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Optimizing Medical Goods Transportation Through Advanced Logistics Networks: A New Paradigm

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Abstract

The purpose of the study is to model the process of assessing the level of organization of logistics networks for the transportation of medical goods. The object of the study is the modern logistics network for transporting goods in the Czech Republic. The scientific task is to formulate a model for assessing the level of organization of logistics networks for the transportation of medical goods. The research methodology includes a modelling method based on correlation-regression analysis and regression equations and a fuzzy modelling method. As a result of the use of these methods, it was investigated how different factors influence the transportation of medical goods. To summarize the analysis of these factors, a model was formed to assess the level of organization of logistics networks for the transportation of medical goods. However, the study has a number of limitations. So, first of all, the limitation concerns the use of the method of correlation-regression analysis and fuzzy modeling. The use of these methods does not allow us to cover the entire set of factors, and only some of them, the key ones, have the greatest impact on logistics networks. Moreover, our analysis focused exclusively on one country and its regions, which may limit the scope of application of the established methodology to other countries. Prospects for further research include expanding the methodological base and increasing the coverage of analysis to other countries.

Keywords: *Logistics Networks, Medical Products, Transportation, Supply Security, Innovative Technologies, International Regulatory Standards, Supply Chain Optimization*

INTRODUCTION

Modern logistics networks in Europe are characterized by a high degree of integration and automation. The use of innovative technologies such as artificial intelligence and the Internet of things allows companies to significantly improve the accuracy and speed of order fulfillment. These technologies provide not only optimization of warehouse management, but also improve inventory management, allowing the sale of goods with minimal losses. However, transporting medical goods requires special conditions. Medical products often include products that are temperature sensitive and have a limited shelf life. This requires logistics networks to be extremely precise in planning and executing deliveries, as well as the use of specialized vehicles and conservation conditions.

The introduction of green technologies and practices has become another important trend in logistics. European companies are actively integrating environmentally friendly vehicles and improving logistics processes to reduce their carbon footprint, which is especially important when developing new medical logistics networks. In addition, standardization of logistics activities remains a huge challenge. Requirements for packaging, labeling and accompanying documents often vary from one country to another, which can create barriers to the effective cross-border exchange of medical goods.

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The issue of security of supply is at the forefront. With growing cyber threats and physical risks, securing supply chains, especially when transporting sensitive medical supplies, requires companies to implement sophisticated security systems.

The transportation system and logistics planning for the transportation of medical goods across the Czech Republic has its own characteristics. At the same time, in this area there is a clear attempt by the Czech government and logistics companies to comply with national and international standards for the transportation of medical goods.

Another key aspect includes strict adherence to quality and safety standards. Czech regulations require that all medical products be certified and clearly labelled with information about origin, composition and expiration date. This ensures a high level of consumer confidence and security. Given the geographical position of the Czech Republic in the centre of Europe, the country plays an important role in international logistics networks. Czech logistics companies use their strategic location to optimize cross-border deliveries, which requires them to have a high level of coordination and interaction with customs and regulatory authorities in other countries.

The logistics networks of the Czech Republic are characterized by ramifications and numbers in each region of the country. This ensures efficient coverage of the entire territory and the ability to quickly respond to local logistics needs, particularly in the field of medical supplies (Fig.1).

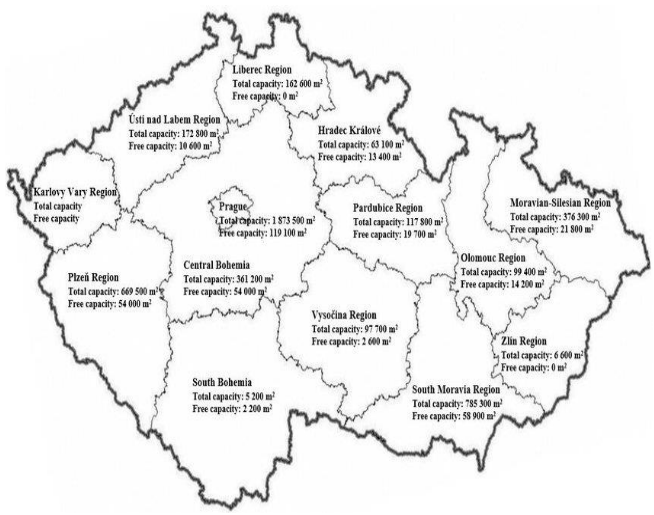

Figure 1: Logistics capacity map of Czech regions

Source: own analysis

Environmental standards also occupy a fundamental place in the organization of logistics activities. The Czech Republic is taking steps to reduce the environmental impact of logistics, including using electric vehicles for deliveries and optimizing logistics routes to reduce carbon emissions. Transportation of medical goods, especially those requiring special storage conditions (for example, vaccines), is carried out using specialized equipment. Logistics companies in the Czech Republic are investing in modern refrigeration units and climate-controlled vehicles to ensure ideal transport conditions.

