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Logistics Network Design System in Eu Through Modern Modelling Techniques: Establishing Strong Transport Links to Improve Foreign Economic Relations

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Abstract

The main goal of this study is to formulate an effective methodological approach for identifying and analyzing the most optimal logistics routes for a transport company operating in the EU. The object of the study is the transport and logistics activities of the Czech Republic. The scientific objective of the study is to identify the most rational route for the key transport route of the selected company through the use of a mathematical analysis method. The following methods were used: the expert opinion method and the network priority ranking method. Through the expert method and our own assessment, 5 key routes were identified that were optimal in the context of time and other conditions. As a result of the ranking, the most optimal route to reach the final destination was discovered. The study has its limitations as we analyzed these routes in terms of limited parameters. The key parameter that was not taken into account when the experts selected the list of routes was the financial aspect, since it is specific to an individual company. In the future, it is planned to expand this analysis, taking into account a larger number of conditions and factors that will influence the choice of transportation routes.

Keywords: *Transport, Logistics, Logistics Network, Ranking, Route, Transportation, Consistency Of Transportation, Cargo Transportation, Transport Logistics, Supply Chains, Foreign Economic Relations*

INTRODUCTION

Currently, road transport is the basis for the socio-economic development of Europe. A well-developed network of quality roads has become a key factor in the efficiency of supply chains and other modes of transport on the continent. The importance of this particular type of transport is due to the unique geographical, economic and infrastructural features inherent in European countries. Most of the features relate to high density of settlements, industrial development and high level of urbanization. Based on the existing developed networks of rail, sea and air transport, in Europe Road transport still plays a key role both in the development of the private sector and in the economic and social development of individual countries and international trade.

But at the same time, European road transport networks face a number of influences and challenges related to both the need for continuous improvement and modern requirements and standards for sustainable development. These requirements relate to the need to reduce the impact of transport on the environment, rationalize fuel resources, as well as reduce the transport load on urban infrastructure.

The development of logistics networks in Europe requires specialists to use modern modeling and planning methods. This allows logistics processes to adapt to rapidly changing economic conditions, while ensuring high efficiency and minimal environmental impact.

Modern modeling methods in logistics are of particular relevance in the European context, where the need for integration and optimization of transport flows is extremely high. These methods allow logisticians to create

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detailed virtual models of logistics networks that take into account the variety of transport routes, cargo flows and other key parameters.

The challenge for European logistics is not only to improve existing networks, but also to develop new transport communication concepts that can meet the challenges of the future. This includes integrating smart technologies, automating processes, using alternative fuels and developing innovative logistics solutions.

Thus, in the European context, the study of logistics network design through modern modeling methods opens up new perspectives for improving the efficiency and consistency of transport operations. This will not only optimize existing processes, but also create the basis for the future development of logistics systems capable of meeting the growing needs of society for high-speed, safe and environmentally friendly transportation. Thus, Fig.1. depicts key EU transport routes

