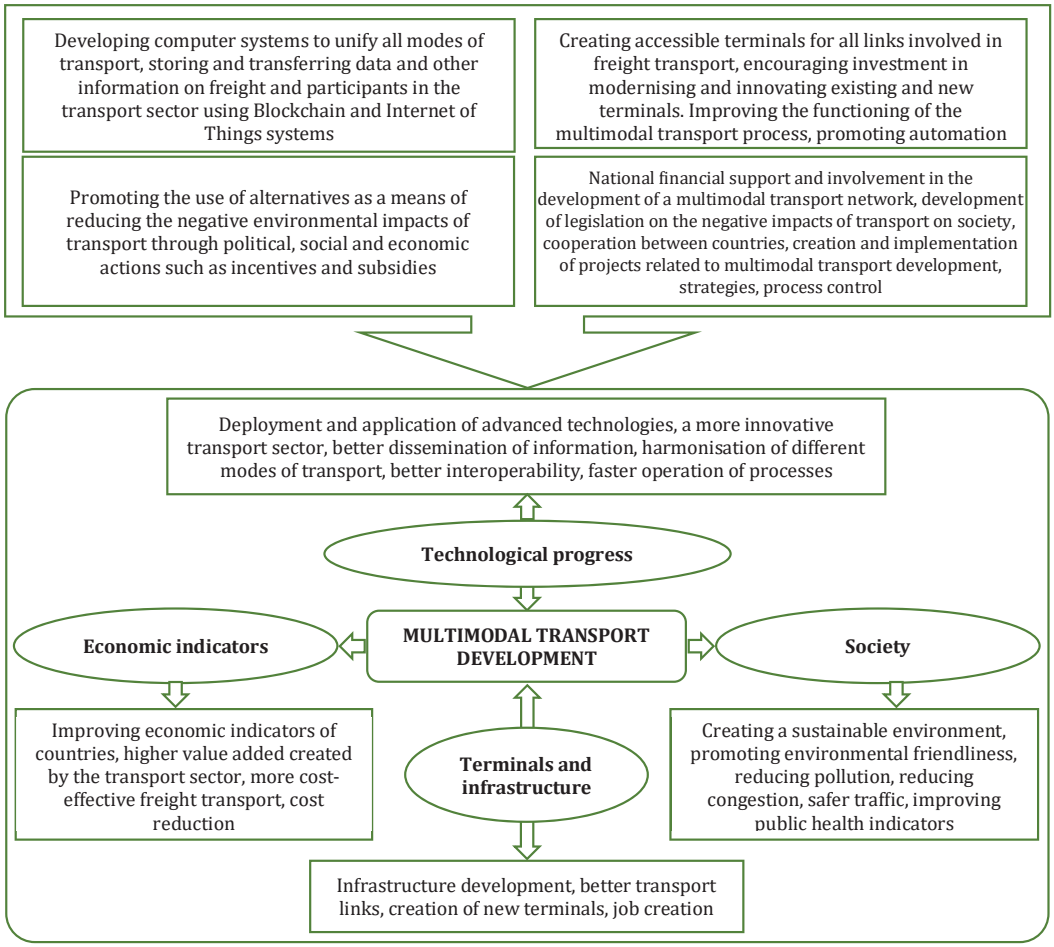


Figure 4. Multimodal transport development model

freight transport are equally important. To exploit the full potential of multimodal transport, businesses must be encouraged to choose this alternative as a means of reducing negative environmental factors through political, social and economic measures such as tax incentives and subsidies. This model would enable the development of a multimodal transport network, the operation of which would make a significant contribution to the creation of a greener, more sustainable, efficient and economically beneficial environment for the transport sector.

2.1. Expert evaluation of the created multimodal transport development model

In order to assess the applicability of the created multimodal transport development model, an expert evaluation method was chosen. This evaluation method is important for testing the feasibility of the model.

2.2. Expert evaluation results

Eight experts took part in the survey (see Figure 5).

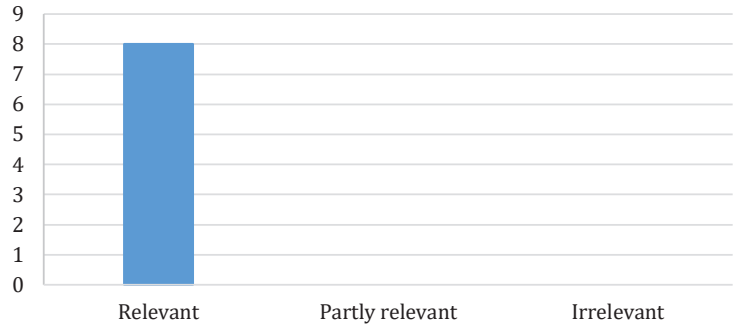


Figure 5. Experts' opinion on the relevance of the multimodal transport development model