The challenge for logistics networks remains the high cost of implementing and maintaining advanced technologies. Although the government provides some support and incentives for the development of innovation in logistics, many small and medium-sized enterprises face financial difficulties when trying to meet high standards.

In conclusion, the integration of the latest IT solutions and modern technology platforms becomes decisive for the further development of medical logistics in the Czech Republic. Thanks to this, you can not only increase the efficiency of processes but significantly improve the level of patient care.

Thus, the purpose of the study is to model the process of assessing the level of organization of logistics networks for the transportation of medical goods. The object of the study is the modern logistics network for transporting goods in the Czech Republic.

LITERATURE REVIEW

Before applying the methodology, a thorough understanding of existing research in the relevant field is important. Therefore, in the literature review section, we systematically analyze modern scientific publications and theoretical works related to logistics networks and the transportation of medical goods. This allows us to identify key trends, challenges and effective practices that have already been developed and tested in this area. The literature review plays a critical role as it provides the foundation for the selection and development of our methodology, ensuring the scientific rigor and relevance of the research conducted. Thus, in the work of De Campos et al. (2023), explore the critical factors influencing the efficiency of logistics processes in the context of end-of-life management of pharmaceutical products. Their work is important for understanding how environmental management practices can be integrated into pharmaceutical logistics processes, which is valuable for our research on medical supply chains.

While Wang et al. (2020) focus on logistics innovation and its impact on supply chain risks in the era of Industry 4.0. They analyze how the ability to innovate impacts the performance of logistics operations, which helps to understand the potential for technological change in medical logistics.

Ageron et al. (2018) describe key challenges and future trends in healthcare logistics and supply chain management. Their review highlights the complexity of healthcare logistics systems and the need for further research to improve these systems.

An interesting study by Schönsleben (2023) highlights integrated logistics management, emphasizing the importance of transactional and intercompany management in supply chains. His work provides a framework for understanding how logistics management affects the overall performance of companies, which is relevant for modeling efficient logistics networks.

Ayadi et al. (2021) propose a new fuzzy modeling approach for locating logistics platforms with a constant perspective. Their development of fuzzy composite indicators helps in the evaluation of various logistics strategies, which contributes to the optimization of medical logistics networks.

Grosso et al. (2019) explore the innovative potential of the European transport sector, analyzing macroeconomic trends and their impact on the development of transport systems. Their work highlights the importance of innovation in solving modern logistics challenges, especially relevant to improving the efficiency of transporting medical supplies.

Sabahi and Parast's (2023) work examines logistics and supply chain management from a product innovation perspective. The authors discuss how innovative practices can impact the operational efficiency and competency of enterprises. Particular attention is paid to the analysis of cases from different industries, which allows for a deeper understanding of how the introduction of product innovations can change logistics processes. This review is useful for understanding the potential of innovation in medical logistics.

The work of Tan et al. (2022) are developing a logistics network model based on a particle swarm optimization algorithm. They demonstrate how this approach is applicable to the design of more efficient and adaptive logistics systems. This work includes simulations that show significant improvements in costs and delivery times, which are important for optimizing the transport of medical supplies, especially in large and complex logistics networks.

A study by Eriksson, et al. (2022) analyze transportation in logistics networks with an emphasis on supply management. Their research highlights key strategies for efficiently positioning and managing traffic flows in multi-party networks. They also discuss how changes in transportation needs affect the overall efficiency of supply chains, which is relevant for medical supplies.

While Zhu and Hu (2017) consider sustainable logistics network modeling for corporate supply chains, emphasizing the importance of environmental and social factors. Their approach focuses on balancing economic goals with sustainability, which is important for companies seeking to reduce the environmental impact of their logistics operations.

Mehmood, et al. (2023) explore the application of Internet of Things (IoT) platforms in supply chain management. They explore how IoT facilitates data collection, resource monitoring and real-time optimization of logistics processes. This work is important for understanding the power of digital technologies to improve logistics operations, including in the medical sector, where accuracy and timeliness are critical.

Despite the great contribution of existing research to the development of logistics systems, many have gaps and shortcomings that limit their ability to fully address the objectives and problems. These gaps may include insufficient research on certain key aspects or limitations in the methodologies used, resulting in a narrow view of the layers and complexity of logistics processes. Often such studies do not take into account rapid changes in technology and management practices, which may lag behind current industry needs. (Table 1).

Table 1: Key scientific gaps and shortcomings of the researched topic

№	Scientific gaps and shortcomings	Essence
1	Adaptation to global challenges	One of the key gaps in logistics research is the lack of analysis of how logistics systems can adapt to global challenges such as pandemics, international political conflicts or economic crises.
2	Application of advanced technologies	Although some technological innovations are already being used, there is a gap in the full potential of automation and digitalization in supply chain management
3	Cross-cultural and regulatory differences	Another significant gap in logistics research is the lack of attention to cross-cultural differences and regulatory differences affecting international logistics networks. Particularly in medical logistics, where each country has its own regulations for the import and distribution of medical goods, such differences can significantly complicate logistics.

