The Impact of Rail Transport Service Quality on Intermodal Transport Quality: a Model for Evaluation

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Rail transport (RT) has a significant share in intermodal chains, so intermodal transport (IT) quality largely depends on RT services' quality. On the other side, the quality of these services depends on many infrastructural-technological, organizational and regulatory-institutional factors. The impact of these factors on the service quality and IT is not easy to precisely quantify. Fuzzy systems are a suitable mathematical tool for solving this task, considering that they provide the possibility of imprecise evaluation of variables. In this paper, a fuzzy system-based model for evaluating the impact of RT services' quality on IT quality is defined. Applying it to the example of Serbia, it was established that this influence in this country is neutral/dual.

Key Words: *intermodal transport, rail transport, quality, fuzzy system, Serbia*

1. INTRODUCTION

Due to the flexibility, development of the infrastructure network and transport means, and other advantages, road transport still dominates continental routes. Nevertheless, the increase in flows and different challenges motivate stakeholders to consider more seriously alternative modes of freight transport and their combinations, intermodal transport (IT). Railway transport (RT) is particularly important. This transport mode plays a key role in the flow of containerized goods and bulk cargo such as coal, grain, etc. Since the 1990s, railway revitalization and IT development have become key objectives of the European Union (EU) transport and logistics policy [1]. RT and IT infrastructure are developing rapidly, especially in countries such as China and India, and the volume of intermodal chains is proliferating. IT and RT have increasing importance and application potential in the city logistics concepts [2], [3].

One of the basic goals of IT development is to increase the service quality [4], [5], [6]. A high level of service quality ensures customer satisfaction, which guarantees a secure position in the market, as well as income [7]. The evaluation of the quality of logistics systems and services is important both for monitoring the logistics performance index [8] and for the possibility of comparison with other countries, as well as for determining the need for improvements [9]. To develop and improve IT quality, various strategies and development plans are adopted [5]. Given that a significant share of continental intermodal chains consists of railway sections, the quality of RT services significantly affects the IT quality. To ensure the competitiveness of intermodal chains about road transport, it is necessary to meet certain quality criteria, such as speed, frequency, regularity, continuity, safety/security, price, simplicity of documents and administrative processes [10]. The quality of RT

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services and their impact on IT depends on a several factors, which may be related to the infrastructure, the organization of participants, or the regulatory framework. Although there are certain numerical indicators, the quality of infrastructure, organization and regulatory framework in RT is usually difficult to precisely quantify. Imprecise or linguistic evaluations and tools such as fuzzy systems (FSs) are suitable for their assessment. Although they have been widely used in logistics and supply chains (e.g. [11], [12], [13]), according to the authors' knowledge, FSs have so far not been applied to evaluate the quality of RT services and their impact on IT quality.

This paper will define a FS-based model for assessing the quality of RT services and their impact on IT quality, and applied to the example of Serbia, with a detailed argumentation of the assigned evaluation. This will achieve the main goals and contributions of the paper.

After the introduction, the second section will describe the problem background and the methods to solve it. In the third section, a model for solving the problem will be proposed. In the fourth section, the model will be applied to the example of Serbia. At the end, conclusions and directions for future research will be given.

2. BACKGROUND

Quality monitoring is important in all areas of human activity. In logistics, IT and RT, different approaches are also being developed to measure it.

2.1. IT and RT service quality

An old Jewish proverb says, „If you don't get better, you will get worse.“ It points to the importance of constant progress, that is, quality improvement. People have always tried to establish norms, standards, and positive examples of people, procedures, methods, products, services, etc. as goals or guideposts in achieving quality in various areas, including logistics and traffic.

Kilibarda and Zečević [14] distinguish between revolution and evolution of quality in economic development so far. For some authors (e.g. [15]), service quality means its adaptation to specifications defined by service providers. According to another approach, service quality is based on assessment and perception [16].

Quality in logistics is a complex and multidimensional concept that needs to be improved from different points of view (marketing, functional, social, etc.) [17]. The logistics systems quality can be viewed through two basic components: management-business and technical-technological structure [14]. According to Bienstock et al. [18], logistics service quality has three components: availability, timeliness, and status (of orders). It can be improved by applying an appropriate logistics strategy or initiative [19], [20], [21]. The quality of a logistics system, such as an IT system, or a service can be evaluated at the level of a single company (e.g. [22], [23]) or at a specific area (local, national, etc.) (e.g. [24], [25]).

