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THE APPLICATION OF THE FUZZY AHP AND DEA FOR MEASURING THE EFFICIENCY OF FREIGHT TRANSPORT RAILWAY UNDERTAKINGS

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Abstract: *Measuring the performance of railway undertakings is inevitably becoming a prerequisite for their survival on the market in today's dynamic and highly turbulent environment. Railway undertakings must find optimal solutions in order to efficiently and effectively operate, survive on the transport market, and develop and maintain their competitive advantages as well. The objective of this research is to define and evaluate the criteria that affect the efficiency of railway undertakings, increase their competitiveness and propose a DEA-based approach (i.e. a Data-Envelopment-Analysis-based approach) to the assessment of the efficiency of railway undertakings in increasing competitiveness. In order to solve the criteria selection problem, the Fuzzy Analytical Hierarchical Processes (FAHP) method was experimented with, which showed the priority of the assessment of the efficiency of railway undertakings, on the basis of the five groups of criteria. The criteria in a group that outperformed the other criteria in that group for their freight transport railway undertakings within a composite normalized range were used as the input and output indicators for the DEA. The evaluation of the efficiency of the railway undertakings was considered by using the DEA approach. The results show that the proposed approach successfully enables the consolidation of a set of criteria (resource, operational, financial, quality and safety) into a single assessment of the efficiency of the railway undertakings, while providing information on the corrective actions that can improve the efficiency of the railway undertakings.*

Key words: *railway undertaking, efficiency, DEA, fuzzy AHP*

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1. Introduction

The twenty-first century can also be called a century of change, and the conditions under which organizations operate can be seen as very complex. The rapid changes in the business world and the increasing competition in the transport services market have imposed on all organizations, including transport companies, the need to harmonize their business with the requirements of the modern business environment. The market has become an arena in which product and service providers are ruthlessly battling for every promile of the market. Survival on the market can be ensured only by the fittest who are able to outperform competitors. New business conditions dictate new market demands and establish new competitive relationships on the market. The struggle for survival in the marketplace is becoming inevitable. In order to persist in this struggle, companies need to accept and adapt to new business conditions. The ever more intensive development of the transport market and the ever more complex demands of the users of transport services, with the growing pressure of competition, requires that the organization of the company should become the central determinant of business and the activities carried out should completely be harmonized and financially viable for both the provider and the user of services. In order to survive on the market, companies seek to find the optimal relationship between the resources invested and the goals achieved. The application of the new European transport policy at the end of the last century caused major changes in Europe's transport system. There is a major transformation of transport companies into the efficient companies that will be operating in a liberalized European transport market in the future. In a large number of European countries, as well as in the other countries of the world, standards have been adopted regarding the restructuring of the railway system. Appropriate legal acts were adopted for the transformation of railways. The previous restructuring stages had not allowed the complete liberalization of the railway transport market, the expected positive operation of the railway sector, the fulfilment of the requirements of the transport market, raising the quality of railway services to the required level, the interests of the community at the national, regional and local levels and others. The restructuring of the railway system only partially brought positive business results in the main railways or pan-European corridors, mainly in transit traffic (Stojić et al., 2012). Although the quality of the services of the railway system has slightly increased, it is still far from the quality required by the transport market. In providing an adequate quality of railway services, railway undertakings have a very important role, in addition to the railway infrastructure, in terms of: reliability, frequency, the timetable, traffic speed, safety, the organization of work in railway stations, competitive prices in the transport market, and so on. In a large number of countries in the present conditions, transport is mainly performed by the national operators that have emerged from the transformation, i.e. division of railway companies. Mostly, these companies are managed by the state. The liberalization of the railway transport market implies, above all, free and non-discriminatory access to the railway infrastructure, bearing in mind the fact that the transport function is performed by a larger number of operators on the appropriate national railway network. The efficiency of transport activities significantly affects the profitability of the business of all the entities involved in the process, but they cannot be provided without much effort in the process of quality management and transport activities. Given the fact that, in modern companies, it is necessary to constantly measure the causes of the achieved effect, it is quite clear that the system for performance/efficiency measurement of the railway operator must include all the criteria that affect it. In order for railway companies to successfully operate, it is very important for them to form a performance/efficiency measurement system appropriate to modern business conditions. Railway operators' operations in today's dynamic and competitive intensive environment require the precise and constant measurement of non-financial criteria, which are identified as the causes of the financial result, so that potential negative trends can be corrected before their effect negatively affects the final result of such operations, which, as a rule, is evaluated from a financial perspective. The subject matter of this research paper stems from the needs of the European countries, regardless of whether they are EU member states or the states applying for the membership, and its aim is to establish the market principles of business in the railway sector. Bearing in mind the fact that the efficiency of railway transport depends on the number of the services offered and the content of the services that have been implemented, it is necessary to determine the criteria that can define efficiency. Based on a detailed analysis of the situation in the research field, a fact was established that the methodological procedure for selecting the key criteria for the evaluation of the efficiency of railway undertakings is not sufficiently researched. For this reason, the objective of this research was to define and evaluate the criteria that affect the efficiency of railway undertakings and propose an approach based on the DEA method for the assessment of the efficiency of railway undertakings in order to increase competitiveness. The contribution of this paper reflects in the criteria selection approach and the evaluation of the efficiency of railway undertakings through the proposed DEA approach. Increasing the revenue, quality and scope of services and reducing the operating costs of the railway undertakings themselves can be improved by applying the proposed efficiency assessment approach.

2. Research Methodology

In addition to general scientific research methods (analysis, synthesis, induction, deduction and analogy), various methods and techniques were used to assess the efficiency of freight transport railway undertakings, such as the Fuzzy Analytical Hierarchical Process (FAHP) and Data Envelopment Analysis (DEA). The research itself was conducted in several phases (Figure 1). The first phase of the research was carried out through several mutually conditioned steps. The initial step in this paper was to identify the problem. Once the problem was identified and the importance of the efficiency of freight transport railway undertakings was determined, the subject matter of the research was defined, together with its objective. The second phase of the research covered an analysis of the literature, scientific and professional information on the railway system for the railway undertakings from the Western Balkans, Slovenia and Croatia, together with the aspects of efficiency measurement, as well as the criteria used. Based on the research done in the most frequently used criteria for the efficiency of railway undertakings from the available literature, the authors defined five groups of criteria. The additional difficulties in the implementation of these tasks imply the mutual influences and conditionality of the mentioned criteria. Thus, for example, the criteria selection problem, which is the initial problem, in a situation of conflicting goals, gives the level of measuring efficiency an additional importance. To select the priority criteria, the Fuzzy Analytical Hierarchical Process (FAHP) was used, which is supported by the literature fact that this method generates the results that are more precise than those obtained by the

AHP method. The third phase was the "core of the research study". In this phase, the previously defined problems related to the evaluation of the efficiency of railway undertakings were solved. A new DEA approach was proposed so as to assess the efficiency of a group of freight transport railway undertakings, which can greatly help in the function of increasing the competitiveness of the railway undertakings. In the fourth phase, the testing of the proposed DEA approach was performed on the selected/proposed (examples of) railway undertakings, with an analysis of the obtained results. This paper provides concluding remarks, as well as directions for future research.