Source: own analysis

In addition, existing work may not provide sufficient attention to new challenges, such as global supply chains, sustainable development, or regulatory changes that are becoming increasingly relevant in the modern world. This lack of an integrated approach may limit the ability to use research findings to formulate effective, adaptive and innovative logistics strategies that can meet the growing demands of the medical industry and society. These gaps define and form the scientific task of the study. The scientific task is to formulate a model for assessing the level of organization of logistics networks for the transportation of medical goods.

METHODOLOGY

Thanks to a detailed study and integration of various scientific approaches, we have developed a comprehensive methodology that includes correlation-regression analysis and fuzzy modeling method. These methods were selected based on their ability to effectively analyse and model complex logistics systems where the interaction of multiple variables requires deep understanding and accuracy. The presentation of the methodology aims to ensure appropriate transparency of scientific processes, opening up opportunities for critical evaluation and further improvement of research methodologies.

For the scientific task set to simulate the process of assessing the level of organization of logistics networks for the transportation of medical goods, we selected a number of methods. The basis of the methodological approach is correlation regression analysis and the fuzzy modeling method, which are used to identify dependencies between factors and optimize processes.

Correlation and regression analysis is a powerful statistical tool that allows you to identify and analyze relationships between two or more variables. The general characteristic of this method is to determine the degree of correlation and develop regression models to predict the values of variables based on independent ones. The advantages of the method include its ability to accurately forecast and analyze big data, which is especially valuable for evaluating logistics networks. In our study, we used correlation and regression analysis to identify key factors influencing the efficiency of medical supply transportation. On the other hand, the use of the fuzzy modeling method can become auxiliary in the process of overcoming fuzzy data and uncertainties, which are a common occurrence in logistics systems and their management mechanisms. This method uses fuzzy set theory to represent and process data that cannot be precisely defined or classified. The peculiarity of using this method in our study was the possibility of modeling processes where it is important to take into account the human factor and several other parameters.

If we combine correlation-regression analysis and the fuzzy modeling method, we will have the opportunity to avoid or minimize all possible disadvantages to the maximum extent. Yes, this will create a flexible and adaptive model for the effective assessment of logistics systems. In the future, this model will better respond to dynamic external conditions and challenges.

Overall, our approach to research methodology was aimed at maximizing the use of available analytical tools to provide in-depth understanding of the impact of various factors on logistics networks. This allowed us not only to identify the most significant factors, but also to develop recommendations for optimizing logistics processes in conditions of high requirements for the quality and safety of medical products.

MATLAB (Matrix Laboratory) is a high-level programming language and interactive environment widely used for numerical computing, data analysis, and algorithm development. Developed by MathWorks, it combines a desktop environment tuned for iterative analysis and design processes with a programming language that directly expresses matrix and array mathematics. MATLAB is especially popular in engineering, scientific research, and applied mathematics for its extensive library of built-in functions and toolboxes, which provide specialized functionality for various applications such as signal processing, image processing, control systems, and financial modeling. Its graphical capabilities allow users to visualize data, create plots, and develop custom graphical user interfaces, making it a versatile tool for both computational tasks and visualization. The justification for using MATLAB lies in its efficiency and ease of use for tasks involving large-scale numerical computations and data analysis. Its matrix-based approach simplifies the manipulation of large datasets and complex mathematical equations, enabling researchers and engineers to prototype, test, and refine their models quickly. Additionally, MATLAB's integration with other programming languages (such as C, C++, Java, and Python) and hardware (such as Arduino and Raspberry Pi) expands its utility across various domains. The extensive community support, documentation, and continuous development by MathWorks ensure that MATLAB remains a cutting-edge tool for academic research, industrial applications, and educational purposes.

RESULTS AND DISCUSSION

Transporting medical goods is a complex and highly regulated process that requires meticulous planning and adherence to strict guidelines to ensure the safety, efficacy, and integrity of the products. Medical goods, which include pharmaceuticals, vaccines, medical devices, and diagnostic kits, often have stringent temperature and handling requirements. For instance, many vaccines and biologics need to be maintained within a specific temperature range, commonly referred to as the "cold chain," to preserve their potency. Specialized refrigeration units, insulated containers, and temperature monitoring devices are employed to ensure that these conditions are met throughout the transportation process. Any deviation from the prescribed temperature range can compromise the quality of these medical goods, potentially rendering them ineffective or harmful.Another critical aspect of transporting medical goods is the compliance with regulatory standards and documentation. Different countries have their own regulations regarding the import, export, and transit of medical products. These regulations are enforced by authorities such as the U.S. Food and Drug Administration (FDA), the European Medicines Agency (EMA), and other national health agencies. Transporting medical goods requires thorough documentation, including certificates of analysis, material safety data sheets, and regulatory approvals. This documentation ensures that the products meet safety standards and can be traced throughout the supply chain, which is crucial for accountability and addressing any issues that may arise during transit (Figure 2).