In the literature, indicators of IT system quality [10], quality of intermodal terminal services [26], efficiency of intermodal terminals [27] etc. have been analyzed. The quality of IT or some of its components is most often analyzed at the level of one country [26] or region [10]. IT in Serbia was considered independently [4], together with neighboring countries [24], and within the Danube region analysis [25]. IT quality, among other things, depends on the RT services' quality. Palšaitis & Ponomariovas [28] defined the quality of RT services as the compliance of user requirements with the technical capacities of the service provider. In the literature, there is a wide range of attributes, criteria, and quality indicators of services and systems in logistics, IT, and railways. According to [10], the main attributes of IT quality are open access and transparency, service quality, safety and security, environmental quality, human resources, IT corridor certification. Although in most papers the IT criteria and evaluations are based on one group of participants, there are papers in which different interest groups are taken into account (e.g. [25]). In RT, the criteria related to information, fleet, reliability, and accuracy were most often considered [28].

In the literature, there are many different mathematical models and approaches to measuring the quality of services in logistics, as well as the IT and RT quality. Kolodizieva et al. [29] developed an FS-based model for assessing of logistics service quality, taking into account 12 criteria, classified into four groups: company reputation, product availability/quality, reliability/flexibility and customer service. Unlike most other models, which evaluate the quality of already implemented logistics services, Kilibarda et al. [29] proposed a model based on multi-attribute decision-making, capable of measuring service quality in the design and offer creation phase. Tadic et al. [25] used multi-criteria decision-making (MCDM) methods to evaluate IT in the countries of the Danube region. Palšaitis & Ponomariovas [28] analyzed the service quality of freight RT, interviewing three groups of respondents, experts, service providers and shippers who rated 22 indicators of service quality. Zeybek [30] used the SERVQUAL (service quality) model to determine the freight RT services quality. More research is needed to measure the quality of RT services from a logistics and supply chain perspective

[31]. Although there are studies of passenger RT service quality in Serbia (e.g. [32]), according to the authors' knowledge, the quality of freight RT services, especially from the aspect of impact on IT, has not been analyzed so far. The services quality, even those provided in RT, is most often expressed by qualitative variables, which are not easy to measure and express [7], [14]. Fuzzy logic is suitable for expressing such variables, and FSs are suitable for solving problems. Despite this, FS has not been applied in previous studies of RT services.

2.2. Fuzzy sets and fuzzy systems

A system where the states of variables (all or some of them) are represented by fuzzy sets is called a fuzzy system [33], [34]. FSs are also defined as a non-linear mapping of the input data vector into the output value [35], i.e. imprecise input values into a precise output value [36]. The basic elements of FS are input and output variables, fuzzifier, rules, inference engine and defuzzifier [36]. The fuzzifier maps numerical values into fuzzy sets. Fuzzy rules are formed based on the knowledge of experts who manage a certain process or perform a task. The inference engine reflects the way rules are combined [35]. Selecting a single value of the output variable represents defuzzification. The membership function enables the calculation of the degree of membership with which a certain element belongs to a set. It can have different shapes (triangular, trapezoidal, etc.).

Fuzzy sets are used to express different variables in logistics, especially in MCDM problems (e.g. [3], [37]). FSs have also found wide application in logistics and supply chains: for locating VAL services in a logistics network [11], evaluating logistics providers [12], etc. There are examples of the FSs application to determine the logistics services quality [13]. However, according to the authors' knowledge, FSs have not been applied so far to determine the RT service quality and the impact on IT.

3. PROPOSED MODEL

The defined problem will be solved by applying FS, Mamdani type, with 8 inputs and 1 output. Membership functions of all variables are defined as triangular. The first group of input variables are infrastructural-technological variables: line infrastructure quality (U_{11}), nodal infrastructure quality (U_{12}), fleet quality (U_{13}), and information and communication systems (ICSs) quality (U_{14}). Certain studies (e.g. [38]) point to the special importance of infrastructural and technological improvements for productivity in RT and service quality. In the area of infrastructure and technological means, the quality of the line infrastructure (tracks and supporting elements, electrification, signaling, etc.) and fleet (locomotives, wagons) are particularly important. On the other side, the quality of the nodal infrastructure, that is, railway stations and terminals also significantly affects the service quality. Finally, bearing in mind the number of participants, their connections and communications and the necessity of timely information exchange, the services quality and their impact on IT quality largely depends on the ICSs application.

