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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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STUDY OF THE POSSIBILITIES FOR DEVELOPING PASSENGER TERMINAL BY APPLYING A MODEL FOR EVALUATION OF THE RAILWAY INFRASTRUCTURE PARAMETERS

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Technical university of Sofia, Bulgaria

Abstract

The present paper aims to explore and analyse possibilities for establishing a passenger terminal for integrated transport of passengers. In the course of the study, a specific model has been used to identify the potential of the railway infrastructure to establish a passenger terminal for passengers, while allowing for comparability and for choice of an option. The obtained results will allow interested parties to assess the possibilities for improving rail passenger services and for interaction of rail transport with other modes of transport.

Keywords: integrated transport, rail transport, passenger terminal, railway infrastructure

1 Introduction

Railway infrastructure is essential for the economic development of countries and regions. In this context intermodal [1] freight and passenger terminals are being developed and built. The railway infrastructure in Bulgaria includes the following elements: Railway lines and facilities, carrying capacity, railroad switches, railway tunnels, railway bridges and crossings; power facilities; security equipment and telecommunications; buildings. The total length of the railway network is 6,474 km, which, when related to the area of Bulgaria, makes an average density of the railway network of 58.9 km / 1,000 km^2. The total length of the electrified railway lines is 4,712 km (around 73 %), including the single and double lines and station tracks. The railway network in Bulgaria has 299 railway stations, 16 separate posts, and 379 stops.
This study, using popular methods for decision making through multi-criteria analysis, evaluates the potential of the railway infrastructure for developing a passenger terminal. Passenger terminals stand for railway stations where passenger flows using different modes of transport cross, merge and separate. According to [2] intermodal passenger terminals can have different forms depending on the characteristics of the location area, the types of modes they serve and the characteristics of the passengers using them. On the basis of these factors, a terminal can belong to one of the following five categories: Intercity terminals, commuter transit centers, interchanges, park and ride terminals and on street facilities.

2 Model for evaluation of the parameters of railway infrastructure

The first phase of model involves a multi-criteria analysis. The Analytic hierarchy process (AHP), developed by Saaty, [3] is one of multiple criteria decision making methods. The AHP method is based on the following principles: structure of the model; development of the ratings for each decision alternative for each criterion; synthesis of the priorities. The first step is to make pairwise comparisons between each criterion using Saaty's scale, table 1.

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Table 1 Comparison scale

Intensity of importance	Definition
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Values for intermediate comparison

The result of the pairwise comparison of n criteria can be summarized in an (n x n) evaluation matrix A in which every element a_{ij} (i, j = 1,…,n) is the quotient of the weights of the criteria [4]. The elements are assigned from Table 1. The matrix elements have the following correlations:

$$a_{ii} = 1; \quad a_{ij} \neq 0; \quad a_{ji} = \frac{1}{a_{ij}} \tag{1}$$

The second step in the AHP procedure is to normalize the matrix. The relative weights are given by the normalized right eigenvector ($W = \{w_1,…,w_n\}^T$) associated with the largest eigenvalue (λ_{max}) of the square matrix A thus providing the weighting values for all decision elements [4]. The largest eigenvalue (λ_{max}) can be calculated by using the following equation:

$$AW = \lambda_{max} \cdot W \tag{2}$$

$$\lambda_{max} = \sum_{i=1}^{n} \left[\left(\sum_{j=1}^{n} a_{ij} \right) \cdot W_i \right] \tag{3}$$

The third step calculates the consistency ratio and checks its value. The consistency ratio is found with the following formula:

$$CR = \frac{CI}{RI} \leq 0{,}1 \tag{4}$$

Where: CI is the consistency index; RI is a random index. The consistency index is:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

Where: λ_{max} is the maximum eigenvalue of the priority matrix, n is the number of elements in the matrix.

Generally, if the CR is less than 0.10, the consistency of the decision-maker is considered satisfactory. But if CR exceeds 0.10, some revisions of judgements may be required. In order to control the results of the methods, the consistency ratio (CR) is used to estimate directly the consistency of pairwise comparisons [4].
In the second phase the “SPS 11 – Stationspreissystem” model for categorization of railway stations of the German railway network is employed [5], [6]. The criteria are divided into levels, classified according to the railway station characteristics in view of the defined thresholds. A certain number of levels are defined for each of the criteria. Using these levels, the so-called ‘multiplier factors’ (MPF) are defined mathematically. In the categorization the maximum va-

lue a station can reach is 100 points. The more points the station has, the higher its importance concerning passenger services. The basic categorisation numbers are shown below:
- Category 1 (100.00 to 90.01 points);
- Category 2 (90.00 to 80.01 points);
- Category 3 (80.00 to 60.01 points);
- Category 4 (60.00 to 50.01 points);
- Category 5 (50.00 to 40.01 points);
- Category 6 (40.00 to 25.01 points);
- Category 7 ‹ 25.01;

The objective of this research is to categorize railway stations as passenger terminals according to the parameters of the railway infrastructure:
- To apply the AHP method for the weights of the criteria;
- To apply a model for categorization of railway stations as passenger terminals.

