Chapter

An Integrated Approach of Strategic Planning and Multi-Criteria Analysis to Evaluate Transport Strategies in Railway Network

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Abstract

This chapter presents a methodology for selecting transport strategy for railway passenger transport development. The strategic planning, as Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) analysis and Strengths - Weaknesses – Opportunities - Threats (SWOT) analysis integrated with Multiple-criteria decision-making (MCDM) have been applied as a tool to make decision. The proposed methodology consists five stages. The first stage formulates the alternatives of the policies for railway manager. The criteria in each PESTLE group have been defined in the second step. The total number of 24 criteria has been studied. In third stage, the SIMUS method based on linear programming has been applied to rank the alternatives and assess the criteria in PESTLE groups. The fourth stage represents the ranking by application the different multi0criteria approaches as distance based, utility based and outranking methods to make decision. The combination the PESTLE analysis with SWOT analysis for strategic planning is done in the fifth stage. The integration of the PESTLE with technical, economic, technological and environmental (TETE) analysis in presented. The application of methodology has been demonstrated with an example for Bulgarian railway network. Three strategies of railway transport development have been evaluated and compared. It was found that the most important are the political (0.29), social (0.25) and technological (0.25) groups in PESTLE analysis.

Keywords: PESTLE, SWOT, MCDM, multi-criteria analysis, SIMUS, TOPSIS, EDAS, MOORA, COPRAS, PROMETHEE, railway transport planning

1. Introduction

The development of railway transport is related to strategic planning and selection of one or another strategy for the development of the railway infrastructure, railway services and rolling stock. The railway managers need to choose the most appropriate development strategy between set of alternatives. This is a complex process in which it is necessary to take into account a set of factors that have to accounted both the expectations of users of railway services and the capabilities of railway operators and the possibilities of investment in railway transport. The strategic planning methods are a powerful tool for analyzing groups of criteria. Such approaches are Strengths – Weakness – Opportunities – Threats (SWOT), Political, Economic, Social and Technological, Legal and Environmental (PESTLE), PESTEL, and others. The SWOT method is a useful procedure to determine the internal and external influences on the investigated system. The PESTLE or PESTEL analysis is more waste and helpful and as compare to the SWOT analysis. It provides the environmental factors to tackle the problems. An integration between these techniques also it is possible. The strategic planning approaches help managers formulate and analyze criteria in each of the groups. Appropriate techniques for assessing the criteria and their influences, as well as for selecting a suitable alternative for development, are the methods of Multi Criteria Decision Making (MCDM). The different multi-criteria decision-making methods have been applied to study various transport problems. In general, the multi-criteria methods can be summarized as follows: Pair-wise comparisons; Distance based; Utility based; Outranking; Linear programming based. Some of multi-criteria methods can be used only to determine the weights of criteria; others serve ranking the alternatives, by setting the weights of the criteria; third solved weights of criteria by applying expert's assessment and scale of evaluating, and also ranking the alternatives. The Sequential Interactive Modeling for Urban Systems (SIMUS) method is a different multi-criteria approach applied linear programming and does not used the weights of criteria for ranking the alternatives. The use of one or another method depends on the decision maker according the problem to be solved.

The aim of this research is to increase the level of decision making by integrating the advantages of strategic planning as PESTLE and SWOT analysis with the advantages of the multi-criteria methods to assess the influence of criteria and evaluate the alternatives of strategic planning. The proposed techniques could help transport managers in their analysis and decisions when chose a suitable strategy in railway transport development. In this study different multi-criteria analysis techniques have been experimented and discussed as a tool for integration with PESTLE-SWOT approach.

This chapter represents a case study for Bulgarian railway network and railway passenger transport. The Bulgarian railway network is a part of TEN-T network. The current situation shows that the average technical speed of passenger trains is one of the lowest in Europe. The railway infrastructure is in process of rehabilitation in order to increase the safety and technical speed of railway sections and lines. The existing rolling stock have low quality and capabilities and have to be renewed and modernized. The existing structure of trains by types could be improved through implementation of new type of trains. Three strategies for improvement of the Bulgarian railway transport development have been assess in this chapter based on proposed integrated approach PESTLE - SWOT- MCDM.