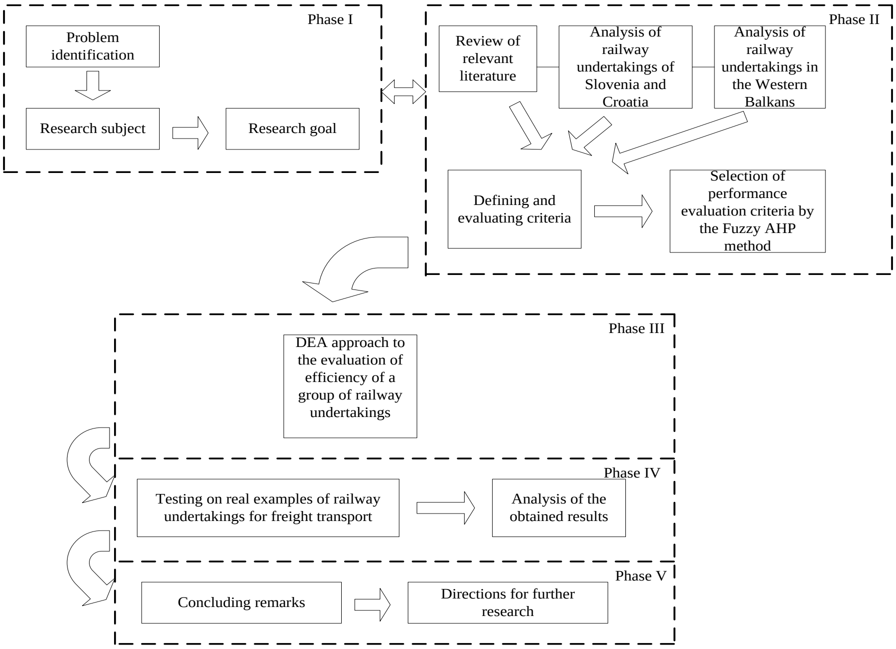

Figure 1 The research methodology

3. The Situation in the Research Area

In the conditions of the global market and increasingly intense competition, the European Union seeks to restructure railways and develop their competitiveness. The European Union is embarking on a comprehensive process for the restructuring and commercialization of rail transport, enabling the reaffirmation and improvement of rail quality and rail efficiency. The starting documents for the achievement of the objective are the Railway Plan, the Freight Charter, Directive 2004/51/EC, the European Technical Strategy for Railway Undertakings (White Paper 1996 and 2011). The main objective of the EU documents is to enable railways to be competitive in the transport market. According to the European Railway Technical Strategy, European Rail Infrastructure Management Managers (2008), the efficiency of rail passenger and freight traffic would increase even more than necessary if the overall costs of the company were reduced. The challenging scenario for railways is to facilitate major economic development in the future, which would generate greater demand for passenger and freight transport while maintaining a high level of the public awareness of the environment and reducing carbon dioxide emissions (increased energy efficiency). The scenario of large-scale economic development is the basis of the aforementioned strategy, as well as the need for the rail sector to be cost-effective and offer an attractive transport mode that will meet environmental standards, while introducing sustainable solutions. In order to be eligible, in line with the scenario presented above, the railway must be multi-functional and should reduce the total cost through: a high capacity (passenger and freight kilometers per kilometer of railway); the high reliability of services (an increased percentage of timely deliveries and fewer delays); the low levels of carbon dioxide emissions (tonnes per passenger and freight kilometers); noise reduction; increased comfort and adequate passenger space (the train station); the increased availability of the rolling stock; better information (before and during the trip); better safety (from the moment of entering the station to the moment of leaving it); a stable confidence level (the total equivalent of the lives lost as a result of the system operation). Garcia-Cebrian and Jorge-Moreno (1999) present the results of a study in which, on an example of 21 railway companies, they observed the impact of organizational change on business efficiency (increased revenue, reduced costs, increased productivity). Ehrma NN (2001) points out the fact that the deficit of state-owned railways is enormous and that the issue of the efficiency of companies has become an issue in economic and political debates. Permanent rail deficits also indicate the fact that an excess capacity throughout the industry, with a lack of state-run rail efficiency, could be a major reason for an insufficient or negative return on invested capital. In times when there is a large public debt throughout the world, the state has a natural interest in adjusting railway undertakings and making the capital allocated to them profitable. In the paper (Borenstein et al., 2004), a methodology is proposed to evaluate the performance of service providers. The goals of this paper were to identify the factors that could be used to evaluate the effectiveness of these decision-making units and identify the groups of similar units that develop the same functions and only differ in resource intensity. The analysis included the comparisons of the relative efficiency of several different units, including postal operators in Brazil, using the DEA. The authors indicated the fact that the proposed methodology could provide the useful information that might be helpful for managers in the decision-making process. Ming-Miin Yu and Erwin T.J. Lin (2008) evaluated the passenger and freight technical efficiency, service efficiency and technical efficiency of the 20 selected railways of other countries for 2002. The study found that those measures differed significantly. Because the data envelopment analysis of the multi-active network models the reality of rail operations, a further insight can be obtained and strategies for the improvement of operational performance can be proposed. In his study entitled "An Efficiency Analysis of European Countries' Railways", Pavlyuk Dmitry (2008) uses stochastic boundary analysis to evaluate the efficiency of the rail system in European countries. He views the rail as a system using its length of operating lines, a number of cars and wagons, employees and a market scale such as the population and tourists to carry passengers and freight. The result of the study showed that the rail systems show huge differences in technical efficiency between different countries, as well as between freight and passenger transport within the same country. Friebel, Ivaldi and Vibes (2010) attempted to measure the impact of reforms in European railways on the technical efficiency of the railways. To do this, they used input and output data analysis, applying the Cobb-Douglas function that implicitly assumes a separation between the input and the output. For the input data, they used the length of the lines on the network and the number of the employees, whereas as the output data, they used passenger km and tonne-kilometers, especially for passenger and freight transport. They worked on a sample of 11 European countries for the period 1980-2003. The three types of the reforms that have taken place in Europe (namely, separation, entry of other companies (competition) and the existence of an independent regulatory body) were added to the prior physical data. Their results indicate the fact that the rail reforms have increased rail transport efficiency, and that the reforms have been more successful when applied sequentially rather than all at once. Lan-bing Li and Jin-Li Hu (2011) model rail transport in their paper into the three processes: the production process (the input and the output), the consumption process (consumption/the output) and the earnings process (earnings/consumption), thus creating a unique multi-phase framework for measuring the Chinese railway performance from 1999 to 2008. First, they used the DEA model to evaluate productivity efficiency, consumption efficiency, and earnings efficiency from a statistical point of view. Then, they used the Malmquist TFP index to evaluate production productivity, consumption productivity, and earnings productivity from a dynamic point of view. They also used the average cumulative Malmquist TFP index to evaluate the impact of the management system reform of the Chinese rail system on rail transport in 2005. Jianjun (2012) analyzes the inefficiencies in production and points out the fact that rail transport has the need for the introduction of economical production by changing the way transport is organized by improving internal contractual relations and optimizing the business organizational structure, the rational use of resources, and an economically significant improvement of efficiency and effectiveness by creating a new way of economically organizing rail transport. Azadeh and Salehi (2014) define a methodology based on the DEA analysis in order to examine the efficiencies of infrastructure managers and railway undertakings and define deficiencies. The authors state that the level of the durability of the system depends on the amount of deficiencies. The smaller the operating deficiencies between the railway undertaking and the infrastructure manager (the smaller the gap between them), the more efficient the company will be in terms of challenges and difficulties in actual operations. Marchetti, D, & Wanke, P. (2017) use the DEA analysis to assess the efficiency of the Brazilian railway concessionaires between 2010 and 2014, when new competition regulations were introduced. The public policies designed so as to increase cluster efficiency are presented, and the options such as increasing, decreasing and magnitude inputs, restructuring, the best management practices, and infrastructure improvements are addressed. Kapetanovic, M. et al. (2017) use the DEA method to evaluate the efficiency of the railway undertakings of the majority of the European countries over the most recent period of time, analyzing the different input-output configurations of the model.