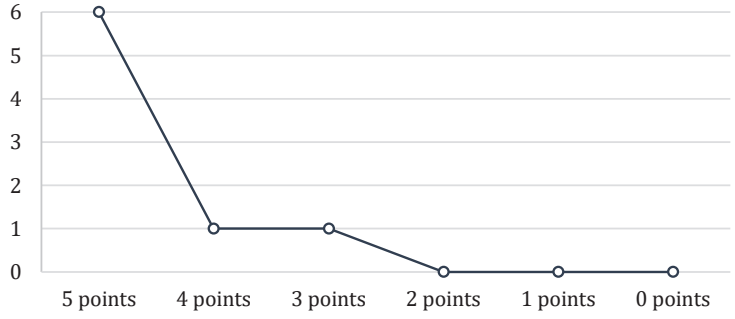


Figure 6. The evaluation of the multimodal transport development model

Figure 5 shows that experts consider the development of multimodal transport to be relevant in promoting a sustainable environment. The next question aimed to find out how the experts perceive the created multimodal transport development model (Figure 6).

Experts were asked to rate the multimodal transport development model on a 5-point scale. Six of the eight experts awarded 5 points, one expert gave four points and one – three points. These results allow concluding that the model is relevant. Practical application of the model would be more appropriate, but it would require considerable resources. The next question aimed to find out what the experts considered to be four additional factors for the success of multimodal transport development that were not mentioned and included in the model. According to the experts, the political and legal environment is one of the most important factors for the development of this freight transport alternative. The experts point out that a certain legal framework could be created to regulate the distance that freight can be transported per vehicle, in this case by road transport, which is the mode of transport that has the greatest negative impact on the environment. For example, having carried a load for a certain distance by road, it should be transferred to other modes of transport, such as rail. In the fourth question, the experts gave their insights on the use and implementation of advanced technologies in multimodal transport and whether this could increase the efficiency of the process (Figure 7).

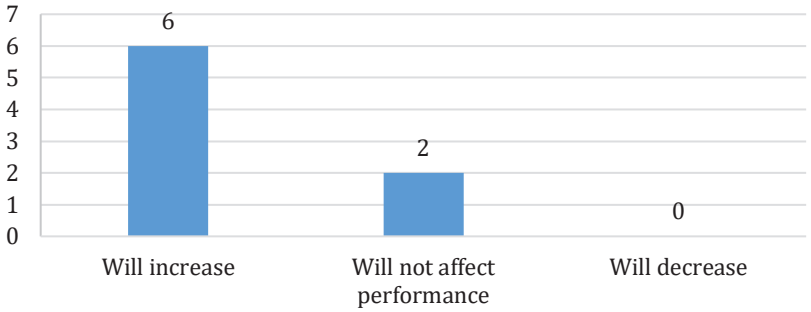


Figure 7. Expert opinion on the benefits of deploying and applying advanced technologies for the efficiency of multimodal transport process

Conclusions

1. The analysis of the scientific literature revealed that the potential of multimodal transport had not been fully exploited, and that there were often problems that prevented smooth running of this process. One of the main problems identified by researchers in the adoption of multimodal transport is the lack of information and communication technologies (ICTs) that could connect all modes of transport, resulting in smooth sharing of relevant information, proper coordination of different modes of transport, documentation, and legal framework.
2. The performed statistical analysis of the data, which aimed to find out the distribution of freight transport volumes between the different modes of transport in Lithuania and Europe, showed that the majority of the freight transported was carried by road, and that during the selected period, road transport was still the dominant mode of transport. The integration of multimodal transport and the use of synergies between different modes of transport for the carriage of a single load had a relatively high prospect of shifting the major share of freight from road to other modes of transport.
3. The survey also confirmed the findings of the statistical analysis and showed that the vast majority of transport service providers ran business using road transport in particular. It was also determined that respondents had a positive opinion on the use of multimodal transport as a means to develop a sustainable environment. The survey also revealed that in order to develop the use of intermodal interoperability in freight transport, the improvement of infrastructure, information management and transmission tools and human resource skills should also be taken into account.
4. The expert evaluation identified the main problems related to the development of multimodal transport. The expert survey confirmed the results of the analysis of the sources of literature, which showed that the main problems related to the design and development of a multimodal transport network were the lack of the adoption of advanced technologies and the shortage of terminals, the selection of their location and other infrastructure elements.
5 Based on the research results, a multimodal transport development model was created, which reflected the main multimodal transport development problems and the ways to solve them. The created model highlights the main issues and actions to be taken to develop a multimodal transport network and to promote a sustainable environment.

6. An expert evaluation method was chosen to evaluate the model, which revealed that experts had a positive opinion of the created multimodal transport development model, seeing that it could be used as a basis for further theoretical and practical research in order to promote the creation of a more sustainable transport environment.
7. Based on the guidelines set out in the multimodal transport development model, a freight transport and logistics network will be developed and improved to provide greener transport services and reduce the negative impacts of transport on society. The application of the model and the development of a green transport sector will benefit both public health and national economies, as multimodal transport is more cost-effective than single modes of transport, according to studies and calculations carried out by scientists. In order to make multimodal transport even more efficient, it is important to address the issue of fuel used for transport. In this context, greater emphasis should be placed on the use of alternative fuels.

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