The second group of input variables are organizational variables: the quality of the RT service providers organization (U_{21}), the quality of the railway infrastructure manager (RIM) organization (U_{22}), and the quality of the other participants organization (U_{23}). Research (e.g. [39]) indicates the importance of efficient participants organization in planning, performing and controlling railway flows for the logistics service and IT quality. Poor management by RIM, late and untimely dispatch of trains by providers, inefficient work of customs, inspection, border police services and other types of poor participants organization can lead to serious problems and disruption of service quality and intermodal chains performing, even and in situations of high infrastructural and technological system development.

The last category, regulatory-institutional variables, includes only one variable, the quality of the regulatory framework and institutional action (U_{31}). It refers to the modernity and quality of current legislation, international agreements, institutional efforts to improve regulations, joining the EU, simplifying procedures, etc.

All input variables are positive (a higher value means a more favorable influence on the output variable). Their weights are respectively [1 0.8 0.9 0.6 0.8 0.8 0.5 0.7]. The output variable is the impact on IT quality (I).

The input variables can take values from the interval [0,10], where the value 0 indicates the most unfavorable (e.g. very low quality of the line infrastructure) and the value 10 is the most favorable impact of the input variable on the quality of IT (e.g. the very high quality of the RT service provider organization affects positive for IT quality).

The output value can also be in the interval [0, 10], where 0 represents the worst and value 10 the best assessment of the overall impact of the RT services quality on IT quality. The following linguistic evaluations and corresponding fuzzy sets are assigned to the input variables: Low (0, 0, 4), Medium (1, 5, 9), High (6, 10, 10), and the following to the output: Very unfavorable (0, 0, 3), Unfavorable (1, 3, 5), Neutral/Dual (3, 5, 7), Favorable (5, 7, 9), Very Favorable (7, 10, 10).

Based on the paper [40], inference rules and their weights based on input weights are defined. Some rules are shown in Table 1. First, the rules were defined in which different evaluations were assigned to only one input. The weights of these rules are equal to the weight of the input variable to which the score is assigned. For example, if U_{11} is Low, then I is Unfavorable, and the weight of that rule is 1, because the weight of the input variable U_{11} is also 1. There are 8 input variables and that each can be assigned 3 grades, so there are 24 such rules. After that, rules are defined in which all input variables have, in order: the best linguistic evaluation (High U_{11}, High U_{12}, etc.), then the worst evaluation (Low U_{11}, Low U_{12}, etc.) and finally the middle evaluation Medium U_{11}, Medium U_{12}, etc.). The weight of all three of these rules is 1, and the output variable takes the values Very Favorable, Very Unfavorable, and Neutral/dual, respectively. After that, rules are defined in which the same values will be assigned to several input variables, High, Medium and Low in the new rules, respectively. First, this procedure was performed for 4 infrastructural-technological input variables, and then for other 4 variables. The weight of these rules is equal to the arithmetic mean of the input variables weights to which evaluations were assigned, rounded to one decimal place. For example, in the case of infrastructural-technological variables, the weight of the rule is (1+0.8+0.9+0.6)/4=0.825, i.e. 0.8. There are 6 such rules, so the total number of rules is 33.

Table 1. Part of the inference rules in a fuzzy system

Rule ordinal number	Rule weight	Rule
1	1	If (U_{11} is High), then (I is Favorable).
2	1	If (U_{11} is Medium), then (I is Neutral/dual).
3	1	If (U_{11} is Low), then (I is Unfavorable).
25	1	If (U_{11} is High), (U_{12} is High), (U_{13} is High), (U_{14} is High), (U_{21} is High), (U_{22} is High), (U_{23} is High), (U_{31} is High), then (I is Very Favorable).
33	0,7	If (U_{21} is Medium), (U_{22} is Medium), (U_{23} is Medium), (U_{31} is Medium), then (I is Neutral/dual).

4. ASSESSMENT OF THE IMPACT OF THE RT SERVICES QUALITY ON IT QUALITY: CASE STUDY OF SERBIA

The model will be applied to the example of Serbia. To define the values of input variables, the results of interviewing providers and users of RT and IT services, conducted in 2023 [41], as well as information from relevant sources describing the state of RT and IT in Serbia were used.