4. The Definition and Assessment of the Criteria for the Evaluation of the Efficiency of Freight Transport Railway Undertakings

Deciding on the selection of the criteria for the assessment of the efficiency of railway undertakings is a very complex process and belongs to the domain of strategic decisions. The adoption of this decision is in the function of managing a railway undertaking and, as such, this activity is complex, creative and permanent. In order to decide on the selection of the criteria for the assessment of the efficiency of railway undertakings, it is necessary to evaluate the proposed variant solutions of different criteria. How to evaluate them is the key issue in determining the method. There is a wide range of the criteria that can be studied when speaking about the efficiency of freight transport railway undertakings. In most cases, there are several criteria that are very often conflicting with one another. To select the best evaluation method or make the best decision when selecting criteria, previous experience and the literature in this field indicate the fact that the problem should be addressed by using multi-criteria decision-making methods. In this paper, one of today's most popular decision-making methods – Fuzzy Analytic Hierarchy Process (FAHP), is experimented with.

4.1. Fuzzy Analytic Hierarchy Process (FAHP)

The Analytic Hierarchy Process (AHP) method, developed by Tomas Saaty, is widely spread and has been in use for over 25 years, with a number of pieces of software developed to support its application. This method is a tool in decision- making, designed to enable decision-makers solve complex decision-making issues, involving a larger number of decision-makers, a greater number of criteria, and multiple time periods. The detailed explanations of this method are provided in many references dealing with decision theory. In this regard, the paper presents a new approach to the AHP method by using interval fuzzy numbers and the application of the modified fuzzy AHP method in defining and evaluating the criteria that influence the evaluation of the efficiency and effectiveness of railway undertakings. Different methods for transferring the previously mentioned AHP method into its fuzzy form are presented in the literature (Bottani, 2005). In addition, the paper (Van Laarhoven and Pedrcyz, 1983) proposes the first study that introduces the principles of fuzzy logic in the AHP method, using triangular fuzzy numbers. At the same time, a study by Buckley (1985) initiates the fact that trapezoidal fuzzy numbers express decision-makers' assessments, while the authors of the study (Boender et al., 1989) present a modification to the fuzzy multi-criteria method proposed in Chang's paper (1996). In the study (Chang, 1996), the severity of the criteria is calculated as the minimization of the logarithmic regression function. In this manner, weight alternatives are calculated by each criterion separately, while the aggregation of calculated weights can determine the fuzzy final result of the alternative. The study (Cebi and Bayraktar, 2003) presents a new approach to solving the AHP phase (FAHP) by using triangular fuzzy numbers. This approach is called an extended analytical method, which can be summarized as follows: define the association function for each attribute and sub-attribute, then calculate their degree of association, and ultimately apply the AHP phase for weight aggregation. Also, Vesković S., et al. (2015) apply the FAHP to evaluate the criteria for public transport obligations. Fuzzy sets generally use triangular, trapezoidal and Gaus fuzzy numbers, which convert uncertain numbers into fuzzy numbers. Using more complicated fuzzy numbers, such as trapezoidal or Gaus, allows a more precise description of the decision-making problem. To solve the problem of defining and evaluating the criteria for the assessment of the efficiency and effectiveness of railway undertakings, triangular fuzzy numbers (Chang, 1996) are used in this paper.

4.2. Criteria for the assessment of the efficiency of freight transport railway undertakings

In the process of defining the DEA approach to efficiency evaluation, it is necessary to consider and define the criteria that affect the efficiency of a railway undertaking. The criteria are chosen so as to allow for the evaluation of the efficiency of railway undertakings. For the purpose of defining and evaluating the criteria, research in the most frequently used literature criteria regarding the efficiency and effectiveness of railway companies was carried out. Based on the conducted research, it was concluded that the used criteria could be categorized into the following criteria groups: the resource criteria (capacity), the operational criteria, the financial criteria, the service quality criteria and the safety criteria. The management of railway undertakings can monitor partial activities and processes with the help of these criteria, but they cannot acquire a complete picture of how the whole system works. It is necessary to define an integrated measure that will somehow integrate all of these criteria. Such a measure would provide a much quicker and more comprehensive picture of how the system works and define appropriate corrective actions as well. The first phase involves the defining and grouping of the criteria. It is desirable at this stage that the information on how the analyzed system works should be used. It is also necessary to group the criteria by the type, by the subsystem they belong to, and by the decision level. Accordingly, a broader set of criteria need to be defined. There are different ways to group criteria in the railway system. In terms of the measurement level, it is possible to define criteria at the strategic, tactical and operational levels. Railway systems are complex systems with numerous interconnected subsystems, processes and activities. Each subsystem, process or activity is characterized by certain criteria. Based on the literature and knowledge, the following criteria of the freight transport operator are defined and shown in Table 1.

Table 1. The criteria for the assessment of the efficiency of freight transport railways undertakings

Group	Criteria
Resource criteria (capacity)	The network length The number of staff per km of the railway network The number of employees
Operational criteria	Commercial speed for freight trains The quantity of transported goods/freight Net tonne km Gross tonne km Train km
Financial criteria	Total income Profit per employee Electricity costs Fuel costs Railway infrastructure charges
Service quality criteria	The suitability of the available services The stability of services The reliability of services (the overdue delivery time) Available rolling stock
Safety criteria	The number of serious accidents per train km The number of accidents per train km The number of incidents per train km

The essence, meaning and reasons of each criteria group are explained further in the paper.