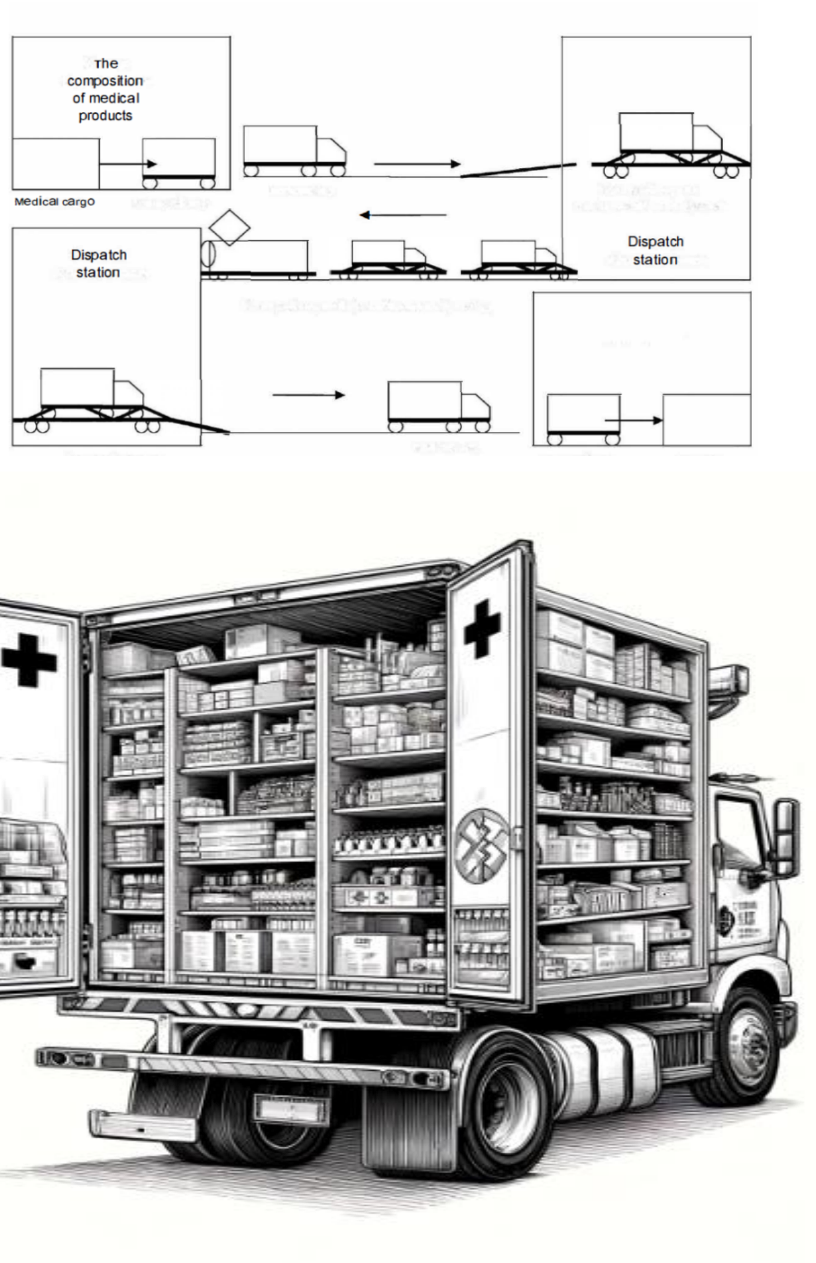

Figure 2: Scheme of transportation of medical goods using ground and rail method

Source: own analysis

Security is also a paramount concern in the transportation of medical goods. Given the high value and critical importance of these products, they are often targets for theft and tampering. To mitigate these risks, transportation companies employ a range of security measures. These include GPS tracking, tamper-evident seals, and secure packaging. Additionally, logistics providers often collaborate with security firms to conduct risk assessments and implement tailored security protocols. Ensuring the integrity of medical goods also involves training personnel in handling procedures and establishing secure supply chain networks to minimize the risk of product loss or contamination.Lastly, the logistics of transporting medical goods must consider the timing and urgency often associated with these shipments. Many medical products, such as emergency medications and blood supplies, are time-sensitive and require expedited shipping solutions. This necessitates a highly coordinated approach involving multiple stakeholders, including manufacturers, logistics providers, healthcare facilities, and regulatory bodies. Efficient coordination ensures that medical goods are delivered on time to their intended destinations, whether it be hospitals, clinics, or remote locations, thus playing a critical role in maintaining public health and responding to medical emergencies.

Within our research, we propose applying the theory of fuzzy sets to develop a fuzzy model for assessing the organization level of logistics networks for transporting medical goods. Table 2 presents the input data for the fuzzy model we have developed for evaluating the organization level of logistics networks for medical goods transportation.

