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USING MULTIPLE CRITERIA DECISION-MAKING TECHNIQUE TO EVALUATE SERBIAN RAILWAY SYSTEM OPERATION PERFORMANCE

Nikola PETROVIĆ[1]
Vesna JOVANOVIĆ[2]
Tanja ŽIVOJINOVIĆ[3]
Jovan PAVLOVIĆ[4]

Abstract *– Freight and passenger railway system operation performance evaluation results are important for government, operators and passengers. In this paper will be used one of the best known Multiple Criteria Decision-Making (MCDM) technique to evaluate the freight and passenger rail system's operation performance. Firstly, the authors will establish the evaluation indicator system based on official data with 5 indicators and a total of 18 sub-indicators to the freight transport as well as passenger transport. These operational data will be used as the input of the approach. Second, formulated approach to obtain the performance evaluation: the Entropy Weight Method (EWM) will be used to calculate the weight of each sub-indicator; and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method will be used to calculate the comprehensive evaluation values and rankings of performance for each year. Third, the Serbian railway with 6 years initial data will be chosen as the case study to test approach, the related suggestions to the freight transport as well as passenger transport will also be given.*

Keywords – Railway, Entropy-TOPSIS method, Operation performance evaluation

1. INTRODUCTION

In the 21st century, there is an awareness of the need for balanced transport development in the EU as well as the encouragement of environmentally friendly transport modes such as rail and inland waterway transport. The development of the railway was one of the best indicators of the country's economic development. About 80% of the railway network was located in the territories of the most developed countries in the world in the first half of the 20th century. However, although rail transport is the most environmentally friendly and energy efficient mode of transport, the volume of freight transport by rail is declining.

Observing all modes of transport in 2018, relative to 2017, it can be noted that increased activity was recorded in all transport modes, except in railway. As regarding passenger transport, the increase was recorded if related with 2013 in all transport modes except railway. Referring to freight transport, the increase was recorded when compared with 2013 in all transport modes, excluding inland waterway transport [1].

The main advantage of the railway is the ability to transport large quantities of goods and people over long distances. From the moment of loading of goods or boarding of passengers, the railway enables the transport of large capacities at high speeds. That is why this transport mode is efficient in areas of high population density or for large amounts of cargo, primarily agricultural products and industrial raw materials.

The railway is a complex system specialized in providing transport services. The railway system has the structure, organization, employees, equipment (infrastructure) and work technology. Railways apply a modern organizational theory based on a multidisciplinary approach (systemic approach to organization, multidimensional level model, dynamic character of the process, stochastic model of discrete events, system adaptability). Many tasks are routine because they are based on experience (processes are already programmed, planned and have procedures) and are realized hierarchically and finally decision-making is centralized. Management (of company) monitors the entire system and makes adjustments that

[1] Faculty of Mechanical Engineering, Niš, Serbia, petrovic.nikola@masfak.ni.ac.rs
[2] Faculty of Mechanical Engineering, Niš, Serbia, vesna.jovanovic@masfak.ni.ac.rs
[3] Faculty of Transport and Traffic Engeneering, Belgrade, Serbia, t.zivojinovic@sf.bg.ac.rs
[4] Faculty of Mechanical Engineering, Niš, Serbia, jovan.pavlovic@masfak.ni.ac.rs

require monitoring of operation efficiency based on available data.

The simplest approach to conceptualise and measure railway operation efficiency is by deriving key performance indicators (KPIs) from published data [2]. This can be sufficient to develop a simple but balanced scorecard. To monitor performance, both cross-sectional indicators (that compare systems) and time series indicators (that measure change over time) are needed. Capturing the full complexity of factors determining railway efficiency would require a very large dataset. This is not easily available and would be subject to inherent limitations regarding data quality. It is all very well and good to define and measure efficiency (however approximately) but the effort expended in defining, collecting and reporting data will have no payoff if there is nothing that can be done to change railway performance. One way to change efficiency, much favoured by traditional, engineering-dominated railway managements, is increased investment (increasing capital intensity) [2].

From a government perspective, evaluation of the railways operation performance is important because of the existence a basis for government subvention, and differences in performance between different evaluation periods are a strong justification for government financial subvention. Also, the results provide important references to the government on how to optimize and improve railway structures.

From an operator's perspective, evaluation of the railways operation performance can be seen as an efficiency assessment that focuses on whether operators are achieving pre-set goals and what jobs they have done to achieve the goals.

From the passenger perspective, evaluation of the railways operation performance can be considered as accessibility to meet the needs of travel, time saving and environmental friendliness, so that their efficiency can be measured by service use, service quality and service satisfaction.

Based on valid statistical data for the railway system of the Republic of Serbia, both for passenger and freight transport in the time frame from 2013 to 2018, the paper evaluates operation performance using Entropy method for determining weight coefficients and TOPSIS method for ranking the observed years.