1) The Resource (Capacity) Group Criteria. The first group of the criteria was considered based on the network length, the number of staff per km of the railway network, and the total number of employees and the available number of the rolling stock of railway undertakings. The efficiency achieved by freight transport railway undertakings by carrying out their activities depends on the results of the work accomplished using resources (the capacity). There is a need to understand the state of the resources and the extent to which the resources have been used. The network length criterion relates to the characteristics of the network and greatly affects the efficiency of railway undertakings; namely, it is important for railway undertakings that railway networks should be branched and well connected. In addition, it is important that it should be well connected with international lines. Our railway networks are small and dense, with highly aligned timetables. The density of the network is significantly reflected through the accessibility of the rail service. *The number of employees* is one of the most sensitive segments of the railway sector restructuring process. The economic transition of the Central and Eastern European countries has resulted in very large differences between the individual systems of railway undertakings. It is actually easy to find the causes in some country-specific or group-of-counties-specific processes, for example: the successfulness of the restructuring of the extractive and heavy industries, the privatization and growth of road transport, the collapse of economic blocks (e.g. Yugoslavia), and the impact of military conflicts. In such circumstances, there is a simultaneous redundancy and shortage of labor. Railway companies' systems are burdened with a substantial excess of staff, which is increasingly evident due to the negative trend of rail transport, while on the other hand, there is a deficit of the labor force that has the knowledge and experience needed to meet new market demands. The number of employees is an important component of the efficient operation of railway undertakings, because low costs are the basis for the achievement of competitive advantages today. Fixed and operating costs of business are under increasing pressure and generally record growth trends. Railway undertakings are, by their very nature, a labor-intensive industry, which means that one of the main cost drivers is the cost of employees. This statement assumes an even greater weight given the fact that almost all transition countries, or their railway systems, have insufficient productivity in relation to the number of employees.

2) Operational Group Criteria. The second group of criteria was considered on the basis of the commercial speed of cargo transport trains, the quantity of the goods transported, net tonne and gross tonne kilometers, as well as driving kilometers. Commercial speed can be viewed as operational and as a quality service criterion. The efficiency of freight transport railway undertakings is indirectly dependent on commercial speed and the retention time in railway stations. Taking into consideration the fact that organizational measures cannot significantly affect the speed and time of travel during the circulation of the car, it can be concluded that, according to this criterion, the development of railway traffic depends on the retention time, i.e. on the criteria that can be influenced by organizational measures. In other words, lower retention times mean fewer circuits and more efficient transport. In the conditions of the further development of railway transport and the growing demands the economy and the population pose in terms of the speed of travel or the transport of goods, the speed of transportation means will play an increasingly important role in transport users' decision-making when selecting a type of transport. Therefore,

transport speed will certainly be one of the most important factors, which must be taken into consideration when conducting comparative analyzes of the efficiency of railway undertakings. The criteria of the production task, the transport of goods, as the main activities of railway undertakings, are expressed through the quantity of the goods transported. Railway undertakings generate certain revenues through the criteria that give the opportunity to see the amount of the work done. In the transport of goods, these are net tonne kilometers (the product of the mass of the goods transported in tonnes and transport distances). Railway undertakings do certain work in net tonne kilometers, which is considered to be a transport service for which the price for the net tonne kilometer is charged.

3) Financial Group Criteria. The third group of criteria was considered on the basis of the total revenue, earnings per employee, electricity costs, fuel costs and charges for the use of the railway infrastructure. Railway undertakings achieve income through the sale of products and services. The main activity carried out by railway undertakings is the transport of goods, and revenues from this activity are defined as transport revenues. In this sense, income is a reliable criterion of efficiency, as well as a precondition for the survival of the company. If a company generates no revenue, then it cannot survive on the market. Hence the obligation of railway undertakings to fully understand the function of demand for their services, because in this way they can assess the level of income they strive to achieve or they do achieve. A company's total income is realized as the product of the transport service and the price of the service. For the transport service as a specific product, the ratio of the consumed production factors (production costs, services) and the realized revenues is all the more significant, since production also simultaneously produces its final consumption, realizes the effects of investment in the transport process and achieves production goals (the financial result of the operations of railway undertakings). Transport costs are defined as the value of the factors consumed in the transport service production process or in the goods transport process. In this sense, according to the economic essence of the transport service production process, the basic structure of transport costs includes the costs of labor, which are a very heterogeneous group of investments in the transport process, which consist of the costs of electricity and the costs of fuel. The amount of these costs for a certain volume of production and the technological labor process is conditioned by objectively standardized consumption according to the quantity, the structure and values in a certain real time, and affects the evaluation of the efficiency of railway undertakings to a great extent. The costs of charges for the use of the railway infrastructure directly affect the situation on the transport market. Newly-introduced charges affect the position and role of domestic railway undertakings on the market. The survival of domestic railway undertakings depends on their conditions (the state of technical means, technology, organization, the commercial sector, etc.). When a domestic undertaking is/domestic undertakings are able to provide an appropriate level of the quality of the transport service, high charges will discourage competition on the railway market. If charges are high, the private sector will have no interest in introducing new railway undertakings. No foreign railway undertakings will come to the countries and railways where these charges are high, either. On the other hand, low charges increase the number of railway undertakings and win better-equipped, more capable, more competitive carriers on the free market. This is particularly true for countries in transition and countries where charges have just been introduced. In the countries and rail markets that are underdeveloped and where domestic railway undertakings cannot provide an

appropriate level of the service quality, the situation is just the opposite. There, high charges can only bear the bargain, which is usually a foreign railway undertaking, so it "chokes" domestic railway undertakings. Low charges stimulate competition, and in equal conditions, again, it will be difficult to "defend" domestic railway undertakings. To conclude, fees directly affect the evaluation of the efficiency of railway undertakings.