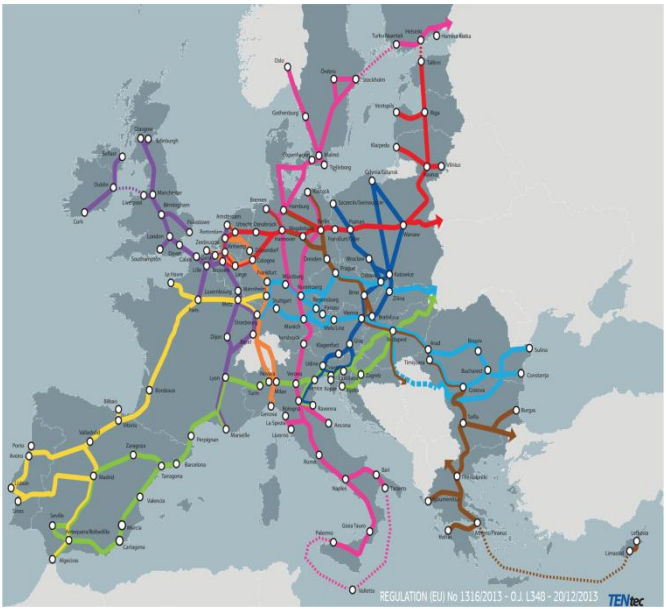

Figure 1. Key EU transport

European logistics companies face a number of challenges when planning transport routes across the European Union, each of which requires careful analysis and innovative approaches to solutions. One of the key problems is the high variability and unpredictability of transport loading, which significantly complicates effective route planning. This requires companies to be flexible and able to quickly adapt to changing circumstances, such as fluctuations in demand or delays associated with border crossings.

At the same time, the complexity of the EU regulatory framework relating to transport is complicated by the fact that each country has its own characteristics and standards, which creates great problems for an individual logistics company. Thus, logistics companies should consider regulatory frameworks, environmental standards and even driver working hours in the context of each country through which the vehicle will travel when planning their operations. This requires the existence of a system of aggregation and prompt updating of existing data on the characteristics of routes and changes in the regulatory framework of EU countries.

Another major challenge facing transportation companies is the need to optimize and redesign their own vehicles to rationalize fuel use and reduce carbon emissions. Such changes are due to increased pressure from EU governments and the public towards greening transport, reducing its impact on the environment, as well as stimulating the development of "green" technologies and innovations.

All these challenges highlight the importance of designing logistics networks through modern modeling methods. These methods allow companies to effectively solve planning problems by optimizing routes based on various factors, including delivery time, fuel costs, environmental standards and regulatory restrictions. Modeling allows you to create flexible and adaptive logistics networks that can withstand fluctuations in

demand, optimize the use of resources and ensure high competitiveness of companies in the market. Thus, modern modeling methods open up new opportunities for logistics in Europe, allowing not only to solve existing problems, but to pave the way for innovative and sustainable development of the industry.

The main goal of this study is to formulate an effective methodological approach for identifying and analyzing the most optimal logistics routes for a transport company operating in the EU. The object of the study is the transport and logistics activities of the Czech Republic.

The structure of the article consists of a literature review, a description of the methodology, a presentation of the results and their discussion, as well as conclusions.

LITERATURE REVIEW

To begin the research, an important step is to create an information base on this topic in order to understand the features of the modern transport system and the activities of transport companies in the EU. This will allow not only to analyze the current state and features of activities, but also to identify existing or future problems, threats and risks, as well as systematize trends in the future functioning of companies in the EU market. The study of modern and relevant scientific works covering the problems of planning logistics routes will become the foundation for the development of research methodology and the formulation of one's own scientific hypotheses.

The work of Ayadi et al. (2021) reveals an innovative approach to choosing a location for logistics platforms using fuzzy composite indicators taking into account constancy. This article provides new methodological tools for comprehensive route assessment, integrating economic, environmental and social aspects, which highlights the value of a broad approach to route selection and can enrich our research.

Research by Bugarčić et al. (2020) analyzes the relationship between Logistics Performance Indicator and international trade in Central and Eastern European countries, focusing on the importance of logistics performance for economic development. They highlight the critical role of logistics in international trade, which indicates the need for our research to focus on route optimization to improve overall efficiency.

Similar studies by Wu et al. (2021), who propose a hybrid meta-heuristic algorithm to solve the complex location-inventory-routing problem considering time windows and fuel consumption. This approach opens up advanced techniques for optimizing logistics routes, which is particularly relevant to our research as it seeks to minimize costs and environmental impact.

A study by Tsoi et al. (2021) is aimed at studying the features of the legal settlement of the issue of decarbonization of transport and the impact of these changes on different economies of the world. Thus, the authors note a significant gap between the policy goals of countries implementing decarbonization measures and the practical consequences. Having made such conclusions, the authors emphasize the importance of creating an international legal framework of environmental standards for the activities of road transport. Thus, this study provides important insight into the need to formulate more effective strategies to achieve sustainable development in the transport industry.