The line infrastructure quality (U_{11}) in Serbia was rated 7. In recent years, projects of high-speed railway reconstruction and construction have been implemented or planned, which greatly improves the line infrastructure. Nevertheless, a significant part of the railway network is still made up of single-track lines, which are dilapidated, unelectrified and unreliable. Of the total construction length of normal gauge railways on the territory of the Serbian Railways Infrastructure (Serb. Infrastruktura železnice Srbije - IŽS) only 8.63% are two-track [42], which significantly affects the capacity of roads. The road quality is the cause of frequent traffic accidents. The electrical network is not adapted to the fleet from EU.

The nodal infrastructure quality (U_{12}) is rated 6. The capacities of railway stations and terminals are often insufficient for the existing, and especially the planned volume of flows. An insufficient number of tracks, their insufficient length, lack of electrification, outdated equipment, along with certain organizational problems, represent the basic problems of the nodal railway infrastructure in Serbia. Research [41] shows that 40-60% of RT and IT service providers and users are dissatisfied with the useful length of tracks in stations. Another problem of railway stations is inadequate capacity for dangerous goods. The problem of border stations capacity and quality is particularly pronounced. The equipment in many terminals is outdated, both technologically and in terms of lifespan, so operations are slowed down and require a large number of workers.

The fleet quality (U_{13}) in Serbia is rated 6. Although there have been contributions to the modernization of the fleet in recent years, significant improvements are still needed. Conducted research [41] shows that 40% of providers and almost 70% of users of freight RT and IT services believe that the number of locomotives should be increased. Railway cars are most often rented from foreign companies, often at unfavorable prices. Part of the providers' fleet is outdated and/or defective. More than half of the users think that the fleet of RT service providers in Serbia is bad or very bad. The time of chains performing is often extended due to waiting for the correct locomotive, breakdowns, accidents, etc.

The ICSs quality (U_{14}) in Serbia was rated 4. Performing of information flows between participants is slowed down, difficult, often impossible. Unreliable or incomplete information and documents are often exchanged. The main problems related to ICSs are technological obsolescence, lack of a system for monitoring the use of resources and terminal capacity, lack of an adequate system for generating timetables, non-integration into European information platforms for railways, the inability of some providers and users to monitor the location of locomotives/trains in real - time. 60% of providers and over half of users communicate with other participants exclusively orally, by phone and/or by email [41]. Documents are exchanged most often in paper form. Dedicated ICSs are used by a very small number of providers (about 10%). For 40% of the surveyed providers, a system for generating timetables is bad or very bad [41]. Although a significant number of providers and users use locomotive/train tracking software, the inability of others to access such software further complicates the organization.

The quality of the RT service providers' organization (U_{21}) in Serbia was rated 6. One of the main organizational problems related to the service providers is insufficient engagement to use the existing potential of communication and cooperation and to ensure transparency, accuracy and timeliness in informing other participants. Other organizational problems are untimely delivery/dispatch to stations, terminals/from stations, terminals, insufficiently efficient work of personnel, delayed, incomplete or inadequate preparation of documentation, non-application of simplified customs procedure (50% of providers do not apply it) [41], lack of agreement on the use of interoperable locomotives, delay of locomotives, inefficient allocation of locomotives and/or drivers, delay about the timetable, resubmission of requests and waiting for a response, inefficiency in the field of dangerous goods logistics

The quality of the RIM organization (U_{22}) in Serbia was rated 6. A significant part of providers and users are dissatisfied with the communication of IŽS with providers and infrastructure managers in other countries and the information literacy of IŽS personnel. Part of the providers believe that IŽS is responsible for the inefficiency of the train handover process at the borders. Providers and users expressed great dissatisfaction with the protection of trains, their marks and goods from theft during transport and stay in terminals, especially in the case of containerized goods. Although there are good practice examples, a large number of users expressed dissatisfaction with the traffic regulation, especially during railway reconstructions. Finally, although some data is tracked (light driving time, number of track closures, etc.), there is no systematic and comprehensive collection and analysis of key performance indicators (station/terminal closure time, train dwell time at signals, etc.). Because of this, a complete overview of the processes in RT and IT and problem-solving is impossible. The aforementioned factors negatively affect the service accuracy and reliability.