4) Service Quality Group Criteria. The fourth group of criteria was considered based on the suitability-ability of the offered services, the stability of services, the reliability of the service – exceeding the delivery deadline and the available number of the rolling stock of railway undertakings. The service quality is what constitutes the mirror of railway undertakings, what the customer sees as their image. The customer sees no business premises, no equipment, no technology, no management system and no organizational structure. Everything the customer sees is the quality of the transport service. The quality of the services rendered by railway undertakings lies in the key competences, i.e. sustainable competitive advantages, in relation to other railway undertakings, and significantly influences the assessment of the efficiency of railway undertakings. The convenience ability of the offered services is the criterion whose goal is to adapt railway undertakings to the requirements of service users in terms of the required capacity, mobility and elasticity in order to satisfy the requested service. Reliability is the core of the quality of a railway undertaking's service, bearing in mind the fact that reliability appears as the most significant qualitative feature from the user's perspective. Research shows that there is a significantly higher reliability effect, as a measure of quality, on the satisfaction of service users than product users. This is particularly due to the specific nature of the transport service: the user's insolvency in the production process and the synchronization of the production and consumption processes, which makes it difficult at the same time to measure and maintain the default level of the service reliability. Thus, the level of the railway service reliability is very important for railway undertakings. The available number of the rolling stock is one of the key criteria for the competitiveness of railway undertakings in the open transport market. It can be seen as the service quality criterion and the operational criterion. The rolling stock is the fixed assets of railway undertakings that have the function of the means of work in the transport service manufacturing process. The rolling stock includes traction vehicles, i.e. locomotives, and hauled vehicles, i.e. all types of freight cars. It is of particular importance for a railway undertaking to achieve the optimal capacity, which implies such a use of the rolling stock which will establish the relatively most favorable relationship between the wearing of their useful properties, on the one hand, and their productivity, on the other. The rolling stock should be fast, energy-efficient and environmentally friendly and, above all, secure in order to achieve a higher quality of the service. With the liberalization of the market, there is growing competition between railway undertakings, both in terms of the scope and in terms of the quality of transport services, so it is very important to dispose of modern means of transport.

5) Safety Group Criteria. The fifth group of criteria was considered based on the number of serious accidents, accidents and incidents per driving kilometer. Safety is an important factor in determining the transport user for certain transport sectors, and therefore a significant factor in the size of transport and the volume of income. In addition to the impact on the transport size and the volume of income, traffic safety

affects the efficiency of railway undertakings as a result of railway accidents, damaging and destroying assets of high value, thus causing great material damage and traffic disruptions, which are also a cost for railway undertakings. Serious accidents mean any collision or slipping/derailing of trains resulting in the death of at least one person, or a serious injury to five or a larger number of persons, or a significant damage to the rolling stock (it implies the damage that may immediately be estimated by the railway investigating authority, the total value being at least EUR 2 million), the infrastructure or the living environment, as well as any other similar accident with an obvious impact on rail safety regulation or safety management. An accident means an unwanted or unintentional event or a special chain of events having severe consequences. Accidents are divided into the following categories: crashes, slipping from a rail track (derailing), accidents at a crossing, and accidents to persons caused by the rolling stock, fires and so forth. An incident means any event which is not an accident or a serious accident, which is related to the traffic of trains and which affects the safety of operation. In order to maintain high-level safety, the European Union has laid down the limit of common safety objectives in its documents.

The assessment of the criteria was based on the Fuzzy AHP (FAHP) method. Experts from the railway sector participated in the process of the evaluation of the relative importance of particular criteria for each group. Experts from the Ministry of Transport (E1), the Railway Directorate (E2), the Railway Safety Agency (E3), the Railway Infrastructure Manager (E4) and the Railway Undertaking (E5) were interviewed. They filled out a survey, in which they evaluated the importance of each criterion against the linguistic preference scale for each group. Table 2 shows the conversion of the linguistic variables into triangular fuzzy numbers (Chang, 1996.).

Table 2. The linguistic variables and their corresponding fuzzy numbers

Linguistic variable	Triangular fuzzy scales	Fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Solving the highest-importance criteria selection problem for the purpose of assessing the efficiency of railway undertakings between the aforementioned groups was initiated by the application of the FAHP approach. For the illustrated example of the highest-importance criteria selection, an example of the selection of the criteria for the operational group is presented in this paper. In Table 3, a fuzzy matrix of the benchmarking criteria from the operational criteria group (Commercial speed for freight trains – B1, The quantity of transported goods/freight – B2, Net tonne km – B3, Gross tonne km – B4, Train km – B5), is given.

Table 3. The comparative matrix for the operational group criteria of freight railway undertakings

		B_1	B_2	B_3	B_4	B_5
	E1	(1,1,1)	(2/7,1/3,2/5)	(2/3,1,2)	(2/3,1,2)	(2/5,1/2,2/3)
	E2	(1,1,1)	(2/5,1/2,2/3)	(1/2,1,3/2)	(2/5,1/2,2/3)	(2/3,1,2)
B_1	E3	(1,1,1)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/3,1,2)
	E4	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(2/5,1/2,2/3)	(2/3,1,2)
	E5	(1,1,1)	(2/7,1/3,2/5)	(1/2,1,3/2)	(2/3,1,2)	(1/2,1,3/2)
	E1	(5/2,3,7/2)	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	(3/2,2,5/2)
	E2	(3/2,2,5/2)	(1,1,1)	(1,1,1)	(1,1,1)	(1/2,1,3/2)
B_2	E3	(3/2,2,5/2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)
	E4	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)
	E5	(5/2,3,7/2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)	(3/2,2,5/2)
	E1	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(1,1,1)	(1/2,1,3/2)
	E2	(2/3,1,2)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,2)
B_3	E3	(3/2,2,5/2)	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(1,1,1)
	E4	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(1,1,1)	(1,1,1)
	E5	(2/3,1,2)	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(1/2,1,3/2)
	E1	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(1,1,1)	(1/2,1,3/2)
	E2	(3/2,2,5/2)	(1,1,1)	(1,1,1)	(1,1,1)	(1/2,1,3/2)
B_4	E3	(3/2,2,5/2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)
	E4	3/2,2,5/2)	(2/3,1,2)	(1,1,1)	(1,1,1)	(1/2,1,3/2)
	E5	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)
	E1	(3/2,2,5/2)	(2/5,1/2,2/3)	(2/3,1,2)	(2/3,1,2)	(1,1,1)
	E2	(1/2,1,3/2)	(2/3,1,2)	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)
B_5	E3	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(1,1,1)
	E4	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(1,1,1)
	E5	(2/3,1,2)	(2/5,1/2,2/3)	(2/3,1,2)	(2/3,1,2)	(1,1,1)

The fuzzy weight of the criteria is calculated by taking the geometric average of the expert's response (Lee, 2009). An example of the geometric mean calculation is only provided for B_{12}, while the other values shown in Table 4 are calculated analogously. An example of the calculation of the geometric mean for B_{12} reads as follows:

$n- = (2/7x2/5x2/5x2/3x2/7)^{1/5} = 0.387$

$n- = (1/3x1/2x1/2x1x1/3)^{1/5} = 0.488$

$n+ = (2/5x2/3x2/3x2x2/5)^{1/5} = 0.677$

Table 4. The fuzzy comparative matrix for the operational criteria group

	B1	B2	B3	B4	B5
B1	(1,1,1)	(0.387, 0.488, 0.677)	(0.536, 0.870, 1.431)	(0.491, 0.660, 1.035)	(0.568, 0.871, 1.516)
B2	(1.477, 2.047, 2.252)	(1,1,1)	(0.574, 1, 1.383)	(0.758, 1, 1.176)	(0.776, 1.319, 1.840)
B3	(0.698, 1.149, 1.864)	(0.723, 1, 1.741)	(1,1,1)	(0.850, 1, 1.319)	(0.699, 1, 1.351)
B4	(0.967, 1.516, 2.038)	(0.850, 1, 1.319)	(0.758, 1, 1.176)	(1,1,1)	(0.500, 1, 1.500)
B5	(0.659, 1.149, 1.759)	(0.543, 0.758, 1.289)	(0.740, 1, 1.431)	(0.667, 1, 2)	(1,1,1)

In addition, the standard steps of the FAHP method are used in this paper (Stević, Ž. et al. 2015). The relative ranking of the importance of particular criteria based upon a criteria-pairwise comparison, for all the groups in freight transport is presented in Table 5.