The structure of the chapter is as follows: Section 2 shows literature review; Section 3 provides the methodology of research. Different multi-criteria approaches are included in methodology. The linear programming approach as SIMUS method, the distance-based approach as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and evaluation based on distance from average solution (EDAS) methods, the utility-based approach as multi-objective optimization on the basis of ratio analysis (MOORA) and COmplex PRoportional ASsessment method (COPRAS) methods, and outranking approach as Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) method are represented. The integration of PESTLE-SWOT-MSDM is shown. Section 4 shows the obtained results for Bulgarian railway network and discussion. Finally, Section 5 provides the conclusions.

2. Literature review

The methods of strategic planning as SWOT, PEST and its modification as STEEP, PESTLE, PESTEL, STEEPLE or others have been applied in the following ways:

- Analysis the sub-criteria in SWOT, PESTLE, or other modification of strategic planning methods groups;

- Combination of PESTLE and SWOT analysis in order to expand the analysis of defined sub-criteria. This approach serves also for identifying the internal and external factors that influence a given system.

- Integration of the PESTLE (SWOT) analysis with multi-criteria analysis methods to determine the weights of sub-criteria in each PESTLE (SWOT) group. This approach is used to identify the sub-criteria that have the main impact of the investigated system.

- Ranking of alternatives based on SWOT (PESTLE) sub-criteria. The determination of the weights of sub-criteria and the ranking is performed by using multi-criteria analysis methods.

Some authors used the strategic management techniques as SWOT, PESTLE or others as a tool to analyze the studied system with purpose to strategic planning. The weights of the criteria in these cases are not determined. The PESTLE analysis has been implemented to analyze of the suborbital flight operation [1]; to determine the weak signals classification to detect threats and opportunities from web [2]; to analyze the renewable energy sector environment [3]. The integration of PESTLE and SWOT analysis is presented in [4] to analyze the Renewable Energy for Island Countries. The PESTEL analysis has been used for assessing the situation of Polish transport enterprises [5]. Some authors consider only the problem with the formulation of the SWOT factors. The SWOT analysis have been conducted to of railway freight transport [6]; of China's High-speed Rail [7]; to develop city public transport strategies [8]; to study the automobile reverse logistics [9]; to analyze the underground pedestrian systems [10].

The PESTLE framework has been also integrated with the methods to decision making and multi-criteria analysis. In [11] the integration of PESTEL analysis and AHP method has been applied to select an optimal location of logistic hubs. The green building industry in Turkey has been assessed by using PESTLE analysis and fuzzy model of the macro-environmental assessment, [12]. The PESTLE analysis and Multi Attribute Value Theory (MAVT) method have been integrated to study Carbon Capture and Storage process, [13]. The unconventional modes of transport have been analyzed based on PESTLE, and an AHP-TOPSIS approach, [14]. The SWOT/PESTLE analysis has been applied to investigate the water system in Serbia [15]; for Port Energy Management System to define the positive or negative effect, [16].

The city's transportation system strategies were evaluated and prioritized based on SWOT analysis and fuzzy complex proportional assessment (COPRAS) method [17]. An integrated SWOT – FUZZY PIPRECIA model was formed to analyze and improve logistics performances for transport of goods [18]. Some of the researchers combined the SWOT analysis with Analytic Hierarchy Process (AHP) or Analytic Network Process (ANP) methods. This approach has been used to study the strategy of development of railway transport in West Africa [19]; to study different mode of transport to determine the transport strategy [20]; to analyses the Long-

Distance Passenger Transportation on a Highway Network [21]; to investigate urban planning [22]; for energy automobile industry [23]. Other authors used an integration of more multi-criteria methods with SWOT analysis, [24–26]. In these cases, one method is used to determine the weights of criteria, and another method is applied to assess the alternatives.