In a study by Muñoz-Villamizar et al. (2019) the use of electric vehicles in urban freight networks is assessed. Analysis of the short- and medium-term benefits points to the significant potential of electrification to improve the efficiency and sustainability of urban logistics. This study helps to better understand the significance of technological innovation in modern logistics.

Wang and Choi (2018) examine the relationship between logistics efficiency and international trade volumes through a comparative analysis of developed and developing countries. They show how high logistics efficiency contributes to trade growth, highlighting the importance of optimizing logistics processes for economic development.

The environmental foundation of this issue is explored by Zhu and Hu (2017), who present a sustainable logistics network model for enterprise supply chains, emphasizing the need to integrate environmental and

social criteria into logistics planning. This study advances the understanding of consistency in the supply chain context and can serve as a basis for the development of more sustainable logistics strategies.

Puertas et al. (2014) analyze the relationship between logistics efficiency and export competitiveness in Europe. Their work demonstrates how improving logistics operations can improve countries' export potential, providing valuable directions for our research in route optimization.

Pamucar et al. (2018) develop a new hybrid multi-criteria decision-making model for selecting the location of a multimodal logistics center. Their approach of evaluating different factors and criteria can provide a comprehensive analysis when selecting optimal routes in our study.

Innovative approaches in this area are presented in the study by Aloui et al. (2022). The authors evaluate the benefits of horizontal collaboration in logistics networks, focusing on energy efficiency. Their study highlights the importance of collaboration in improving the efficiency of logistics operations, which is relevant for the development of integrated logistics strategies. Also interesting in this context is the study of Liu et al. (2023), who investigate the design of an underground logistics network. Their approach to developing innovative logistics solutions can inspire the search for unconventional ways to optimize logistics networks.

After a thorough review of the existing literature in the field of logistics and transport route planning, we found that despite a significant amount of research in this area, gaps and shortcomings still exist. This indicates that the current state of scientific knowledge does not fully solve all the challenges and tasks facing modern logistics. Therefore, there is a need for further development and research on this topic to develop more effective strategies for planning and optimizing logistics routes.

Systematizing, we identified a number of key shortcomings and scientific gaps (Table.1).

Table 1. Key shortcomings and scientific gap in the topic being studied

Gap and shortcomings	Short description
Limited analysis of regional characteristics	Much of the research focuses on creating unified strategies that should, in theory, be suitable for any region. At the same time, the specifics of each region, its problems and advantages, infrastructure features, regulatory requirements and environmental standards are ignored. This may result in less effective results.
Insufficient use of modern analysis technologies	Despite the rapid development of technology and the enormous potential of artificial intelligence, machine learning and rich data in logistics, existing literature is often limited to traditional analysis methods. This means that many potential opportunities to optimize and automate route planning processes remain untapped.
Lack of an integrated approach	Many studies focus on individual aspects of logistics routes, such as minimizing costs or reducing delivery times, without considering the need for an integrated approach. This results in important factors such as sustainability, flexibility and route adaptability being often overlooked, which can limit the effectiveness and sustainability of logistics strategies in a changing market environment.

Thus, the scientific objective of the study is to identify the most rational route for the key transport route of the selected company through the use of a mathematical analysis method.

METHODOLOGY

In the context of our research, which focuses on the optimization of logistics networks, special attention is paid to analysis methods that can provide accurate assessment and selection of optimal transport routes/

The basis of our research is the method of expert judgment, which involves the knowledge and experience of qualified specialists to evaluate various delivery routes. This method was chosen due to its ability to provide in-depth analysis of various aspects of transport operations, including cost, speed, reliability and environmental friendliness. The use of expert opinion will allow us to determine the five most optimal ways for a transport company, based on a comprehensive assessment of the specified parameters.

The second key method of our research is network priority ranking, which allows us to systematically determine the most efficient route among all possible options. This method is based on the evaluation and comparison of different routes, taking into account a set of criteria such as delivery time, cost-effectiveness and environmental safety. Thanks to a detailed analysis of each option, ranking the priority of networks allows to objectively assess the advantages and disadvantages of each path, based on a methodologically sound comparison system.