The quality of the other participants' organization (U_{23}) in RT and IT systems of Serbia, such as customs, inspection, and border police services, was rated 6. Customs procedures are complex and require a long waiting time. At some border crossings, customs clearance is performed exclusively at the passenger station, which increases customs clearance time. Also, the working hours of customs services are limited, so trains arriving at border stations at the end of working hours often have to wait for several hours. Finally, the work of customs officers is not completely efficient. The basic organizational factors of the ineffectiveness of the inspection services operations are similar: unnecessary procedures, limited working hours and inadequate location. Detailed and rigorous border police security checks adversely affects service through additional retention at border stations/terminals. A significant number of service users are particularly dissatisfied with the information provided by these services.

The quality of the regulatory framework and institutional action (U_{31}) in Serbia was rated 5. Although there are efforts for more efficient institutional action and regulatory framework improvement, there are numerous problems in these areas. Current regulations and agreements are outdated. Between IŽS and Srbija Kargo, which used to be part of the same public company, there is no clear division of responsibilities. In some situations, none of these companies take responsibility or initiative for a particular activity. At the borders, passenger transport, certain categories of goods (containerized goods, energy products) and certain providers have priority. The impossibility of dispatching freight trains at the desired moment due to the time limit on the use of railway tracks for freight RT contributes to congestion in stations/terminals, and thus to delays. The inefficiency of customs operations is largely the responsibility of the state apparatus, due to ineffective institutional action in the field of simplification of procedures, inclusion in international agreements, affirmation of interoperability, negotiations on EU accession, etc. Some other problems are institutional responsibility: lack of adequate professional staff (engineers, train drivers, inspectors), insufficiently productive and/or responsible work of personnel, inadequate prevention and sanctioning of corrupt acts, inadequate protection of infrastructure, trains and goods, inadequate response to traffic accidents, unsafe transportation of hazardous materials etc.

When the specified values of the input variables are entered into the FS, the value of I is equal to 5.6. That value indicates that the impact of the RT services quality on IT with the highest degree of membership can be characterized as neutral/dual.

5. CONCLUSION

The RT services quality affects the IT quality and depends on various factors, which are not easy to quantify. FSs are a suitable tool for this issue. In this paper, an FS-based model for assessing the RT quality impact on IT quality is defined and applied to the example of Serbia, along with a detailed description of the state of the railway system in the country. This achieved the main goal and contribution of the paper. Unlike previous similar models of quality evaluation, in which the final characteristics of the service are dominantly taken into account (e.g. reliability, security, speed, etc.), in this model the input variables are related to the fundamental aspects and factors of creating IT and RT services, which, as such, give a more complete picture of the current quality of these services, as well as the potential for improvement. When evaluating the input variables in the specific example, the points of view of service providers and users, and information on the state of RT and IT from relevant sources were taken into account. It was determined that the impact of the RT services quality on IT in Serbia is neutral/dual (evaluation 5.6/10). The positive aspects of the impact stem from the quality and intensified development of line and nodal infrastructure and the successful organization of a significant number of participants in the railway system. Negative aspects are the insufficient efficiency of the information flow implementation and significant risks of delays and traffic accidents. The reasons for this are infrastructural deficiencies, especially in the field of ICS, but also the need for additional improvement of the logistics infrastructure, organizational problems, as well as the inertness and insufficient expediency of regulatory-institutional action. One of the future research directions is the analysis of ways to overcome the mentioned problems. Also, it is necessary to evaluate the RT service quality and its impact on IT in Serbia using other mathematical models (e.g. MCDM) and compare the results with the conclusions of this paper.

REFERENCES

[1] Kalem A, Tadić S, Krstić M, Čabrić N, Branković N. Performance Evaluation of Railway Infrastructure Managers: A Novel Hybrid Fuzzy MCDM Model, *Mathematics*, Vol. 12, No. 10, 1590, 2024.

[2] Tadić S, Zečević S. *Modeliranje koncepcija city logistike*, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 2016.

[3] Tadić S, Zečević S, Krstić M. A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection, *Expert systems with applications*, Vol. 41, No. 18, pp. 8112-8128, 2014.

[4] Tadić S, Zečević S. Development of Intermodal Transport and Logistics in Serbia, *International Journal for Traffic & Transport Engineering*, Vol. 2, No. 4, pp. 380-390, 2012.

[5] Tadić S, Zečević S, Milenković D. Tretman intermodalnog transporta u razvijenim i zemljama u razvoju, *Tehnika*, Vol. 67, No. 6, pp. 897-902, 2017.

