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Review of the doctoral dissertation

of Mr. MSc Eng. Artur Budzyński entitled *Forecasting prices for road freight transport services using machine learning*

The review (report) was prepared in accordance with art. 190 section 3 of the Act of 20 July 2018. The basis for preparing the review of the doctoral thesis of Mr. MSc. Eng Artur Budzyński is the letter RDILGT. 512.32.205 dated 20 February 2025 of the Chairman of the Disciplinary Council of Civil Engineering, Geodesy and Transport of the Silesian University of Technology, dr hab. inż. Piotr Folęga, prof. PŚ.

The reviewed doctoral thesis is written in English as a written work and consists of 112 pages. The structure of the work includes 6 chapters and a bibliography. The work begins with an introduction, through the concept of the work and chapters containing research methods, analysis of the obtained data and their application in practice, ending with a summary with conclusions. The doctoral thesis also has appropriate summaries required by legal Act. It is important that the Author of the dissertation presented the practical application of the method using a statistical example, which strengthens the research value of the work. The supervisor of the doctoral thesis is Prof. dr hab. Aleksander Śładkowski and the auxiliary supervisor is dr hab. inż. Marcin Michalak

When preparing the review of the doctoral dissertation of Mr. MSc Eng. Budzyński, I referred to the conditions set for doctoral dissertations, and at the same time to the features that the reviewed dissertation should demonstrate, which were specified in Article 187 of the Act of 20 July 2018. I verified whether it meets the requirements specified in Article 187 of the Act, which constitute the fundamental criteria for assessing a doctoral dissertation. They include both the substantive and formal scope of the dissertation. In accordance with the statutory requirements, the doctoral dissertation should present the doctoral student's general theoretical knowledge in a given discipline and confirm their ability to conduct independent scientific work. In addition, the doctoral dissertation should constitute an original solution to a scientific problem or an original application of research results in the economic or social sphere, in the form of a written work, scientific monograph, collection of scientific articles, design, construction, technological or implementation work. With the above in mind, when preparing this

evaluation of the doctoral dissertation, I analysed in detail its compliance with the above requirements, taking into account both the scientific value of the work and its compliance with the formal criteria relating to a doctoral dissertation.

1. Determination of the fulfillment or lack of fulfillment of the requirement referred to in Article 187 paragraph 2 of the Act of 20 July 2018 - The Law on Higher Education and Science (Journal of Laws 2024, item 1571, consolidated text) concerning the subject of the dissertation:

1.1 Does the doctoral dissertation fall within the discipline of civil engineering, geodesy and transport?

The doctoral dissertation can be easily assigned to the discipline of civil engineering, geodesy and transport, because it discusses key aspects of road freight transport, which is an integral element of logistics systems and transport infrastructure. I will present the justification for this assignment in several key points.

Firstly, the dissertation addresses the transport aspect, the research focuses on road transport, which is one of the main areas of transport engineering. It addresses operational issues, the efficiency of the transport system and adaptation to changing economic and logistic conditions.

Secondly, the doctoral dissertation discusses issues related to infrastructure and logistics, such as supply chain continuity, door-to-door availability and regional differences in the functioning of transport systems, indicating connections with civil engineering and transport infrastructure management.

Thirdly, in the field of statistical analysis of transport systems, the dissertation cites research on road transport in many European countries, such as Croatia and Austria, and refers to quantitative analysis methods, which are an important element of research in the field of transport and logistics. The research presented in the doctoral thesis also concerns Lithuanian carriers and indicates the importance of cargo loading control, which is an important element of transport engineering and road safety.

To sum up this point, I can clearly state that the doctoral thesis of Mr. MSc. Eng. Artur Budzyński fits into the discipline of civil engineering, geodesy and transport, because it refers to key issues related to the functioning of road transport, its efficiency, safety and management, which is an important area of transport engineering research.

1.2 Confirmation of the fulfillment or lack of fulfillment of the original solution to the scientific problem.

The scientific problem solved by the doctoral student is the difficulty in forecasting road freight transport prices, resulting from the large number of interdependent variables and the time-consuming nature of this process. The complexity of data, taking into account various transport features, such as the type of cargo, organizational requirements, transport relations or seasonality, which makes effective modeling difficult and limits the effectiveness of traditional forecasting methods. As part of his doctoral dissertation, MSc Eng. Artur Budzyński attempted to solve this problem by developing a method using machine learning, which allows for effective management of complex dependencies and optimization of the price forecasting process. Thus, the scientific problem in this study can also be defined as a research problem, consisting in the search for effective methods of price prediction in road transport using modern analytical tools. In order to solve the research problem, MSc Eng. Artur Budzyński developed an innovative solution related to machine learning.