3. Methodology

The methodology of the research consists fifth stages, **Figure 1**:

- First stage: Formulation the alternatives of the policies for railway operator.
- Second stage: Definition of the criteria in PESTLE groups. The initial decision matrix represented the values of each criterion for each alternative is formed.
- Third stage: The SIMUS method is applied to rank the alternatives and assess the criteria in PESTLE groups. The criteria significance is dependent on the set of alternatives to evaluate. It is a similar concept to using Shannon entropy, to evaluate criteria weights.

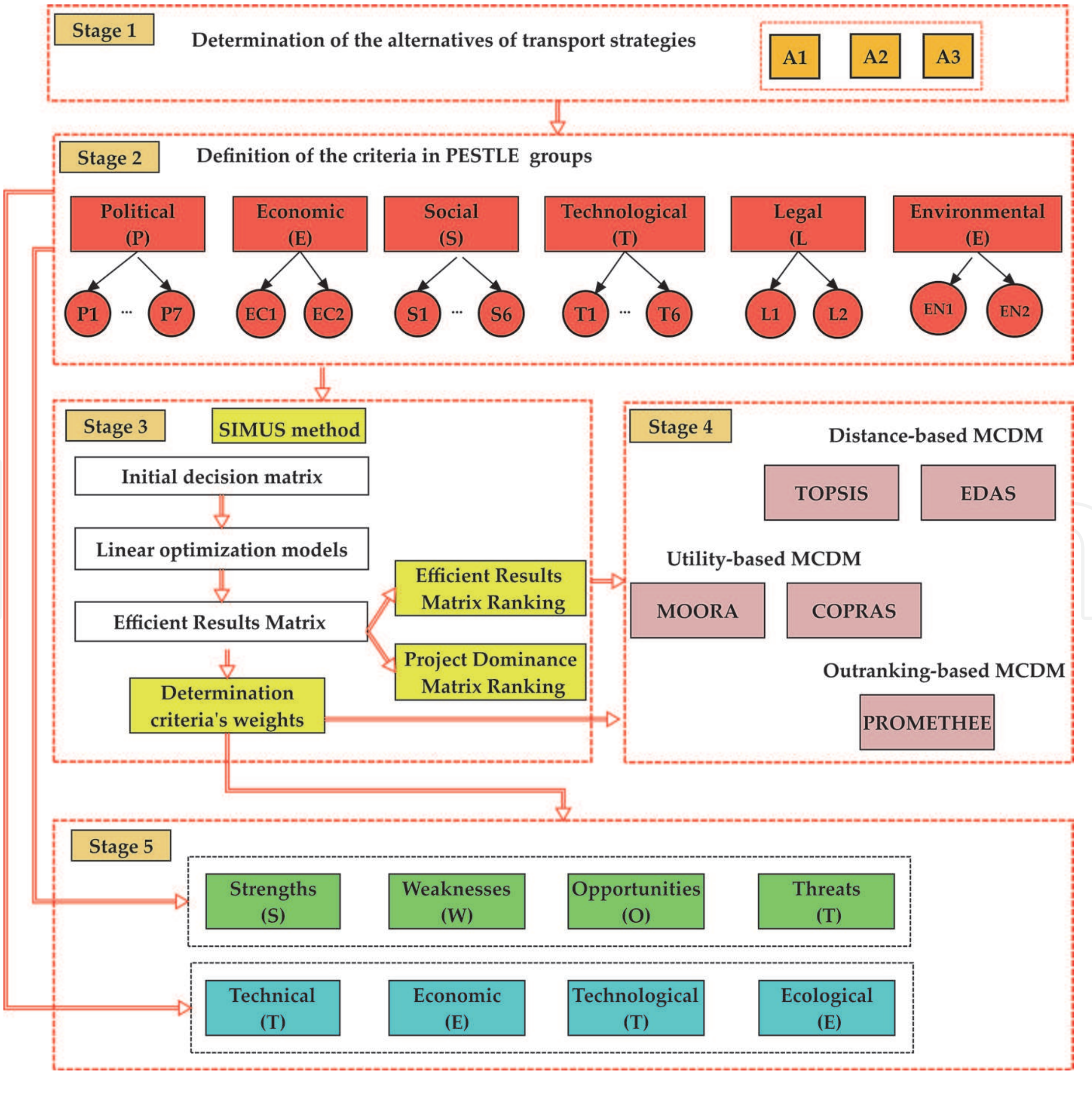

Figure 1.
Scheme of methodology.