This research is focused on the railway stations in Sofia – Plovdiv, Plovdiv – Burgas and Plovdiv – Svilengrad sections of the railway network in Bulgaria. These directions are part of the Pan-European transport corridors. Figure 1 and 2 show a map of the Pan-European transport corridors, passing through Bulgaria and a map of the railway network in Bulgaria. Figure 3 shows the structure of a model for evaluation of the parameters of the railway infrastructure.

Figure 1 Map of the Pan-European transport corridors, passing through Bulgaria

Figure 2 Map of the railway network in Bulgaria

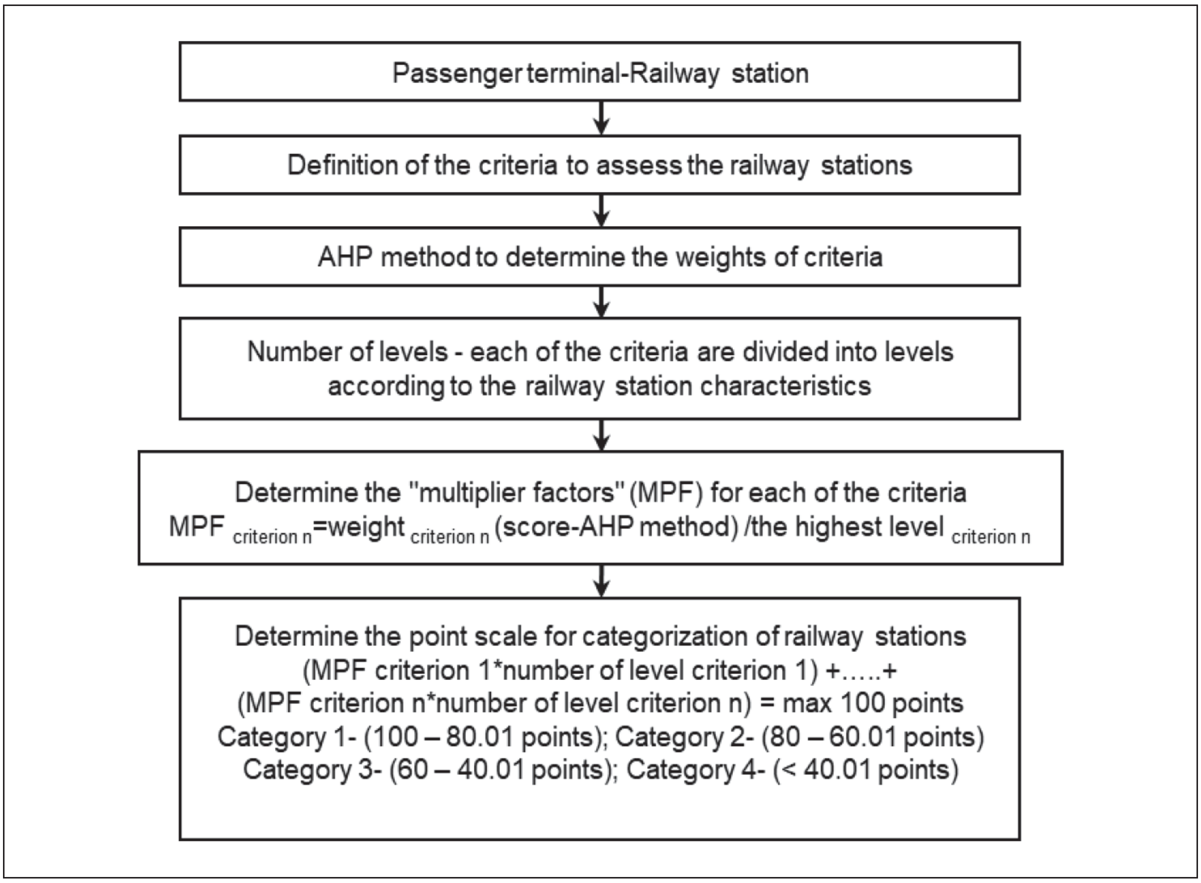

Figure 3 Structure of the model for evaluation of the parameters of the railway infrastructure