The selected methods will allow us not only to effectively solve the problems, but also to ensure a high level of validity and objectivity of the results obtained. A holistic approach to analysis, combining expert knowledge and systematic ranking, creates a reliable basis for developing and improving logistics networks capable of meeting the complex challenges of today's transportation market.

In the context of our research, special attention will be paid to the practice of the Czech transport company «VseslavLogistic», which has its head office in picturesque Prague. This company is an important player in the logistics services market, in particular in the field of international transport. One of the key activities of «VseslavLogistic» is the Prague-Barcelona route, connecting Central Europe with the Iberian Peninsula, playing a strategic role in the company's logistics operations .

Since this route is critical from a business point of view for the company we have chosen, the study will focus specifically on the analysis and selection of the most optimal transportation routes from Prague to Barcelona. Ultimately, taking into account all the parameters and conditions, one key route will be selected. In the process of implementing the methodology, various aspects of transportation, possible risks and threats will be taken into account. This approach was formed not only to optimize the transport activities of «VseslavLogistic», but also to form a framework for improving logistics processes through the use of advanced analysis methods and practical experience of experts.

The application of expert judgment methods and ranking of network priorities in the context of this specific area will allow the development of detailed strategic recommendations that will be aimed at increasing the efficiency and consistency of «VseslavLogistic's» transport operations. This approach will not only provide greater competitiveness for the company, but will help create a more efficient and environmentally sustainable logistics network.

RESULTS AND DISCUSSION

We note that through specialists and experts, we identified five logistics routes from Prague to Barcelona that can be used for cargo transport (Table 2).

Table 2. The main types of transportation along the specified route

Mark	Name	Route Name of the road	Description
T1	The Scenic Alpine Route	D1 (CZ) > A6/A93/A8 (DE) > A96 > A14 (AT) > A13 (CH) > A9 (FR) > AP-7 (ES)	From Prague's D1, head towards Munich via the A6, A93, and A8. Switch to the A96 towards Lindau, then take the A14 through Austria to the A13 through the Swiss Alps. Enter France via the A9 towards Montpellier, then follow the AP-7 to Barcelona
T2	The Direct Highway Route	D1 (CZ) > A6/A93/A9 (DE) > A6 (FR) > AP-7 (ES)	Starting on the D1 from Prague, you'll transition onto the A6 in Germany towards Nuremberg, then follow the A93 and A9 towards Munich. Crossing into France, continue on the A6 towards Lyon, and finally, in Spain, the AP-7 will lead you directly to Barcelona
T3	The Western Europe Explorer	D1 (CZ) > A6/A5 (DE) > A4/A35 (FR) > A9 > AP-7 (ES)	Depart Prague on the D1, transition to the A6 and A5 in Germany towards Karlsruhe, then take the A4 and A35 through France past Strasbourg and Lyon. Continue on the A9 to the Spanish border, then the AP-7 to Barcelona.

T4	The Mediterranean Coastal Route	D1 (CZ) > A6/A93/A8 (DE) > A7 (FR) > A9 > AP-7 (ES)	Starting on the D1, move to the A6, A93, and A8 in Germany. In France, pick up the A7 towards Marseille, following the Mediterranean coast via the A9, then onto the AP-7 in Spain, leading to Barcelona
T5	The Eastern Adventure	D1 (CZ) > A4 (DE) > A72/A9/A7 (DE) > A6 (FR) > AP-7 (ES)	Begin on Prague's D1, then take the A4 in Germany towards Dresden, and switch to the A72/A9 towards Munich. Follow the A7 towards Ulm, then take the A6 in France through Lyon, and finally, the AP-7 in Spain to Barcelona

Each route has its own unique characteristics, from direct, fast highways to scenic roads that offer picturesque views and cultural experiences. These routes leverage major European highways, ensuring a relatively smooth and efficient journey from Prague to Barcelona, albeit with different experiences and travel times. Along with this, each of the routes has a certain tangential relationship with the other. Be it road crossings or shared tracks. If so, it should be represented through the graph of connections in Fig. 2.