[6] Zečević S, Tadić S, Krstić M. Intermodal transport terminal location selection using a novel hybrid MCDM model. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, Vol. 25, No. 6, pp. 853-876, 2017.

[7] Kilibarda M, Andrejić M, Popović V. Research in logistics service quality: A systematic literature review, *Transport*, Vol. 35, No. 2, pp. 224-235, 2020.

[8] Arvis JF, Ojala L, Wiederer C, Shepherd B, Raj A, Dairabayeva K, Kiiski T. *Connecting to Compete: Trade Logistics in the Global Economy. The Logistics Performance Index and Its Indicators*, World Bank, Washington DC. 2018.

[9] Tadić S, Zečević S, Milenković D. Problems regarding intermodal transport in the Danube Region. in Proc. *4th International Conference on Traffic and Transport Engineering, ICTTE 2018*, Belgrade, Serbia, pp. 483-489, 27-28 September 2018.

[10] Cukrov M, Badurina-Tomić P, Jugović A. Intermodal Transport System Quality Indicators in the Context of the Adriatic-Ionian Region. *Naše more: znanstveni časopis za more i pomorstvo*, Vol. 63, No. 4, pp. 249-255, 2016.

[11] Tadić S, Krstić M, Veljović M, Zečević S, Locating VAL services in the logistics network. In Proc. *20th International conference on transport science*, Portoroz, Slovenia, pp. 387-393, 23-24 May 2022.

[12] Liu HT, Wang WK. An integrated fuzzy approach for provider evaluation and selection in third-party logistics. *Expert systems with applications*, Vol. 36, No. 3, pp. 4387-4398, 2009.

[13] Kilibarda M. *Modeli logističkog kontrolinga u integrisanim logističkim sistemima*, magistarski rad, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 1998.

[14] Kilibarda M, Zečević S. *Upravljanje kvalitetom u logistici*, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 2008.

[15] Crosby, P. *La calidad no cuesta. El arte de cercionarse de la calidad*. CECSA, Mexico City, 1991.

[16] Thai V. V. Logistics service quality: conceptual model and empirical evidence. *International Journal of Logistics Research and Applications*, Vol. 16, No. 2, pp. 114–131. 2013.

[17]Zečević S, Kilibarda M. Logistic service quality, *Tehnika*, Vol. 4, No. 6, pp. 1-9, 2004.

[18]Bienstock CC, Mentzer JT, Bird M. Measuring Physical Distribution Service Quality, *Journal of Academy of Marketing Science*, Vol. 25, No. 1, pp. 31–44, 1997.

[19]Tadić S, Zečević S, Petrović-Vujačić J. Globalni trendovi i razvoj logistike. *Ekonomski vidici*, Vol. 18, No. 4, pp. 519-532, 2013.

[20]Tadić S, Zečević S, Krstić M. City logistics - status and trends, *International Journal for Traffic & Transport Engineering*, Vol. 5, No. 3, pp. 319-343, 2015.

[21]Tadić S. *Modeliranje performansi integrisanih city logističkih sistema*, doktorska disertacija, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 2014.

[22]Jusufbašić A, Stević Ž. Measuring logistics service quality using the SERVQUAL model. *Journal of Intelligent Management Decision*, Vol. 2, No. 1, pp. 1-10, 2023.

[23]Kilibarda M, Zečević S, Vidović M. Measuring the quality of logistic service as an element of the logistics provider offering. *Total Quality Management & Business Excellence*, Vol. 23, No. 11-12, pp. 1345–1361, 2012.

[24]Brnjac N, Tadić S, Kuharić M. State of intermodal transport in Croatia and Serbia. In Proc. *1st Logistics international conference, LOGIC 2013*, Belgrade, Serbia, pp. 149-154, 28-30 November 2013.

[25]Tadić S, Kilibarda M, Kovač M, Zečević S. The assessment of intermodal transport in countries of the Danube region, *International journal for traffic and transport engineering*, Vol. 11, No. 3, pp. 375-391, 2021.

[26]Abramović B, Lovrić I, Stupalo V. Analysis of intermodal terminals service quality in the republic of Croatia, *Promet-Traffic &Transportation*, Vol. 24, No. 3, pp. 253-260, 2012.

[27]Tadić S, Krstić M, Brnjac N. Selection of efficient types of inland intermodal terminals, *Journal of Transport Geography*, Vol. 78, pp. 170-180, 2019.