Table 5. The relative ranking of the importance of particular criteria based upon the criteria-pairwise comparison of all the groups in freight transport

Group	**Criteria**	**W'** (fuzzy weight vector)	**W** (normalized weight vector)
Resource criteria (capacity)	The network length	0.101	0.065
	The number of staff per km of the railway network	1	**0.654**
	The number of employees	0.430	0.281
Operational criteria	Commercial speed for freight trains	0.632	0.151
	The quantity of transported goods/freight	**1**	**0.240**
	Net tonne km	0.841	0.202
	Gross tonne km	0.878	0.210
	Train km	0.821	0.197
Financial criteria	The total income	0.916	0.213
	Profit per employee	0.919	0.214
	Electricity costs	0.816	0.190
	Fuel costs	0.639	0.149
	Railway infrastructure charges	1	**0.233**
Service quality criteria	The suitability of the available services	0.738	0.256
	The stability of services	0.512	0.177
	The reliability of services (the overdue delivery time)	0.638	0.221
	The available rolling stock	1	**0.346**
Safety criteria	The number of serious accidents per train km	1	**0.558**
	The number of accidents per train km	0.473	0.264
	The number of incidents per train km	0.318	0.178

The comparative analysis carried out by using the FAHP method showed that, for each group, the priority criteria affected the assessment of the efficiency of the railway undertakings. Based on the results shown in the above Table 5, a conclusion can be drawn that, for the group of the resource criteria, the greatest relative weight is that of the *Number of staff per km of the railway network* (0.654), only to be followed by the *Operational criteria* group, *The quantity of goods transported* (0.240), the *Financial criteria* group, *The cost of charges for the use of the railway infrastructure* (0.233), the *Service quality* criteria, *The available rolling stock* (0.346) and the *Safety criteria* group, the highest relative weight being that of *The number of serious accidents* criterion (0.558), based on the railway experts' survey. The criteria that took precedence over the other criteria in their respective group(s) were used as the inputs and outputs for the evaluation of the efficiency of freight transport railway undertakings by applying the DEA method.

5. The Application of the DEA Method in Order to Assess the Efficiency of Freight Transport Railway Undertakings

Regardless of the system type, there is a need to monitor and quantify the effects of business. One of the basic criteria implies defining the relationship between the resources invested and the goals achieved. In the literature, that ratio is known as efficiency. Common to most approaches in the literature is the fact that the term “efficiency” pertains to the best utilization of resources while providing as many services as possible. In the literature, the problem of measuring the efficiency of railway undertakings has been emphasized as the problem of measuring the efficiency of multiphase (multistage) processes. The most commonly used method for the evaluation of the efficiency of multiphase processes is the Data Envelopment Analysis (DEA) method. There is a full range of models in the literature intended for the evaluation of the efficiency based on the DEA models. The DEA method makes it possible to compare the efficiency of comparable units, in this case a group of undertakings with a greater number of input and output variables. In this paper, a new approach to the assessment of the efficiency of freight transport railway undertakings is proposed. The proposed approach is based on the evaluation of efficiency by using the DEA method. The implementation/application of the proposed approach envisages several stages. First, it is necessary to define the inputs and outputs for the Decision-Making Unit (DMU), which requires an evaluation of efficiency and effectiveness (in this case, these are railway undertakings). Furthermore, the DEA approach is executed through two parallel processes. The first process implies the classifications of DMUs as either effective or ineffective, depending on the CCR grade (a model named after the initial letters of the surnames of the authors, Charnes, Cooper, Rhodes), and the BCC grade (a model named after initial letters of the surnames of the authors, Banker, Charnes, Cooper, 1984). The second process requires an RTS classification. This enables the identification of the DMUs that need rationalization. Finally, the optimal values for the inputs and outputs are derived by using the slack-based CRS (Constant Returns to Scale) model. The proposed DEA approach is shown in Figure 2.

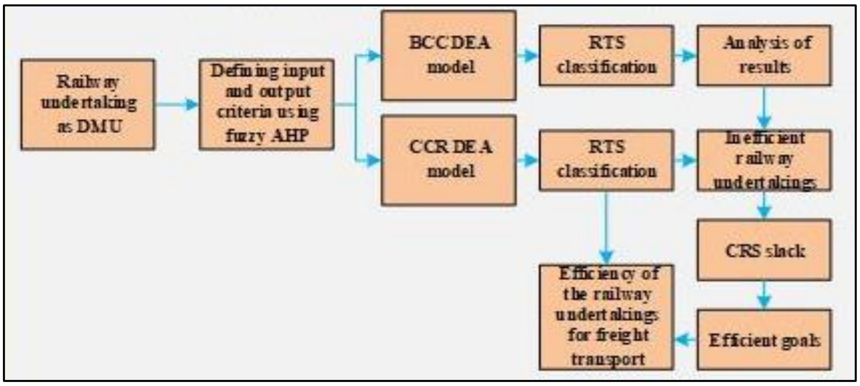

Figure 2. The application of the DEA method for the assessment of the efficiency of freight transport railway undertakings

The proposed DEA approach was tested and verified through a survey conducted on a sample of the national goods transportation railway undertakings in the Western Balkans, Slovenia and Croatia, which is accounted for in Table 6.

Table 6. The freight transport railways undertakings

Country	Railway undertakings	Abbreviation
Albania	Hekurudha Shqiptarë SH	HSH
Bosnia and Herzegovina	Railways of the Republic of Srpska	ŽRS
	Railways of the Federation of Bosnia and Herzegovina	ŽFBH
Montenegro	Montecargo	Montecargo
Croatia	Croatian Railways Cargo d.o.o.	HŽ-Cargo
North Macedonia	Railways of the Republic of North Macedonia Transportation Department J.S.C. Skopje	MŽT
Slovenia	Slovenian Railways-Freight Transport	SŽ-Freight Transport
Serbia	Serbia Cargo	SK

The freight transport railway undertakings as DMUs were designated with four inputs and one output, as previously determined by the Fuzzy AHP and as shown in Figure 3 below. The first input stands for the number of employees per kilometer of the railway network; the second input stands for the cost of the fees paid by the railway undertaking to the payment infrastructure manager; the third input stands for the available number of the vehicles of the rolling stock, and the fourth input stands for the number of serious accidents. The output of the model is the quantity of the goods transported.