- Fourth stage: Ranking by application the following distance based multi-criteria methods: TOPSIS and EDAS, utility based multi-criteria methods: MOORA and COPRAS; and outranking approach PROMETEE. These multi-criteria methods have different techniques versus SIMUS method. They have been selected to compare the results of PESTLE – SIMUS approach with the integration of PESTLE with other multi-criteria approach. Because these methods use the weights of criteria, they have been taken into account as equal to these determined by SIMUS method.

- Fifth stage: Combination the PESTLE analysis with other analysis for strategic planning. This serves to determine the weights of the main groups criteria of the compared types of analysis. The methodology consists two types of combination: (a) combination the PESTLE analysis with the SWOT analysis. For this purpose, the interpretation of the PESTLE criteria as SWOT criteria is formed. (b) Combination the PESTLE analysis with the technical, economical, technological and ecological (TETE) group criteria.

3.1 Determination of the alternatives

The alternatives represent strategies of the railway manager about the development the railway transport. The case for Bulgarian railway is considered as follows: there are three alternatives, or strategies, the first of which is to maintain the state of affairs as it is; the second, to replace the rolling stock only on some lines of the network, which is a partial improvement; the third, partial improvement on some lines with replacement of some of the rolling stock and also partial improvement of the railway infrastructure.

The characteristics of the alternatives are presented as follows:

A1 – Reconstruction on railway infrastructure. This mean rehabilitation of railway sections and railway lines to increase transport speeds and safety. This process is carried out in accordance with national transport programs.

A2 - New rolling stock on some lines. It means a staged update of rolling stocks, decommissioning of depreciated and obsolete rolling stock. This strategy takes also into account the reconstruction of railway infrastructure.

A3 –Introduction of new services. In this research, a strategy for the service “car on the train” named also motorail trains is proposed. The motorail trains offer service at which passengers can take their car along with them on their journey. The passengers are carried in the train, while the cars are loaded separately in specialized wagons of the same train. This strategy takes also into account the reconstruction of railway infrastructure.

3.2 Defining the criteria in PESTLE groups

The PESTLE analysis consists Political, Economic, Social, Technological, Legal and Environmental factors that have an impact on the investigated alternatives. A PESTLE analysis helps to understand the business and strategically position of the investigated system. In this study the criteria in PESTLE groups can be defined as quantitative and qualitative. The quantitative criteria are set with their values for each of the studied alternatives. The quality criteria are set in the following ways: with a scale for evaluating the performance of the criterion or by using the answer “yes” or “no”. In the first case, the following rating scale is proposed: 0, 1, 2 or 3. The value “0” indicates non-fulfillment of the respective indicator; a value of “1”, “2” or “3” means low, medium or high performance respectively. In the second case, if the answer is “yes” - “1”is written, otherwise - “0”.

In this study the following criteria in PESTLE groups are proposed:

Political (P) with the following criteria:

P1 - Increasing the quality of railway infrastructure. This means some reconstructions in railway infrastructure to increase the operating speed of the trains. The possible values of this criterion are 1 or 2. The values of "1" means increase of the admissible speed of the railway. The value of "2" means that the investigated alternative allows an increase in the permissible speed also by the rolling stock. The objective of this criterion is of maximum.

P2 - Development of the TEN-T network. This means the development the core TEN-T network in Bulgaria through the implementation of European programs and projects for the development of railway junctions, railway nodes, railway section, harmonization the Bulgarian 'railway system with the European ones. The possible values of this criterion are 1 or 2. The values of "1" means increase of the development of the railway infrastructure core TEN-T network in Bulgaria. The value of "2" means development the harmonization of the railway system with European railway. The new rolling stocks allows the introduction of new systems for electronic on-board system of locomotives and the development of the European railway traffic management system. The objective of this criterion is of maximum.