In this paper, after a given introductory section which discusses about importance and performance analysis of the railways to the economy of a country and the users of its services, the second chapter is devoted to a review of the literature on the application of methodologies and approaches for evaluating the performance of rail transport. In the third chapter, sets of input data for passenger and freight rail transport are established. The fourth chapter gives a brief overview of the methods used to calculate the weighting coefficients and to rank the operation performance of rail transport in the Republic of Serbia for a certain time interval and to present the obtained results. At the end of the paper, the main conclusions and an overview of future research tasks will be presented.

2. LITERATURE REVIEW

When reviewing the literature about railway performance analysis, it is seen that in a limited number there are studies that use different decision-making methods with multiple criteria to obtain an assessment of railway transport efficiency. There are several approaches to measuring and evaluating railway performance. On the one hand, parametric approaches are very rarely used because they need certain assumptions to establish the desired function, while on the other hand researchers prefer to use nonparametric approaches that involve fewer assumptions [3].

Based on searches in the Scopus and Science Direct databases, various MCDM techniques are used to measure and evaluate performance in railway traffic such as AHP (Analytical Hierarchy Process), ANP (Analytical Network Process), TOPSIS, DEMATEL (Decision making trial and evaluation laboratory), VIKOR (VIše Kriterijumska Optimizacija Kompromisno Rešenje), etc. Also, the use of the DEA (Data Envelopment Analysis) method can be found in different areas of the railway [4]. This method was used alone or in combination with MCDM methods.

Yu (2008) used the DEA method to conduct an efficiency and effectiveness study for a group of 40 large railway systems (passenger and freight) in 2002 [5]. In [6] the authors used the DEA method to evaluate the efficiency of European railway companies, taking into account different input and output configurations. Although companies from Western Europe showed higher performance than companies from Central and Eastern Europe in terms of passenger and overall transport, this was not the case with freight transport.

The operation performance evaluation of the urban railway system in the Chinese city – Chengdu during 34 months using the Entropy – TOPSIS methods was performed in [7].

3. INPUT DATA

Indicators are frequently defined as quantitative measures that can be used "to illustrate and communicate complex phenomena simply, including trends and progress over time" [8]. Indicators can perform different functions. Collected information can be made suitable for analysis by those involved in decision-making and thus contribute to making better decisions.

In the conducted analysis were used available data collected by regular monthly, quarterly and annual statistical reports of transport enterprises („Serbia Train“ a.d., „Serbia Cargo“ a.d., “Combined transport“ d.o.o., Despotija. d.o.o. and „Infrastructure of Serbian railways“ a.d.) and were taken from [9]. Table 1 shows the 5 indicators and 18 sub-indicators used to assess the performance of passenger and freight railway transport. The basic indicators that used are Basic indicators of railway transport, Employees in railway transport, Generating power of railway transport, Consumption of fuel and electricity in transport and Railway asset.

4. THE APPROACH, CASE STUDY AND RESULTS DISCUSSIONS: THE SERBIAN RAILWAY

In order to make a good decision, it is necessary to specify alternatives by defining appropriate criteria. It is also necessary to define the weighting coefficients for each criterion ie the importance of each criterion in relation to the others. The weight coefficients are numbers that can be obtained by any of the following methods (Eigenvector method, Least squares weight method, Entropy method, etc.).

Tab.1. Indicators and sub-indicators of railway transport

Indicator	Sub-indicator	Specification of each sub-indicator	Unit of each sub-indicator
Basic indicators of rail transport	f_1	Passenger transport (locomotive km)	train km, thous.
	f_2	Freight transport (locomotive km)	train km, thous.
	f_3	Passenger transport	gross-ton km, mill.
	f_4	Passenger transport	gross-ton km, mill.
	f_5	Number of transported passengers	thous.
	f_6	Realized pkm	passenger-kilometers, thous.
	f_7	Quantity of goods transported	thous. t
	f_8	Realized tkm	ton-km, thous.
Employees in rail transport	f_9	-	number
Generating power of rail transport	f_{10}	Internal-combustion engines	kW, thous.
	f_{11}	Electric engines	kW, thous.
Consumption of fuel and electri-city in rail trans.	f_{12}	Liquid fuels	thous. t
	f_{13}	Electricity	thous. MWh
Railway asset	f_{14}	Effective length of tracks	km
	f_{15}	Passenger wagon stock and motor trains	number
	f_{16}		seats thous.
	f_{17}	Freight wagon stock	number
	f_{18}		tons of carrying capacity, thous.

Determining the objective weights of criteria according to the Entropy method is based on measuring the uncertainty of information contained in the decision matrix and directly generates a set of weight values of criteria based on the contrast of individual criteria values of alternatives for each criterion and then simultaneously for all criteria [10].