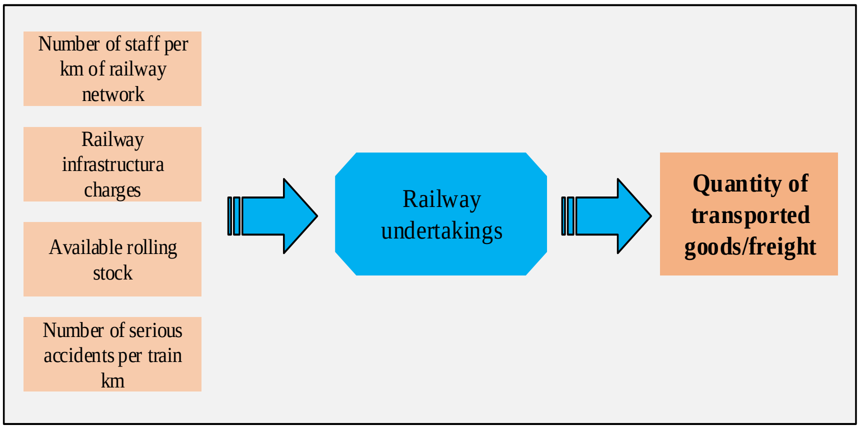

Figure 3. The railway undertaking as the DMU for efficiency assessment

The values for the input and output parameters for all the eight national railway undertakings are shown in Table 7. The data for the railway undertakings were obtained from the UIC statistics and the railway undertakings' annual reports for the year 2018 (https://www.uic.org/).

Table 7. The input and output parameters for the DEA model

Railway undertakings	Number of staff per km of the railway network	Railway infrastructure charges (Euro)	Available number of rolling stock	Number of serious accidents per train km	Quantity of the transported goods/freight (tons)
HSH	2.3	2.2	592	6	930000
ŽRS	4	2.1	2134	6	4568698
ŽFBH	2	2.1	2271	10	9120000
Montecargo	6	3.0	577	5	1000000
HŽ-Cargo	1.1	3.3	5513	7	6870000
MŽT	4	2.0	1353	3	1680000
SŽ Freight Transport	1	2.23	3142	13	20436000
SK	0.7	1.1	6901	6	10160000

The CCR is an original DEA model for the determination of relative efficiency for a DMU group. The one formulation of the CCR model aims to minimize inputs, while maintaining a given output level, i.e. the CCR input-oriented model (Model A1). The second formulation of the CCR model aims to maximize the outputs without increasing the value of any of the observed inputs, i.e. the CCR output-oriented model (Model A1'). The CCR models assume a constant CRS (Constant Returns to Scale), and CCR ratings measure overall efficiency.

Model A1 (primal)	Model A1' (dual)	
$\theta^* = min\ \theta$ With conditions: $\sum_{j\in\{1,2,3,\dots,n\}} \lambda_j\, x_{ij} \le \theta_{xio}, i = 1,2,3,..,m;$ $\sum_{j\in\{1,2,3,\dots,n\}} \lambda_j\, y_{rj} \ge y_{ro}, r = 1,2,3,..,s;$ $\lambda_j \ge 0, j = 1,2,3,\dots,n.$	$\phi^* = max\phi$ With conditions: $\sum_{j\in\{1,2,3,\dots,n\}} \lambda_j\, x_{ij} \le x_{io}, i = 1,2,3,\dots,m;$ $\sum_{j\in\{1,2,3,\dots,n\}} \lambda_j\, y_{rj} \ge \phi y_{ro}, r = 1,2,3,.,s;$ $\lambda_j \ge 0, j = 1,2,3,\dots,n.$	(1)

If in the models A1 and A1' $\sum \lambda_j = 1$ is added, then the BCC input-oriented and the BCC output-oriented models are obtained, respectively. The BCC models assume the variable VRS (Variable Returns to Scale), and the BCC ratings measure pure technical efficiency.

In the paper (Seiford and Thrall, 1990), a connection was established between the solutions obtained by using the A1 and A1' models. $\lambda_j^*,\ j = 1,2,3,\dots,n$ and θ^* are the optimal solutions obtained with the model A1; then, there are the corresponding optimal solutions, $\lambda_j^{**},\ j = 1,2,3,\dots,n$ i ϕ^* obtained with the model A1', whereby $\lambda_j^* = \frac{\lambda_j^{**}}{\phi^*}$ i $\theta^* = \frac{1}{\phi^*}$. In this paper, the CCR and BCC models are used to investigate the sources of the inefficiency of the railway undertakings. In general, the sources of the inefficiency of railway undertakings may be caused by their inefficient operation or the noncompetitive conditions within which they operate. For this purpose, the Scale Efficiency Score $SS = \frac{Q_{CCR}}{Q_{BCC}}$ is used. This approach describes the sources of inefficiency, i.e. whether it is caused by inefficient work practices (BCC efficiency) or the noncompetitive conditions shown by a proportional efficiency assessment (SS) or both.

There are several approaches in the literature dedicated to the DEA that may be used to evaluate the RTS (Return to Scale) classification. The paper (Seiford and Zhu, 1999a) shows that there are at least three equivalent RTS methods. The first CCR RTS method is that introduced by Banker (Banker, 1984). The second BCC RTS method was developed by Banker et al. (1984), “Some models for estimating technical and scale inefficiencies in data envelopment analysis”, Management Science, Vol. 30, No. 1-9, pp. 1078-1092), as an alternative approach to using free variables in the BCC dual model. The third RTS method is based on the Scale Efficiency Index, and the same is proposed in the paper (Fare et al., 1994a). The CCR RTS method is based on the sum of the values of the dual variables λ_j in the CCR model, and the same was used for the RTS classification of the observed railway undertakings.

The methods for the estimation of the RTS classification in the DEA provide important information about possible input and output data perturbations in a DMU analysis. This information may have a positive effect on the result achieved by the DMU. They allow ineffective DMUs to determine guidance in order to improve efficiency.

The problem of the determination of the optimum values for the inputs and outputs of those DMUs that demonstrate inefficiency can be solved by using additive DEA models. These models can simultaneously set effective goals to be pursued. This allows those DMUs that demonstrate inefficiency to achieve the optimum input/output ratio (Ralevic, 2014). The optimum values for each input and output separately can be calculated by determining input and output slots. The results and the analysis of the real-example model test results are presented further in this paper.

6. Analysis of the Research Results

Using the model A1, relative efficiency was developed for the observed group of the 8 freight transport railway undertakings. The CCR and BCC characteristics for each railway undertaking are given in Table 8.