3 Definition of the criteria

The railway infrastructure is evaluated according to two main criteria: raillway stations and railway track. The first main criterion assesses the integration of the railway station with other modes of transport and the quality of passenger services. The second main criterion assesses the condition of the railway lines- fast and safe transportation of passengers. In this research the following criteria and sub- criteria are used:

RS1 – Railway stations are divided into eight sub-criteria;
S11 – Possibility of direct international transfer with other modes of transport;
S12 – Number of passengers per day;
S13 – Connection of the station with other modes of transport – urban transport, air transport, maritime transport, taxi, coach;
S14 – Distance of the station from the settlement;
S15 – Direct connection with other modes of transport to a tourist or resort center at a distance of up to 30 km;
S16 – Information – information enables travellers to orientate themselves as well as to discover and get to know an unfamiliar place with ease.
S17 – Accessibility – adequate accessibility to the railway stations for all users (especially the disabled);
S18 – Comfort;
RT2 – Railway tracks are divided into three sub-criteria;
T21 – Electrified railway lines;
T22 – Design speed km/h;
T23 – Level of safety and security system – ERTMS/ (European Rail Traffic Management System);

4 A study of Bulgarian railway stations

This research is focused on the railway stations in the Sofia – Plovdiv, Plovdiv – Burgas and Plovdiv – Svilengrad sections of the railway network in Bulgaria, which are part of the Pan-European transport corridors. Super-Decision is used to calculate the weights of the criteria and the consistency index (CR) of the judgments and Graphical Sensitivity Analysis. The Super-Decision software was developed in 2003 by William J. Adams from Embry Riddle Aeronautic University, Daytona Beach from Florida and Rosanne W. Saaty from Creative Decisions Foundation from Pittsburgh, [7, 8]. A group of experts participated in our research and gave an overall score on the scale of Saaty. Figure 4 presents AHP Model created in Super – Decision Software. Table 2 shows the prioritization matrix and the weights of criteria. Tables 3 and 4 present the results of weights of the sub-criteria received with AHP method. The sub-criterion connection of the station with other modes of transport has the greatest weight. Second in weight are the information and level of safety and security system sub-criteria. The lowest weights are of the electrified railway lines and distance of the station from the settlement sub-criteria. Table 3 presents the results of the weights of the main criteria received with the AHP method.

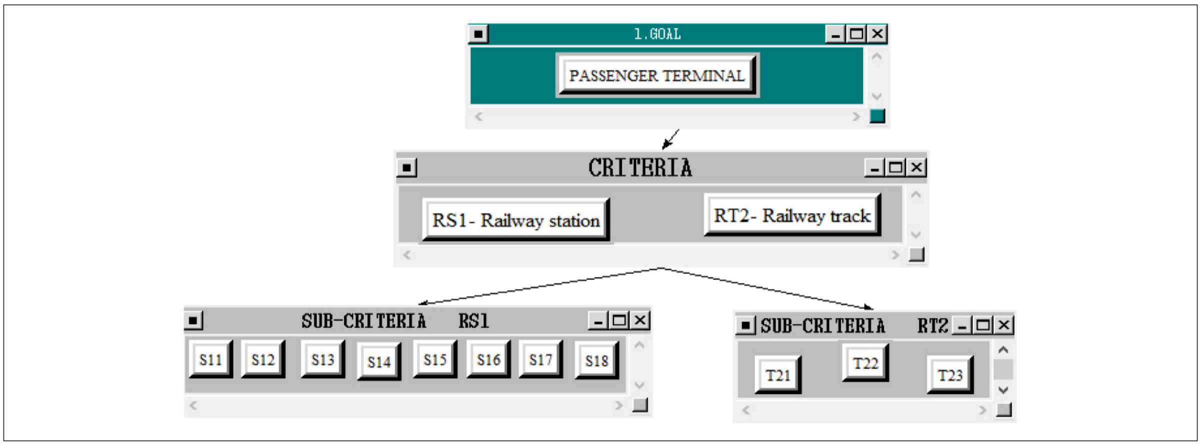

Figure 4 AHP Model created in Super – Decision Software

Table 2 Prioritization matrix and the weights of the main criteria

CRITERION	RS1-Railway station	RT2- Railway track	Weight	CR
RS1-Railway station	1	3	0.75	0
RT2- Railway track	1/3	1	0.25	