P3 – Modernization of the rolling stock. This means purchasing the new locomotives, new type of wagons and electric multiple units to operate in some railway routes. The possible values of this criterion are 1, 2 or 3. The values of "1" means carriage with existing rolling stocks, some modernization in locomotives could to be done. The values of "2" means implementation of the new locomotives and electric multiple units to operate in the main railway routes; the values of "3" means implementation of new type of wagons for carriage the cars. The objective of this criterion is of maximum.

P4 - Increasing the quality of road infrastructure. The road transport is competitive with the railway transport, especially on parallel routes. Improving the quality of road infrastructure makes it possible an increase of the speed of cars and busses. The possible values of this criterion are 0 or 1. Value 1 shows benefit of carriage for road operators. Value "0" shows benefit of carriage for railway operators. The quality of railway transport services increases when offering comfortable, high-speed and safe transport. The objective of this criterion is of minimum.

P5 - Delayed purchase of rolling stock. This means a delay in the scheduled purchasing time due to financial and other reasons. The values of this criterion are 0 or 1. The value "0" is set for alternatives which do not depend on the purchase of new rolling stock. The value of 1 indicates lack of purchase of rolling stock or delay in the purchase plan. The objective of this criterion is of minimization.

P6 - National policy for priority railway transport development. This means that the state should prioritize railway transport by assisting in the financing of railway infrastructure projects and the renewal of rolling stock. The values of this criterion are 0 or 1. The value "0" is set when the national policy is aimed at infrastructure projects for railway rehabilitation. The value "1" means that the expanding national policy by investing in the modernization of rolling stock and trains. The objective of this criterion is of minimum.

P7 - Development of intercity railway transportation. This means development the network of intensity trains with increasing speed. The values of this criterion are 0 or 1. The intercity trains suggest comfort, security and high-quality service between major cities in the railway network. The value "0" is set when only some reconstructions in railway line is met. The value of "1" means the high quality of intercity railway service. The objective of this criterion is of maximum.

Economic (EC) with the following criteria:

EC1 - Operating costs (EUR/day). The operating costs depend on the number of trains. They include the costs for train movement (electricity), costs for maintenance and repair of rolling stock, costs for locomotive crew, depreciation costs and other operating costs, and also the infrastructure charge. The costs for investments for rolling stock, as well as for reconstruction are not taken into account. The objective of this criterion is of minimization.

EC2 - Additional fees for loading and unloading operations. These fees are connected with motorail trains for loading and unloading the cars. The values of this criterion are 0 or 1. The value "0" is set when no service is offered with motorail trains. The value "1" means presence of motorail services. The objective of this criterion is of minimum.

Social (S) with the following criteria:

S1 – Security. The values of this criterion are 1, 2 or 3, which show the level of security. The reconstructions on railway infrastructure, the modernization the rolling stocks, the introduction the motorail services increase the level of security of transport. The larger number indicates the availability of more security in railway service. The objective of this criterion is to maximize security.

S2 – Reliability. This criterion is assessed as 1, 2 and 3. The renovation of the railway lines increase the reliability. The modernization of the rolling stock increases also the reliability of transport. The motorail trains also increase additionally the ratability od railway transport taken into account that the cars carried by trains reduce the traffic on the road infrastructure. The larger number indicates the availability of more reliability in railway service. The objective of this criterion is of maximum.

S3 – Comfort. This criterion is assessed as 1, 2 and 3. Travel comfort is expressed by ensuring the convenience of traveling in clean, renovated or renewed rolling stock. The comfort also increases when the motorail service is added because the drivers could use their free time to rest. The larger number indicates the availability of more comfort in traveling. The objective of this criterion is of maximum.

S4 – Additional services. The values of this criterion are 0, 1 or 2. The new rolling stock has equipment with modern information systems, and WIFI networks in the trains. The motorail trains offer the carriage the cars of the passengers. The larger number indicates the availability of more additional services. The objective of this criterion is of maximization.