Table 8. The evaluation of the efficiency of the freight transport railway undertakings

Railway undertakings	Efficiency evaluation by the CCR model	Benchmarks	Efficiency evaluation by the BCC model	RTS classification	Scale Score (SS)
HSH	0.242	SŽ- Freight Transport	1	Increasing	0.242
ŽRS	0.480	SŽ- Freight Transport, SK	0.933	Increasing	0.514
ŽFBH	0.617	SŽ- Freight Transport	0.988	Increasing	0.624
Montecargo	0.266	SŽ- Freight Transport	1	Increasing	0.266

HŽ-Cargo	0.597	SŽ- Freight Transport, SK	0.955	Increasing	0.625
MŽT	0.350	SŽ- Freight Transport, SK	1	Increasing	0.350
SŽ- Freight Transport	1		1	Constant	1
SK	1		1	Constant	1
Average	0.569		0.984		0.578

The results presented in the table show that there are two railway undertakings with the CCR ratings equal to 1. This rating measures the overall efficiency when a constant RTS is assumed. These are the railway undertakings of the Slovenian Railways – Freight Transport and Serbia Cargo. These railway undertakings can be seen as realistic and useful benchmarks for the other inefficient railway undertakings. Slovenian Railways – Freight Transport is one of the two undertakings with the best result. In addition, it is the undertaking that is apparently considered to be a benchmark. The railway undertakings rated below the average (0.569) are considered to be inefficient. Each railway undertaking is distinguished by its specific characteristics in rail transport; nonetheless, the railway undertakings should be open to improving performance and there should be one or more railway undertakings as an example for them to follow. The selection of the relevant benchmarks was derived from the calculation of the CCR DEA model by using the values obtained for the dual variables. The results shown in the fourth column of Table 9 show, for each inefficient railway undertaking, another railway undertaking suitable for comparison out of the set of the efficient ones. The BCC rating measures efficiency by assuming the variable RTS. In this empirical study, there are five railway undertakings awarded the BCC effective status, in addition to the two already retaining their previous effective status. For example, it can be concluded that the railway undertakings Hekurudha Shqiptarë SH., Montecargo and the Railways of the Republic of North Macedonia Transportation Department J.S.C. Skopje are efficiently operated, i.e. $(\theta^*_{BCC} = 1)$. In addition, it can be considered that the Railways of the Federation of Bosnia and Herzegovina have a BCC rating above the average, which means that they have good operating efficiency. Based on the results of the proportional efficiency evaluations, these are the railway undertakings with a good ratio of the achieved work result and the engaged resources (work in competitive conditions): SŽ-Tovorni promet, Srbija Cargo, Railways of the Federation of B&H and HŽ Cargo. Their relative efficiency scores are higher than the average value (0.578).

7. Conclusion

Measuring and improving the efficiency of the operations of railway undertaking are a precondition for their successful business and survival on the market. Measuring the efficiency of a company is one of the key managerial activities in modern companies that provides us with an insight into the current status of the company, the goals to be achieved in the future, as well as its current position on its way towards the achievement the set goals. Such a system is undoubtedly of strategic importance for every company that wants to survive and develop in today's conditions. Therefore, such a system must adequately be integrated into the strategic management system. Efficiency has a positive impact on a number of other important criteria pertaining to the work of railway undertakings, such as a better use of resources, a more rational use of energy, increased safety, an increased quality of service and so on. In order to evaluate the proper performance of operations in goods rail transport, i.e. the efficiency of railway operations, it was necessary to define and determine appropriate criteria. In this paper, group criteria are defined and evaluated, and priority criteria are selected for the purpose of evaluating the efficiency of freight transport railway undertakings based upon multi-criteria decision making and the fuzzy AHP method.

From each group, the used FAHP method revealed the priority criteria for the assessment of the efficiency of railway undertakings. The criteria that achieved an advantage within the composite normalized range over the other criteria from their respective group for the freight railway undertakings are as follows:

- from the resource criteria group, the number of employees per kilometer of the railway network has the highest relative weight;
- from the operational criteria group, it is the quantity of the transported goods;
- from the financial criteria group, it is the costs of the fees for the use of the railway infrastructure,
- from the service quality group, it is the available number of vehicles, and
- from the safety criteria group, it is the number of serious accidents that has the highest relative weight.

The DEA method was chosen so as to evaluate the efficiency of the railway undertakings, because it enables an analysis of mutually comparable units despite heterogeneous data, expressed by different units of measurement and affecting business efficiency in different ways.

An approach to the assessment of the efficiency of freight transport railway undertakings by using the DEA method is proposed, which enables the aggregation of all the groups of criteria into a single efficiency assessment, thus also providing information on the corrective actions that can improve the efficiency of railway undertakings. The paper evaluates the efficiency of the freight transport railway undertakings performed on the basis of the selected priority criteria and by using DEA excel solvers, using the CCR output-oriented model (the model assumes constant return in relation to the investment volume) and the BCC output-oriented model (the model assumes a variable return relative to the volume of investment/input). The output criterion on the basis of which the efficiency of railway undertakings was evaluated was the quantity of the transported goods. The output used in the analysis is a realistic one. The proposed approach based on the DEA method was tested and verified through a survey conducted on a sample of eight freight transport railway undertakings.

The model testing results show that there are two railway undertakings with the CCR ratings equal to 1, which is to say that this rating measures the overall efficiency when a constant RTS is assumed. These are the railway undertakings Slovenian Railways – Freight Transport and Serbia Cargo. These railway undertakings can be seen as realistic and useful benchmarks for the other inefficient railway undertakings.

Thus, the railway undertakings demonstrating good efficiency appear as benchmarks for those inefficient railway undertakings. The Slovenian Railways - Freight Transport has the best result. Also, it is the railway undertaking that appears most as a benchmark. The selection of relevant benchmarks was derived from the calculation of the CCR DEA model by using the values obtained for the dual variables.

Based upon the results of the BCC evaluation that measures efficiency under the assumption of the variable RTS in this research, it can be concluded that five railway undertakings out of the observed eight are efficiently operated.

These are the railway undertakings Slovenian Railways – Freight, Serbia Cargo, Hekurudha Shqiptarë SH., Montecargo and the Railways of the Republic of North Macedonia Transportation Department J.S.C. Skopje. The results show, for each inefficient railway undertaking, which railway undertaking is suitable for comparison with it from the set of the efficient ones. Each railway undertaking is characterized by its specific characteristics in rail transport; nonetheless, a railway undertaking should be open to improving performance and there should be one or more railway undertakings as an example for it to follow in order to improve its efficiency.

This paper opens a possibility of channeling the research into a narrower scientific field, which could be the identification of the new criteria that may affect the redefinition of the models and the development of the new models that would combine the proposed approach with other approaches, such as fuzzy logic, simulation, optimization models and others. In that manner, certain limitations would be overcome and the railway undertaking efficiency evaluation process would be improved.

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