Table 2: Factors influencing the transportation of medical goods

Factor	Marks
Forecasting and planning of the transport and logistics system	Z1
Analysis and assessment of the transport and logistics system	X1
Level of influence of endogenous factors on planning	X2
Level of innovation in transportation	X3
Functional components of the transport and logistics system	Z2
Level of organization of supply logistics	X4
Level of logistics within the production organization	X5
Logistics level of sales activities	X6
Level of organization of transport logistics	X7
Level of organization of warehouse logistics	X8
Level of application of new generation information systems	X9
Diagnostics of the management efficiency of the transport and logistics system	Z3
Level of sales volume of transport services for the transportation of medical goods	X10
Profitability of transport and logistics services	X11
Transport fleet utilization rate	X12
Level of transport and logistics potential	X13
Control mechanism for transporting medical goods	Z4
Level of control and optimization of transport and logistics flows	X14
Monitoring changes in organization and coordination	X15
Level of implementation of new forms of organization and management of logistics	X16
Level of application of modern technologies for effective management of the transportation process	Z5
Level of application of blockchain technologies	X17
Level of application of modern technologies based on modern information systems with artificial intelligence modules	X18
Level of application and implementation of European and world experience in transporting medical goods	X19

Source: own analysis

When evaluating input parameters, the range of their application can be quite large. However, to ensure the model is not overly cumbersome yet adequate, we suggest using methods that involve experts, formalize this knowledge, and apply it in the absence of relevant analytical relationships for correctly constructing the proposed model. The formalization of expert information was carried out using the Delphi method.

The input parameters we propose for the model assessing the organization level of logistics networks for medical goods transportation reflect our scientific perspective. These parameters can be adapted to a specific enterprise by decomposing the indicators, taking into account the characteristics of the particular enterprise or company.

The functional dependencies of the parameters of the model for assessing the level of organization of logistics networks for the transportation of medical goods can be generally presented as follows (1):

$$
\begin{aligned}
&Z1=f1(x1;x2;x3)\\
&Z2=f2(x4;x5;x6;x7;x8;x9)\\
&Z3=f3(x10;x11;x12;x13) \qquad (1)\\
&Z4=f4(x14;x15;x16)\\
&Z5=f5(x17;x18;x19)\\
&\gamma=f(Z1;Z2;Z3;Z4;Z5)
\end{aligned}
$$

The specific type of membership functions is determined on the basis of various additional assumptions about the properties of these functions (symmetry, monotonicity, continuity of the first derivative, etc.), taking into account the specifics of the existing uncertainty and the real situation. In particular, fuzzy numbers with a triangular membership function μ(t) are called triangular fuzzy numbers (2):

$$\mu(t)=\begin{cases}\dfrac{t-tmin}{tc-tmin}\\[4pt]\dfrac{t-tmax}{tc-tmax}\end{cases} \qquad (2)$$

To realize a clear logical conclusion, it is necessary to make a transition from statements to vague logical equations. These equations are obtained by replacing the values of xij with the values of their membership functions μ xij (xi) of the parameter xi ∈ xi , xi by the fuzzy term xij "or" fuzzy logical operations «.», « ∨ ». The weight of the rules is taken into account through the product of the fuzzy expression that corresponds to each row of the base and the corresponding weight value ω1 . Thus, the following fuzzy logical equations correspond to the linguistic statements of the knowledge base:

μ γ1(z1,z2,z3 z4 z5)=ω1 [μв (z1) ·μв (z2) · μв (z3) · μв (z4) · μв (z5) ·] v

ω2 [μс (z1) · μв (z2) · μв (z3) ·μв (z4) · μв (z5) ·] v

ω3 [μв (z1) · μс (z2) · μв (z3) · μв (z4) · μв (z5)]

μγ2 (ω4 z1,z2,z3 z4 z5 [μв (z1) ·μс (z2) ·μв (z3) ·μв (z4) ·μс (z5)] v

ω5 [μс (z1) ·μв (z2) ·μв (z3) ·μв (z4) ·μс (z5)] v

ω6 [μв (z1) ·μс (z2) ·μс (z3) ·μв (z4) ·μв (z5) ·]

μγ3 (z1,z2,z3 z4 z5)= ω7 [μс (z1) ·μвс(z2) ·μс (z3) ·μс (z4) ·μвс(z5)] v

ω8 [μв (z1) ·μвс(z2) ·μс (z3) ·μс (z4) ·μс (z5)] v

ω9 [μс (z1) ·μс (z2) ·μс (z3) ·μв (z4) ·μс (z5) ·]

μγ4 (z1,z2,z3 z4 z5)= ω10 [μн (z1) ·μс (z2) ·μс (z3) ·μс (z4) ·μс (z5)] v

ω11 [μс (z1) ·μс (z2) ·μ(c)(z3) ·μн (z4) ·μс (z5)] v

ω12 [μс (z1) ·μс (z2) ·μс (z3) ·μнс(z4) ·μнс(z5)]

μγ5 (z1,z2,z3 z4 z5)= ω13 [μн (z1) ·μс (z2) ·μс (z3) ·μн (z4) ·μн (z5) ·μн (z6)] v

ω14 [μс (z1) ·μнс(z2) ·μн (z3) ·μс (z4) ·μс (z5) ·] v

$\omega 15\ [\mu н\ (z1)\ \cdot\mu(н)(z2)\ \cdot\mu н\ (z3)\ \cdot\mu н\ (z4)\ \cdot\mu н\ (z5)\ ]$

Solutions of a system of fuzzy logical equations is a fuzzy logical solution, that is, a set of values of the membership functions of the original variable.