S5 - Position in the transport market (quality). This criterion can have values 1, 2 or 3. The position of the railway transport on the market of transport services increases, with the improvement of the condition of the rolling stock and the railway infrastructure. The larger number shows a higher position in the transport market. The objective of this criterion is of maximization.

S6 – Transport in certain months. The values of this criterion are 0 or 1. The motorail services usually applied during the summer months, mine are associated with an increase in tourist travel. The objective of this criterion is of minimum.

Technological (T) with the following criteria.

T1 - Frequency, pair trains/day. The number of trains increase when the new rolling stocks is added. The objective of this criterion is of maximization.

T2 – Average operating speed, km/h. This criterion is determined according all fast and high-speed trains in the railway network. The increase of the operational speed is achieved with the reconstruction of the infrastructure and also the modernization of rolling stock. The value of average operating speed increases when there are conditions for some trains to run at high speed. The objective of this criterion is of maximization.

T3 – Directness. This criterion means services with a reduced number of intermediate stops. This criterion may have the following values: 0 or 1. The value "0" means lack of direct trains with increased speed. The introduction of direct express intercity trains, which have reduced stops in only a few places along the route, allows to increase the directness of the journey, to reduce its duration between stations, as well as for the entire route. The value "1" means presence of direct trains with increased speed. The objective of this criterion is of maximization.

T4 - Total travel time. This criterion includes the time for travel and the tome for acceptance and loading of cars in specialized wagons in motorail train composition. This criterion may have the following values: 0 or 1. The value "1" means increased total time due to motorail service; the value "0" is set when such service is not available. The objective of this criterion is of maximization.

T5 – Frequency of motorail trains. This criterion shows the number of pairs motorail trains per day. The objective of this criterion is of maximization taken into account that such service increases the transport satisfaction of the passengers of railway services. The objective of this criterion is of maximization.

T6 – Transport door-to-door. This means the possibility for passengers to travel with their own car from their home to the start railway station, then to load the car on the specialized wagon, and at the final railway station the car is unloaded and the passenger continues his journey with his own car to the final destination. This criterion may have the following values: 0 or 1. The value "1" means service door-to-door; the value "0" is set otherwise. The objective of this criterion is of maximization.

Legal (L) with the following criteria.

L1 - Possibility of increase the level of European Rail Traffic Management System (ERTMS) system. This criterion may have the following values: 0 or 1. ERTMS is a train signaling and traffic management system, created to assist interoperability by using a unique signaling and communication standard throughout Europe. There are three levels of the application of ERTMS depending on the need for existing railway infrastructure. The value "1" shows increase the level of ERTMS taking into account the level of communication system in locomotives and moving block technology. The objective of this criterion is of maximization.

Environmental (EN) with the following criteria.

EN1 - CO2 emissions. The values of CO2 emissions are calculated according the electricity generation for movement of the trains, t/MWhe.

EN2 - Saved CO2 emissions. This criterion takes into account the CO2 emissions saved by cars when transported in a specialized wagon. The value depends on the number of motorail trains.

3.3 SIMUS method

The SIMUS method is based on Linear Programming, Weighted Sum and Outranking, [27]. This approach considered the criteria as objectives in Linear optimization models. The first step of the method consists of the forming the initial decision matrix with alternatives in the columns and criteria in the rows. In the next step the normalization of the initial decision matrix is made by applying some of the normalizing procedures. In the third step, the linear optimization models are formed taken into account each criterion as objective and the optimal scores for the alternatives are determined. The results are placed in an Efficient Result Matrix (ERM). This matrix is considered as a new decision matrix, composed of the optimal values. The next step consists ranking the alternatives. The SIMUS uses two different multi-criteria procedures to rank the alternatives - Weighted Sum method and outranking approach. The first approach is called ERM ranking and is based on ERM matrix; the second ones is called Project Dominance Matrix (PDM) ranking and uses a new matrix which is formed based on ERM matrix. The results of both methods give the same ranking. This allows the result to be validated. The SIMUS method give also the marginal utilities for each criterion, and allow to determine the robustness of the solution. For this purpose, the ERM matrix is used to determine the weights of criteria. Determining the weights of the criteria allows the decision maker to assess their impact on the investigated system. The values of criteria are not used when ranking the alternatives.