[28]Palšaitis R, Ponomariovas A. Assessment of rail freight transport service quality, *Transport and Telecommunication Journal*, Vol. 13, No. 3, pp. 188-192, 2012.

[29]Kolodizieva T, Zhelezniakova E, Melnykova K, Pysmak V, Kolodiziev O. Assessment of logistics service quality based on the application of fuzzy methods modeling, *Problems and Perspectives in Management*, Vol. 20, No. 3, pp. 552-576, 2022.

[30]Zeybek H. Service Quality and its Importance for Rail Freight Customers, *International Journal of Transportation Engineering*, Vol. 7, No. 2, pp. 115-126, 2019.

[31]Shan J, Bešinović N, Schönberger J. Service quality assessment of international rail transport with multiple border crossings: Eurasian rail transport as an example, *Journal of Rail Transport Planning & Management*, Vol. 29, 100432, 2024

[32]Đorđević D, Stojić G, Stević Ž, Pamučar D, Vulević A, Mišić V. A new model for defining the criteria of service quality in rail transport: the full consistency method based on a rough power Heronian aggregator, *Symmetry*, Vol. 11, No. 8, 992, 2019.

[33]Zadeh LA. Fuzzy sets, *Information and Control*, Vol. 8, No. 3, pp. 338–353, 1965.

[34]Klir G, Yuan B. *Fuzzy sets and fuzzy logic* (Vol. 4, pp. 1-12), Prentice hall, New Jersey, 1995.

[35]Mendel JM. Fuzzy Logic Systems for Engineering: A Tutorial, *IEEE 83*, pp. 345-377, 1995.

[36]Teodorović D, Šelmić M. *Računarska inteligencija u saobraćaju*, Univerzitet u Beogradu, Saobraćajni fakultet, Beograd, 2012.

[37]Veljović M, Tadić S, Krstić M. Last Word in Last-Mile Logistics: A Novel Hybrid Multi-Criteria Decision-Making Model for Ranking Industry 4.0 Technologies, *Mathematics*, Vol. 12, No. 13, 2010, 2024.

[38]Chornopyska N, Stasiuk K. Logistics potential of the railway as a key for sustainable and secure transport development, *Transport Means*, Vol. 25, pp. 421-425, 2020.

[39]Abramović B, Zitricky V, Biškup V. Organisation of railway freight transport: case study CIM/SMGS between Slovakia and Ukraine, *European transport research review*, Vol. 8, No. 27, 2016.

[40]Paul SK, Chowdhury P, Ahsan K, Ali SM, Kabir G. An advanced decision-making model for evaluating manufacturing plant locations using fuzzy inference system, *Expert Systems with Applications*, Vol. 191, 116378, 2022.

[41]Tadić S, Zečević S, Krstić M, Veljović M. *Preparation of Study on the current situation of bottlenecks in railway traffic for project INPUTRANS*, Pokrajinski sekretarijat za privredu i turizam, IPA Cross-border Cooperation Program Hungary – Republic of Serbia), 2023.

[42]Infrastruktura železnice Srbije (IŽS), *Izjava o mreži 2023*, broj: 5/2021-370-155, 2021.

REZIME

UTICAJ KVALITETA USLUGA ŽELEZNIČKOG TRANSPORTA NA KVALITET INTERMODALNOG TRANSPORTA: MODEL ZA OCENU

Železnički transport (ŽT) ima značajan udeo u intermodalnim lancima, pa kvalitet intermodalnog transporta (IT) umnogome zavisi od kvaliteta usluga ŽT. S druge strane, kvalitet tih usluga zavisi od mnoštva instrastrukturno-tehnoloških, organizacionih i regulativno-institucionalnih faktora. Uticaj ovih faktora na kvalitet usluge i IT nije lako precizno kvantifikovati. S obzirom da daju mogućnost nepreciznog ocenjivanja promenljivih, fuzzy sistemi su pogodan matematički alat za rešavanje ovog zadatka. U ovom radu definisan je model za ocenu uticaja kvaliteta usluga ŽT na kvalitet IT, zasnovan na fuzzy sistemu. Primenom na primeru Srbije ustanovljeno je da je taj uticaj u ovoj zemlji neutralan/dvojak.

Ključne reči: *intermodalni transport, železnički transport, kvalitet, fuzzy sistem, Srbija*