In Figure 3 we present a fragment of the implementation of input data for the model for assessing the level of organization of logistics networks for the transportation of medical goods of the intermediate parameter z_1.

Figure 3: Fragment of introducing input factors to a model for assessing the level of organization of logistics networks for the transportation of medical goods implemented in Matlab software

Source: own analysis

In the following figure 4, we present the implementation of the intermediate module z_2: functional components of the transport and logistics system, which in turn has six components (x).

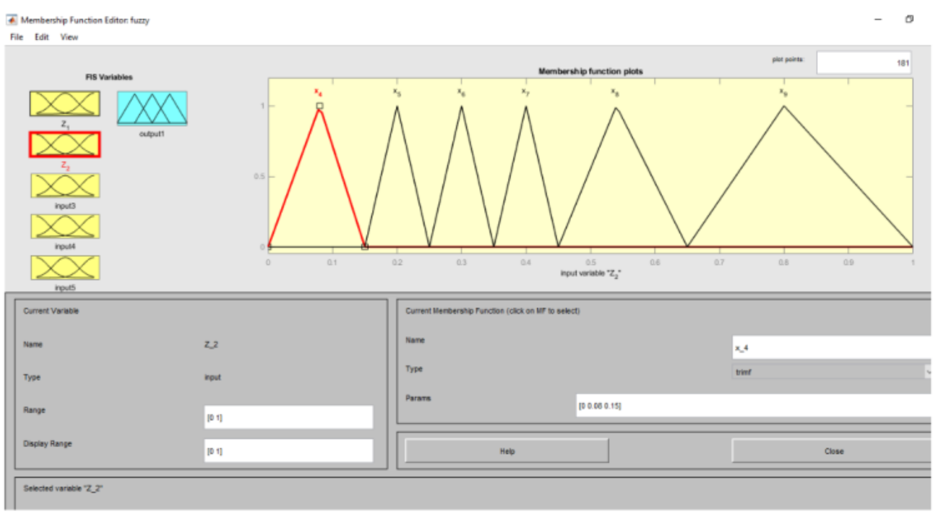

Figure 4: Representation of the input and intermediate factor of the intermediate module z_2: functional components of the transport and logistics system of the model developed by us in the triangular form of the representation implemented in the Matlab software environment

Source: own analysis

In the following figure we present the introduction of the rule base for the model we have developed for assessing the level of organization of logistics networks for the transportation of medical goods. The rule base can be adapted for practical implementation for a specific enterprise or logistics company of the national economy; the more accurate the database and rules are adapted for a specific logistics company, the more accurately the model will practically reflect the characteristics of the organization and the possibilities for improvement in real time (Figure 5).

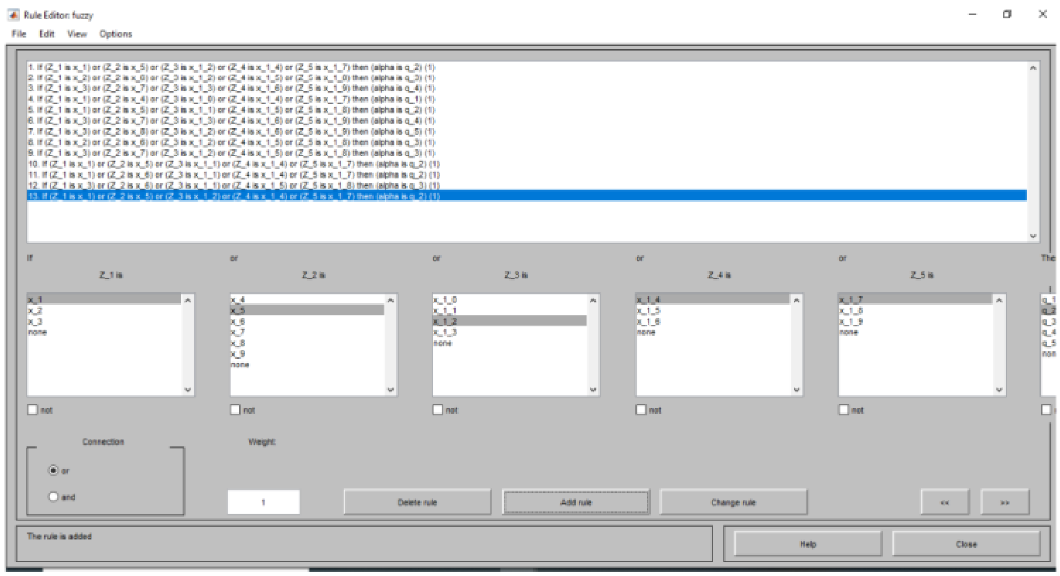

Figure 5: A fragment of the introduction of the rule base of the developed model for evaluating the level of organization of logistics networks for the transportation of medical goods

Source: own analysis

The next stage of the implementation of the model developed by us will be the defuzzification of intermediate modules to the final level of the developed model for evaluating the level of organization of logistics networks for the transportation of medical goods, which we will present in Figure 6.