In 1981, Hwang and Yoon developed the TOPSIS method. The basic concept of the TOPSIS method is that the chosen alternative should have the smallest distance from the ideal solution and the largest distance from the negative ideal solution, in the geometric sense. During normalization, the transformation of minimization into maximization criteria is not performed. For each alternative, the distance from the ideal and negative ideal solution is calculated in relation to each criterion, taking into account the criteria that are minimized and maximized. The weight/significance of each alternative is finally determined based on the relative closeness of the alternatives to the ideal solution [11].

Based on the adopted indicators, for both passenger (Tab. 2) and freight transport (Tab. 3), evaluation operation performance of the Serbian railway was done by Entropy method for determining weight coefficients and the TOPSIS method for ranking the observed years.

The calculation results of weighting coefficients show in both passenger and freight rail transport: Employees in rail transport (0.1883) and the Generating power of rail transport - Internal-combustion engines (0.2010) are the two most important indicator (sub-indicator) in the evaluation system. Railway asset – Effective length of tracks has the smallest weighting coefficient for both passenger (0.0002) and freight (0.0003) rail transport and shows that this indicator has minor importance in the operation performance evaluation process. By ranking with TOPSIS method on the basic of adopted indicators for passenger transport of the Serbian railways in the time frame from 2013 to 2018, it can be seen that the best operation performances were in 2016, while in 2018 they recorded the worst case scenario (Tab. 2). When it comes to the obtained results for freight transport of the Serbian railways by ranking the appropriate indicators, it can be concluded that the operation performance since the beginning of the observed period in 2013 has improved and the best performance is expressed in 2018 (Tab. 3).

5. CONCLUSION

Increasingly modern rail transport provides a more convenient and cheaper way of daily transport of passengers and goods, so that the support of the state is necessary. It is important to set operational goals in advance and optimize the allocation of resources. In this paper, the evaluation of the railway operation efficiency in the Republic of Serbia is performing based on data collected by regular statistical reports of traffic business entities, with those help are form of which two sets of indicators for: passenger and freight

Tab.2. Passenger railway transport – indicators, weighting coefficients and ranking

	f_1	f_3	f_5	f_6	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	Rank
w_i	0.1293	0.0194	0.0378	0.1177	0.1883	0.2010	0.0451	0.0158	0.0373	0.0002	0.0746	0.1335	
2013	11531	1745	7158	612	18047	190	626	9	148	3819	786	48	**3**
2014	11170	1666	6443	452	17078	180	626	9	139	3819	748	45	**5**
2015	16256	1624	6258	509	16622	153	605	10	136	3766	833	56	**2**
2016	10930	1957	6092	438	13641	191	687	10	120	3766	883	59	**1**
2017	16644	1529	5638	377	10229	129	585	10	116	3764	691	48	**4**
2018	10417	1727	5062	347	10207	89	462	11	110	3752	542	30	**6**

Tab.3. Freight railway transport – indicators, weighting coefficients and ranking

	f_2	f_4	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{17}	f_{18}	Rank
w_i	0.0279	0.0160	0.0216	0.0071	0.3169	0.3383	0.0759	0.0267	0.0628	0.0003	0.0641	0.0424	
2013	5947	5520	10463	3022	18047	190	626	9	148	3819	8452	431	**6**
2014	5878	5464	10826	2988	17078	180	626	9	139	3819	8486	432	**5**
2015	5919	5731	11887	3249	16622	153	605	10	136	3766	8486	432	**3**
2016	5103	4870	11896	3087	13641	191	687	10	120	3766	7277	411	**4**
2017	4997	5081	12352	3288	10229	129	585	10	116	3764	6781	342	**2**
2018	5424	5390	12297	3187	10207	89	462	11	110	3752	6589	371	**1**

transport. The total number of used indicators is 5 and 18 sub-indicators, ie individually for passenger and freight 5 indicators and 12 sub-indicators, based on which the input matrices were formed in the observed period from 2013 to 2018. The importance of each indicator calculated by the Entropy method, while the TOPSIS method was used to evaluate operation performance, ie to rank the results on an annual basis.

In both passenger and freight rail transport, the weighting coefficients show that the Employees in rail transport (f_9) and the Generating power of rail transport - Internal-combustion engines (f_{10}) are the most important while the Effective length of tracks (f_{14}) is the least important indicator (sub-indicator).

Using the TOPSIS method the adopted indicators, for the passenger rail transport system of the Republic of Serbia, were ranked in the time frame from 2013 to 2018, based on which it can be seen that the best operation performances were in 2016, while in 2018 they recorded the worst scenario. When it comes to freight rail transport, it can be stated that the operation performance since the beginning of the observed period in 2013 has improved and the best operational performance is expressed in 2018.

The framework of future research would be reflected in the use of this approach to assess the performance of other systems using compatible evaluation indicators.

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