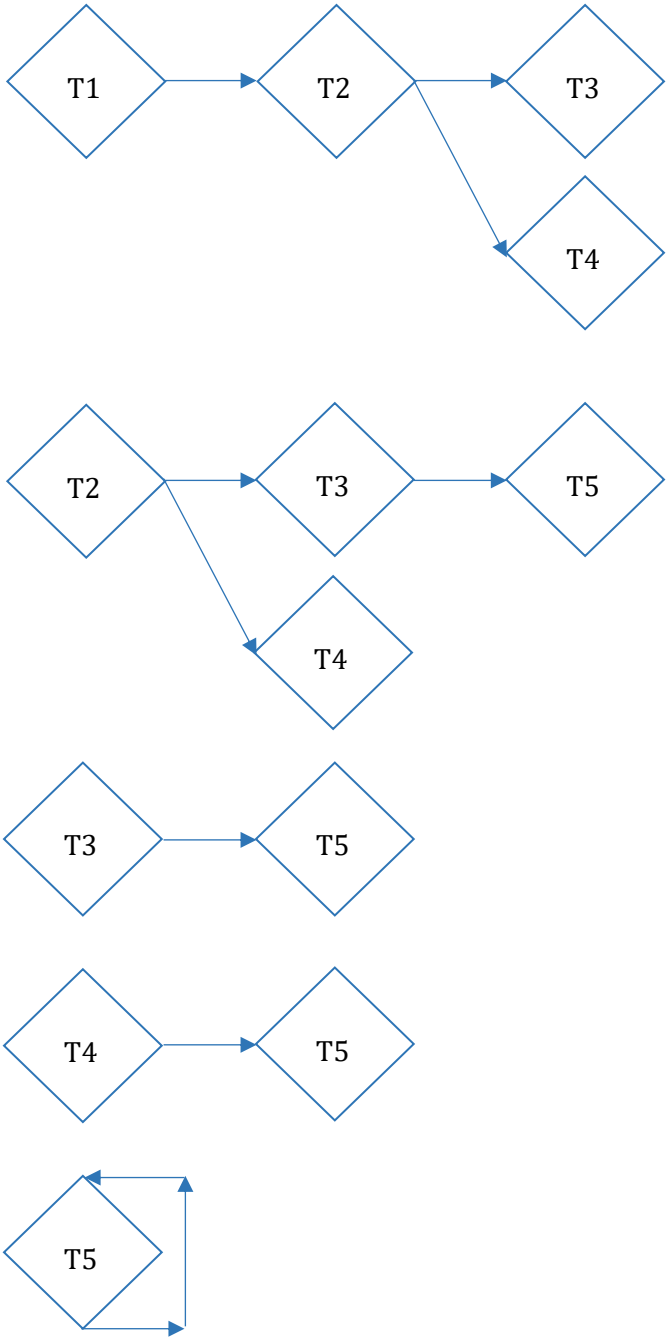

Figure 2. Graphs of multi-level interconnections of routes

Having connections, the calculation of the optimality of the direct and indirect value of these routes and their integral dependence was carried out. For this, a number of notations should be made (Table 3).

Table 3. Initial information for determining the optimal route

w	Formula	i

$w_1=10$		1-direct connection of combinations
$w_1=5$		2 – mediated connection of connections
$w_1=-10$	$C_{ij}=s_{ij}w_i(i=1,2,3,4; j=1....n)$	3 – the dependence of two combinations is straight
$w_1=-5$		4 – the dependence of two connections is mediated

After summarizing these data, we will get a table. 4 to establish the ranks of each of the proposed transport connections.

As can be seen from the Table 3, max|C3j | = 30, max|C4j | = 5. The specified values according to are added in each row to the sum of values in columns C1j, C2j, C3j and C4j. Now you can set and define rankings (Fig.3).