Figure 6: Defuzzification of data using the Mamdani method implemented in Matlab software is implemented

Source: own analysis

Figure 6 presents the final results of the conducted simulation of determining the level of organization of logistics networks for the transportation of medical goods using the Mamdani defuzzification method, carried out in the Matlab software environment, fuzzy logic submodule. In Figure 7, we will present a graphical interpretation of the modeling of the definition of the assessment model of the level of organization of logistics networks for the transportation of medical goods implemented in the MatLab software.

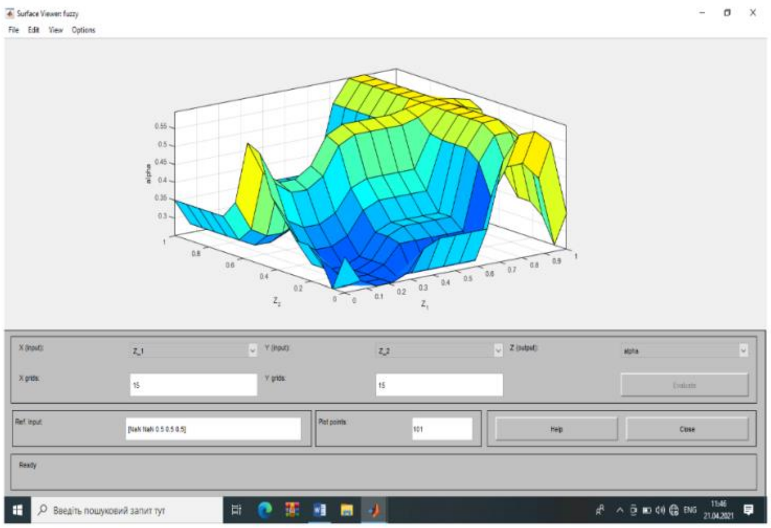

Figure 7: A graphical representation of the model for assessing the level of organization of logistics networks for the transportation of medical goods is implemented in MatLab software

The general area of the boundaries of the resulting indicator of the level of evaluation of the level of organization of logistics networks for the transportation of medical goods corresponds to 100%. Therefore, the obtained result, according to the conducted modeling of the evaluation of the level of organization of logistics networks for the transportation of medical goods, using the theory of fuzzy sets, and the software environment based on artificial intelligence modules fuzzy logic, is a coefficient of 0.421, which according to the defined subject area refers to the average level of organization of logistics networks for transportation medical products. At the same time, z_1 - the parameter of the model developed by us is the level of forecasting and planning of the transport and logistics system, and according to the conducted simulation, the coefficient is 0.5 - which, according to the scale of the subject area of the output indicator, belongs to the average level (35-50%), z_2 the module of the functional model developed by us the components of the transport and logistics system of the corresponding modeling are a coefficient of 0.41, which falls into the lower limits of the area of determining the final indicator - the average level (35-50%). The indicator z_3, which evaluates the level of diagnostics of the efficiency of the management of the transport and logistics system in the model developed by us, this indicator according to our modeling (Fig. 3.13) is a coefficient of 0.396, which falls into the lower part of the range of values - the average level (35-50%) . All this is shown in the database for Czech carriers of medical goods.

The practical significance of the developed model is that it is possible to adapt the database and knowledge to a specific transport enterprise, by supplementing or correcting the input or intermediate modules of the model, as well as the use of the applied Matlab software will allow monitoring and correction in real time, and the system can "self-learn".

DISCUSSIONS

In order to prove that the results of our study are xrelevant and bring scientific novelty, an important final step will be to compare the results obtained with existing studies.

Thus, Saberi et al. (2023) explore the application of blockchain technology in the context of sustainable supply chain management. They analyze how blockchain can improve transparency and reduce risk in supply chains. Our research, focusing on modeling logistics networks for medical supplies, extends these findings by showing how correlation-regression analysis and fuzzy modeling can be used to optimize logistics processes taking into account various factors, which may include the use of blockchain technologies to improve efficiency and reliability.

Vledder et al. (2019) conducted a large-scale experiment around the world aimed at improving supply chains for life-saving medicines. Their findings highlight the importance of accurate and efficient healthcare logistics solutions. Our research is distinguished by its focus on modeling and analysis of the organization level of logistics networks, allowing for the integration of aspects that contribute to further improvement of supply chains in such contexts.