Table 3 Prioritization matrix and results of the weights of the sub-criteria

	S11	S12	S13	S14	S15	S16	S17	S18	Weight	Weight RS1	Final score,%
S11	1	3	1/2	2	1	1/2	1/2	1/2	0.11	0.75	8
S12	1/3	1	1/3	1	1/2	1/2	1	1	0.08		6
S13	2	3	1	2	2	2	2	2	0.22		16.5
S14	1/2	1	1/2	1	1	1/2	1/2	1/2	0.07		5
S15	1	2	1/2	1	1	1/2	1/2	1/2	0.09		7
S16	2	2	1/2	2	2	1	1	2	0.16		12
S17	2	1	1/2	2	2	1	1	1	0.14		10.5
S18	2	1	1/2	2	2	1/2	1	1	0.13		10
CR										**0.04**	

Table 4 Prioritization matrix and results of the weights of the sub-criteria

	T21	T22	T23	Weight	Weight RT2	Final score,%
T21	1	1/2	1/3	0.17		4
T22	2	1	1	0.39	0.25	10
T23	2	1	1	0.44		11
CR				**0.02**		

The sub-criteria are divided into levels, classified according to the railway station characteristics according to defined thresholds:

S11 – Level 0 – no direct connection; Level 1- direct connection;
S12 – Level 1- up to 99 passengers per day; Level 2 – 100 to 299 passengers per day; Level 3 – 300 to 999 passengers per day; Level 4 – from 1000 passengers per day;
S13 – Level 1 – one mode of transport; Level 2 – two modes of transport; Level 3 – more than two modes of transport;
S14 – Level 1 – outside the settlement; Level 2 – in the settlement;
S15 – Level 0 – no direct connection; Level 1 – direct connection;
S16 – Level 0 – no information; Level 1 – information boards or ticket offices or loudspeakers; Level 2 – information boards and ticket offices, information boards and loudspeakers, loudspeakers and ticket offices; Level 3 – information boards and ticket offices and loudspeakers;
S17 – Level 0 – not available; Level 1 – escalators; Level 2 – elevators; Level 3 – escalators and escalators;
S18 – Level 1 – only a waiting room; Level 2 – a waiting room and a café; Level 3 – a waiting room, a café and shops; Level 4 – more than two waiting rooms, a café and shops;
T21 – Level 0 – no; Level 1 – yes;
T22 – Level 1 – up to 60 km/h; Level 2 – up to 100 km/h; Level 3 – up to 130 km/h; Level 4 – up to 160 km/h;
T23 – Level 0 – not available; Level 1 – available

Table 5 presents the results of the 'multiplier factors' (MPF) for each of the sub- criteria.

Table 5 The results of the 'multiplier factors' (MPF) for each of the sub- criteria

MPF S11	MPF S12	MPF S13	MPF S14	MPF S15	MPF S16	MPF S17	MPF S18	MPF T21	MPF T22	MPF T23
8	1.5	5.5	2.5	7	4	3.5	2.5	4	2.5	11

The results indicate that the railway stations can be classified into four categories of passenger terminals:

- Category 1 (100 – 80.01 points) includes the railway stations of Sofia and Plovdiv. These railway stations are classified as passenger terminal of national and international importance, with more than three modes of transport and over 1500 passengers per day.
- Category 2 (80 – 60.01 points) includes five railway stations – Burgas, Stara Zagora, Svilengrad, Dimitrovgrad and Pazarjik. These railway stations are classified as passenger terminals of national importance or border checkpoints, with two modes of transport and with 1000 passengers per day.
- Category 3 (60 – 40.01 points) includes 20 railway stations. These railway stations are classified as passenger terminals of regional and local importance, with one or two modes of transport and up to 400 passengers per day.

• Category 4 (‹ 40.01 points) includes five railway stations. These railway stations are classified as passenger terminals with one mode of transport and low passenger traffic (up to 50 passengers per day).

5 Conclusions

The proposed methodology for categorization of railway stations as passenger terminals could forecast the priority development of the elements of the railway infrastructure. The study has the following results:

- Criteria for categorization of passenger stations and 11 sub-criteria have been defined in the research.
- The AHP method has been applied for the weights of criteria and for determining the 'multiplier factors' (MPF) for each of the sub-criteria.
- Railway stations have been classified into four categories of passenger terminals.

The model can be applied to the study of all stations and stops on the railway network.

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