So most optimal will be T2. The essence of this route lies in its scenic beauty. It's a pathway that cuts through the very spine of Europe, offering views that can rival any painting. The Swiss Alps, with their awe-inspiring peaks and tranquil valleys, provide not just a backdrop but a compelling narrative to the journey. Travelers find themselves enveloped in landscapes that change with every mile, from lush forests to mirror-like lakes, each vista inviting a pause, a moment of reflection, or perhaps a spontaneous exploration. This natural beauty is complemented by the cultural landmarks that dot the route. Each region along the way tells its own story, from the medieval charm of German towns to the Renaissance elegance of Austrian architecture, culminating in the vibrant tapestry of cultures in Barcelona (Fig.4).

Figure 4. Optimal end road in T2 option

The infrastructure along this route, especially through countries like Germany, Austria, Switzerland, and France, before entering Spain, is among the best in Europe. The highways (A13 in Switzerland, for instance) are well-maintained, ensuring minimal disruptions due to road conditions. This reliability can lead to more predictable travel times, reducing the risk of delays in delivering goods. Compared to more direct, heavily trafficked routes that may pass through densely populated urban centers, the Scenic Alpine Route can offer less congestion, particularly on stretches away from major cities. This can result in smoother transportation of goods with fewer

stops and starts, reducing fuel consumption and wear and tear on vehicles. For logistics companies, this means potentially lower operating costs and a reduced carbon footprint.

DISCUSSION

In order to confirm the relevance and scientific novelty of our research, it is important to compare the results obtained with existing studies and their scientific achievements. Such a comparison allows not only to confirm the relevance and value of the study, the practical usefulness of the selected methods, but also to identify disagreements or possible limitations. In this context, we have selected a number of modern studies, the topics of which go back to ours, and the scientific reliability and relevance have been confirmed. A comparison of our research will reveal key contributions to the theoretical framework of the modern transport and logistics sector.

In the analysis of modern research that affects logistics and optimization of transport routes, one can find interesting differences and additions to our own research. Reviewing the work of Fazlollahtabar et al. (2019), we see the use of the FUCOM method for group selection of equipment in a warehouse, highlighting the importance of accurately tailoring decision-making methods to specific needs. While this study focuses on internal train logistics, our study expands the macro-level context of route planning by offering a holistic view of logistics operations.

In Zhang et al. (2017) a multimodal logistics network model is proposed that takes into account time constraints and environmental requirements. This study highlights the importance of integrating environmental issues into logistics planning, which resonates with our approach to identifying sustainable routes. However, our study goes beyond this by providing a detailed analysis of the impact of different routes on the overall performance of the logistics system.

A study by Boral et al. (2020) focuses on the integration of fault analysis techniques using fuzzy logic, which highlights the importance of precision in assessing risks and uncertainties in logistics. Our research is distinguished by the application of these principles not only to risk assessment, but also to route optimization using big data analysis and machine learning algorithms, providing a new dimension to decision making.

Proceedings of Coulombel et al. (2018) highlights the social and environmental costs of urban freight logistics, providing a critical analysis of the environmental impact of urban freight. A distinctive feature of our research is its focus on developing effective strategies to reduce this impact through innovative logistics solutions and the use of electric vehicles.

The work of Tan et al. (2022) focuses on the development and simulation of a logistics network model through a particle optimization algorithm. This study shows the power of computer simulation in developing efficient logistics systems. What makes our research different is the broader use of artificial intelligence technologies to analyze real data, allowing us to predict optimal routes in real time.

Turks et al. (2020) analyze production and reconditioning solutions in a reverse logistics system, taking into account carbon management constraints. This work focuses on the importance of environmental considerations in logistics decisions. Our research moves away from this by focusing on developing more flexible logistics routes that can adapt to changing environmental regulations, ensuring the sustainability of logistics operations.