In addition, in order to solve the research problem, a fairly extensive research question was formulated, which included three key aspects of the analysis and was the basis for the research method. The author of the dissertation posed the following research question: What factors influence the pricing of road freight transport services, how can a methodology for processing transport offer data be developed to effectively train machine learning models, and can the use of these methods provide greater forecasting accuracy compared to expert-based approaches?

The extensive structure of this question resulted from the need for a holistic approach to the problem of forecasting road transport prices and took into account both theoretical and practical aspects. Each of the three components of the research question answered important issues that were analyzed to effectively solve the scientific problem:

1. Identification of key factors influencing road transport prices. The author of the dissertation correctly noted that understanding what variables shape the prices of transport services is the foundation of effective forecasting. In this context, both direct factors, such as type of cargo, distance, demand and supply, and more complex factors, such as seasonality, macroeconomic conditions or legal regulations, were analyzed.
2. Development of a method for processing transport offer data in order to effectively train machine learning models. MSc Eng. Artur Budzyński correctly noted that the effectiveness of machine learning models in generating reliable forecasts depends on the development of an appropriate data processing method. This includes the process of

data acquisition, its initial cleaning, the selection of appropriate features, and the optimization of model training algorithms.

3. Assessment of the effectiveness of machine learning methods compared to approaches based on expert knowledge. The author of the doctoral thesis notes that the traditional approach to forecasting transport prices is based mainly on the experience and intuition of experts. The conducted research aimed to determine whether the use of modern data analysis methods and artificial intelligence can increase the accuracy of forecasts and improve the decision-making process in the transport industry.

The research question formulated in this way allowed for a comprehensive analysis of the problem and the determination of the potential benefits resulting from the use of machine learning methods in forecasting road freight transport prices. In addition, it indicates the interdisciplinary nature of the conducted research, combining elements of transport, data analysis and artificial intelligence, which is in line with the modern approach to logistics and transport management.

To sum up this point, I can state that the premise regarding the original solution to the research problem has been met.

2. Confirmation of fulfillment or lack of fulfillment referred to in Article 187 paragraph 1 of the Act of 20 July 2018 - The Law on Higher Education and Science, regarding the solution for the application of the results of own scientific research in the economic or social sphere.

The results of the research conducted by the PhD student have practical applications for both transport companies and policy makers, confirming that these results have economic and regulatory potential.

Thanks to the developed method, using machine learning, transport companies can improve their pricing strategies by adjusting rates to dynamic market conditions. In addition, they can improve cost management, minimizing the risk of mispricing and operational inefficiencies, and can increase operational efficiency by reducing the time consumption of traditional forecasting methods and optimizing the use of resources.

In turn, policy makers and regulators can use the obtained results to shape transport policy, basing their decisions on precise transport price forecasts, and can implement the optimization of infrastructure development, taking into account key factors influencing transport costs and its efficiency. In addition, they enable the creation of a more flexible regulatory framework that supports the competitiveness and sustainable development of the sector.

Although the research focused on the European Union market, the method used is highly flexible and can also be implemented outside the EU. By using ISO country codes, models can be configured to analyze markets in different regions of the world, which increases their versatility and value for global logistics.

To sum up this point made to doctoral dissertations, I can say that the research carried out by the doctoral student provides a comprehensive analysis of the factors influencing the prices of road freight transport and sets a new standard of forecasting accuracy. The developed method, which exceeds the effectiveness of traditional expert approaches, is an example of the importance of machine learning in solving complex data-based problems. It thus opens the way to further research and practical implementations in the area of transport cost forecasting, contributing to the development of the industry and economic efficiency. The developed method and the obtained results meet the premise of practical application, enabling their implementation in enterprises and the economy on a large scale not only in Poland and the European Union, but also in other countries outside the union.

3. Confirmation of fulfillment or lack of fulfillment of the prerequisite referred to in Article 187(1) of the Act of July 20, 2018, Law on Higher Education and Science, concerning the presentation of general theoretical knowledge and the ability to conduct independent scientific research.

The presented doctoral thesis demonstrates the doctoral student's skills in formulating research problems, which is a key element of conducting independent scientific research. It also proves his ability to develop a comprehensive research workshop, including both an appropriate methodological approach and the selection of appropriate analytical tools.

In addition to the research question discussed by me in the previous part of the review, the author of the dissertation formulated a research hypothesis and subjected it to empirical verification. Based on a detailed analysis of the literature, he proposed the following hypothesis: implementing machine learning techniques in forecasting the prices of road transport services will increase the accuracy of forecasts and enable transport companies to better adapt operational decisions to changing market conditions.