Jazairy and von Haartman (2020) analyze the institutional pressures driving shippers and logistics services to adopt green supply chain management practices. Their work highlights the environmental demands placed on logistics today. In the context of our study, the use of fuzzy modeling techniques can help to better adapt logistics networks to environmental requirements, striking a balance between efficiency and consistency.

While Szymanska et al. (2021) explore innovative solutions to develop sustainable transport and improve accessibility to tourist regions. Their approach to sustainability could be adapted into medical logistics to improve transport infrastructure in areas with limited access. Our study contributes to this field by showing how integrated modeling can help optimize logistics networks considering various factors and needs.

Lindquist, et al. (2022) explore the role of actors and the interaction of the public and private sectors in network modernization processes, analyzing the case of geofencing for urban freight transport in Sweden. This experience highlights the importance of collaboration between different parties for successful innovation in logistics. In our study, analysis and modeling of logistics networks reflect a similar need for integration and coordination between various participants in the process, which allows logistics problems in the medical field to be more effectively solved.

An interesting study by Kannarkat, et al. (2024), who in their paper focus on improving the security of the drug supply chain. Their approach includes analyzing threats and implementing measures to strengthen supply chains against counterfeiting and other challenges. Our research adds insight into how correlation-regression analysis and fuzzy modelling can be used to identify potential weaknesses and influential factors in logistics networks, providing deeper analysis and the ability to predict emerging problems.

Ferrara et al. (2021) explore how logistics management can provide greater efficiency, control and regulatory compliance in clinical pharmacies. Their work highlights the importance of a strategic approach in logistics management. Our research extends these ideas by showing how fuzzy modelling techniques can be used to optimize logistics decisions in the broader context of medical supply, especially when adapting to changing conditions and unstable market demands. Fornasiero et al. (2020) survey innovation pathways in supply chains, suggesting routes for future research and innovation. They focus on the need for new technologies and methodologies to improve the efficiency and sustainability of supply chains. In our research, we introduce several advanced analytical methods to analyze and improve logistics networks in more detail, making significant contributions to the theoretical and practical aspects of medical supply logistics.

Sathiya et al. (2023) explore reimagining medical supply chains using Chain-of-Things technology, taking into account lessons learned during the COVID-19 pandemic. They focus on using IoT to improve transparency and efficiency. Our work extends these findings by including an analysis of the impact of various technological and operational factors on logistics networks and proposes models that can help further expand and optimize the use of modern technologies in medical logistics.

The innovation of the research is that the methodology is an integrated approach that optimally combines correlation-regression analysis and fuzzy modeling methods for assessing and optimizing logistics networks. The synthesis of these two methods makes it possible to fully identify the key impact factors and, based on them, propose ways to optimize the system for transporting medical goods. In the context of our research, a key role is played by the fuzzy modeling method, which allows us to simulate the processes of leveling uncertainty and introduce decision-making flexibility into existing models. Considering all of the above, we can say that the research is innovative and brings scientific novelty.

CONCLUSIONS AND RECOMMENDATIONS

Today, most of the logistics systems of the European Union, including the Czech Republic, are faced with a number of qualitatively new problems, challenges and threats. There is no exception in the field of transportation of medical goods. Key to this set of problems is the complexity of planning an entire logistics operation, given the differences in rules, standards and regulation for the transportation of medical goods for each EU country. Environmental challenges are no less important today. Given this relevance of the issue, in our study we paid attention specifically to the planning and modeling of logistics networks for medical goods, in particular using the example of the Czech Republic. In this context, the methods of correlation-regression analysis and fuzzy modeling turned out to be the most optimal for our research.

The study carried out a detailed analysis of existing logistics procedures for transporting medical goods. This analysis allowed us to identify key problems and inefficiencies. The analysis not only demonstrated the basis of the problem, but also formed an understanding of the relationships between different elements of the logistics system. The basic vector of our research was, based on the analysis carried out, to determine the key influence of external and internal factors on modern logistics networks.

Further, as part of the study, a methodology for improving the level of organization of logistics networks was developed and proposed. Our methodology helps logistics companies improve the efficiency of transporting medical supplies by reducing risks and delays. Finally, we systematized the data obtained to prepare recommendations for improving logistics operations. These recommendations will form the basis for further strategic decisions in the field of medical logistics aimed at increasing efficiency and reliability.

However, the study has a number of limitations. Firstly, the use of correlation-regression analysis and fuzzy modelling methods may not take into account all potential external factors affecting logistics networks. This includes political changes, global economic crises, as well as socio-cultural aspects that can significantly affect the results of the study. In addition, focusing on Czech logistics systems may be a barrier to the wider use of our proposed methodology. Taking into account all the listed limitations, the prospects for further research will be the unification and adaptation of the proposed methodology to the realities of the functioning of other countries. In addition, an important perspective for further research will be to expand the methodology through the use of additional factors, in particular such as environmental and technological innovations, which also have an important impact on modern logistics networks. Such expansion can be achieved through the use of additional research methods. All these changes can make the proposed methodology more effective and adaptive to the modern realities of the functioning of logistics systems.

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