Pamučar and Ćirović (2015) use the MABAC method to select transport and processing resources in logistics centers, highlighting the importance of integrated assessment in resource planning. The differences in our research lie in the use of a wider range of analytical tools to evaluate logistics routes, which allows not only to select resources, but also to optimize the entire supply chain.

A study by Bektas et al. (2019) focuses on the role of operational research in green freight transport, highlighting the potential of scientific methods in making logistics greener. Our approach expands on this idea by integrating operational research on emerging technologies to develop sustainable and efficient routes.

After all, Eriksson et al. (2022) explores transportation in supply networks, providing in-depth analysis of how transportation decisions interact. Our research examines transportation as a key element in supply chains, using data to develop optimized routes that provide high efficiency and minimize environmental impact.

Thus, each of these studies makes a valuable contribution to the development of logistics knowledge, but our study attempts to integrate and expand these ideas, proposing new solutions for optimizing logistics networks taking into account modern challenges and trends.

Having carefully compared our results with those obtained from other studies, we can state that the findings are highly relevant and relevant to the modern logistics industry. The analysis showed that our research not only meets the needs and challenges facing transport and logistics companies in the European Union, but also brings significant scientific novelty to the determination of optimal routes. We discovered new aspects and factors influencing the efficiency of transport flows, and also proposed original methodological approaches to the analysis and planning of logistics routes. These results complement and extend existing knowledge in the field, highlighting the importance of continued research in this direction to develop more effective logistics planning strategies.

Based on our analysis, our study has three key advantages that set it apart from other work in the field of logistics and transport planning:

Comprehensive methodological approach. One of the main advantages of our study is the use of integrated analysis, combining the method of expert assessments and the method of ranking network priorities. This approach allowed us to not only identify key routes with maximum efficiency, but also take into account various important criteria such as delivery time and route reliability. The result is a deep and multifaceted understanding of optimal routes, providing important practical contributions to the industry.

Focus on a specific region. Our research is distinguished by a deep focus on the specifics of transport and logistics activities in the Czech Republic, which allows us to accurately take into account local characteristics and needs. This regional focus not only enriches the theoretical basis of the study, but also makes practical recommendations of particular value for logistics operators operating in this region.

etermination of the most optimal route. Finally, the key advantage of our study is the successful identification of one, the most optimal route among all those considered. This result not only confirms the effectiveness of our methodological approaches, but also opens the way to focus further optimization efforts, promising significant efficiency improvements and cost reductions for transportation companies.

CONCLUSION

Planning optimal logistics routes in the context of the European Union is a complex task that requires taking into account a multifaceted infrastructure network, regulatory requirements and regional development features. Modern logistics is faced with challenges related not only to the physical aspects of delivery, but also to the need to adapt to changing market conditions, technological innovation and environmental standards. Given these challenges, determining the most efficient route becomes a key task to improve the competitiveness of transport companies.

The main goal of our research was to develop a methodology for analyzing and determining optimal routes for a transport company operating in the EU, with an emphasis on transport and logistics activities in the Czech Republic. During the study, the method of expert assessments and the method of ranking network priorities were used, which made it possible to identify five key routes that were optimal in terms of delivery time and other criteria.

Based on detailed analysis and ranking, it was determined that one route outperforms the others in terms of efficiency and compliance with the set goals. This result emphasizes the importance of an integrated approach to the analysis of logistics routes, which allows one to go beyond generally accepted practices and find innovative solutions to optimize logistics processes.

It is important to note that the analysis did not limit itself to examining the financial aspect, focusing instead on other critical parameters such as delivery time and resource efficiency. This approach allowed us to evaluate the potential effectiveness of routes without being limited to just one aspect of cost.

However, it is necessary to take into account the limitation of our study, which is the analysis of selected routes with a specific set of parameters. This approach has its limits, since it does not take into account all the possible dynamics and variables that can affect logistics processes in real conditions.

Our study paves the way for further research in this area, highlighting the need to expand the analysis to include more parameters and consider different conditions that may influence route choice. Future research has the potential to expand our knowledge and provide greater insight into logistics route optimization.

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