Mr. MSc. Eng. Artur Budzyński rightly noted that machine learning improves the precision of forecasts by analyzing complex patterns in large and diverse data sets, overcoming the limitations of traditional methods. Moreover, thanks to the possibility of updating models in real time, these techniques enable dynamic adjustment of pricing and

operational strategies to the current market situation. The conducted research confirmed that the implementation of machine learning techniques can indeed improve the accuracy of price forecasts, which consequently allows transport companies to more effectively adapt their operational decisions to changing market conditions. The hypothesis was therefore positively verified.

The doctoral student demonstrated the ability to identify important scientific issues, precisely define research goals and plan effective methods for their implementation. In addition, he correctly selected research tools, adapting them to the specifics of the problem, which allowed for obtaining reliable and valuable results.

As part of the work, the doctoral student diagnosed a significant research gap in the area of forecasting prices of road freight transport services and developed research tailored to this problem. This study aimed to fill the existing gaps in the literature and practice by creating a comprehensive machine learning method that allows for more precise prediction of transport costs. The doctoral thesis focused on developing a solid analytical framework, including data collection, pre-processing, model selection, training, validation and implementation of methods adapted to the specifics of the road freight transport sector.

The entire doctoral thesis proves that Mr. M.Sc. Eng. Artur Budzyński has advanced research competences, covering both theoretical and practical aspects, which is an important element of his scientific development and preparation for conducting further research in the chosen discipline, i.e. civil engineering, geodesy and transport, and the doctoral student also has great potential to conduct research in the discipline of management and quality science. The doctoral thesis clearly confirms that the doctoral student has the ability to independently conduct scientific research, thus fulfilling the key premise set for doctoral theses. The doctoral student independently identified a research gap, formulated a scientific problem and developed an appropriate method to solve it. All these elements prove that the doctoral student has met the requirement for independent scientific work, demonstrating the ability to conduct research at a high substantive and application level.

Technical and editorial notes for a doctoral thesis

1. In science, there are terms: methodology, method and approach and they are different from each other. Please do not use them interchangeably.

2. Acronyms should have an explanation, because not all of them are known to a wide audience and for example BP is Backpropagation (p.5)?
3. The description for Figure 3 (p.66) talks about numbers, while Figure 7 gives percentages.
4. The description for Figure 9 (p.68) says that the average cost is the lowest in Hungary, while Figure 9 shows that it is also in Denmark.
5. The description for Figure 10 (p.69) mentions the cost of 2 Euro, while the Figure shows 2.01. This would not be a mistake if at the same time the description did not show the value of 0.98 Euro for Spain and the same value is in the Figure. That is, the description included two decimal places. This should also be described in the case of Spain.
6. In Figure 13 (p. 71) there is no caption under the beginning of the line (what year and month).
7. There is no consistency between Figure 13 and 14, because in July there is once the highest average price and once the lowest. Perhaps it was necessary to write in which year this lowest value in July occurred.
8. The sentence regarding the correlation between fuel price and transport costs on p. 88 "This suggests that the increase in fuel prices may have a direct impact on the increase in transport costs, which is typical for the transport industry" is not reflected in the presented Figure 27 (p. 89).
9. The abbreviation [k²] in table 40 (p. 92) is incomprehensible.
10. The notation is unfortunate: Methods for implementing the method (p. 105).

The identified shortcomings in terms of technical (typographical) errors, although important from the perspective of precision and diligence, do not affect the overall positive evaluation of the doctoral dissertation of Mr. M.Sc. Eng. Artur Budzyński. In the context of such a dissertation, the key factors are primarily the substantive quality, the innovativeness of the research approach, and the significance of the achieved results. Mr. Budzyński's work demonstrates a high academic and scientific level, and the proposed method aligns with the latest trends in the field of transport and machine learning. For this reason, despite minor technical errors that should be corrected in the future, the dissertation fully deserves recognition and a positive evaluation. These shortcomings do not impact the overall assessment, as they do not undermine the fundamental scientific value of the dissertation.

Questions for a doctoral student related to his doctoral dissertation:

1. Please explain how the GDP table was developed and what the individual values mean, because it is difficult to interpret the data presented from the description presented in the doctoral thesis.
2. Please explain whether the summer period affects the increase or decrease in the price of transport services?

Final conclusion and evaluation

I, the undersigned, declare that the reviewed doctoral dissertation of Mr. MSc. Eng. Artur Budzyński meets the conditions specified in art. 187 of the Act of 20 July 2018 - The Law on Higher Education and Science (Journal of Laws of 2021, item 478) and request the Discipline Council of Civil Engineering, Geodesy and Transport to admit Mr. MSc. Eng. Artur Budzyński to further stages of the proceedings for awarding the degree of doctor in the discipline of Civil Engineering, Geodesy and Transport.