3.4 TOPSIS method

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is based on the principle that best alternative should have the shortest distance from the ideal solution and farthest distance from the negative ideal solution. TOPSIS consists the following steps, [28]:

Step 1: Determination the decision matrix $(\boldsymbol{x_{ij}})_{\boldsymbol{nxm}}$ consisting of n alternatives and m criteria. Calculation of normalization matrix $(\boldsymbol{r_{ij}})_{\boldsymbol{nxm}}$. The values of normalization matrix are:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}, i = 1, \dots, n; j = 1, \dots, m \tag{1}$$

where: $i = 1, \dots, n$ is the number of alternatives; $j = 1, \dots, m$ is the number of criteria.

Step 2: Calculate weighted normalized matrix $(v_{ij})_{mxn}$. The elements of this matrix are:

$$v_{ij} = r_{ij}.w_j; \sum_{j=1}^{m} w_j = 1 \tag{2}$$

where: w_j is the weight of criterion j.

Step 3: Calculate the ideal best v_j^+ and ideal worst v_j^- value for each criterion j.

$v_j^+ = \min_i v_{ij}$ for non-benefits criteria; $v_j^+ = \max_i v_{ij}$ for benefits criteria.

$v_j^- = \max_i v_{ij}$ for non-benefits criteria; $v_j^- = \min_i v_{ij}$ for benefits criteria.

Step 4: Determination the Euclidean distance from the ideal best D_i^+ solution and the Euclidean distance from the ideal worst D_i^- solution.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^+\right)^2}; D_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^-\right)^2} \tag{3}$$

Step 5: Calculate Performance Score C_i that presents the relative closeness of each alternative i with reference to negative ideal measure D_i^- as follow:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}; 0 \le C_i \le 1 \tag{4}$$

The ranking of the alternatives is based on the C_i values. The best alternative based on the Performance Score has the highest assessment value.

3.5 EDAS method

EDAS method determines the optimal alternative based on the higher distance from the nadir solution and lowest distance from the ideal solution. The EDAS method consists the following steps, [29]:

Step 1: Determination the decision matrix $\left(x_{ij}\right)_{nxm}$ consisting of n alternatives and m criteria.

Step 2: Determination the average solution according to all criteria.

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{5}$$

Step 3: Determination the positive $\left(PDA_{ij}\right)$ and the negative distance $\left(NDA_{ij}\right)$ from average matrices

$$PDA_{ij} = \frac{\max\left(0, \left(x_{ij} - AV_j\right)\right)}{AV_j}, \text{for beneficial criteria} \tag{6}$$

$$PDA_{ij} = \frac{\max\left(0, \left(AV_j - x_{ij}\right)\right)}{AV_j}, \text{otherwise} \tag{7}$$

$$NDA_{ij} = \frac{\max\left(0, \left(AV_j - x_{ij}\right)\right)}{AV_j}, \text{for beneficial criteria} \tag{8}$$

$$NDA_{ij} = \frac{\max\left(0, \left(x_{ij} - AV_j\right)\right)}{AV_j}, \text{otherwise} \tag{9}$$

Step 4: Determination of the weighted sum of positive (SP_i) and negative (SN_i) distance:

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij}; SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \tag{10}$$

Step 5: Normalization of the weighted sum of positive (NSP_i) and negative (NSN_i) distance as follows:

$$NSP_i = \frac{SP_i}{max_i(SP_i)}; NSN_i = 1 - \frac{SN_i}{max_i(SP_i)} \tag{11}$$

Step 6: Determination the appraisal score. The ranking is according to the decreasing values of appraisal score. The optimal alternative based on the appraisal score has the highest assessment value.

$$AS_i = \frac{1}{2}(NSP_i + NSN_I); 0 \le AS_i \le 1 \tag{12}$$

3.6 MOORA method

The multi-objective optimization on the basis of ratio analysis (MOORA) method uses both beneficial and non-beneficial objectives (criteria) for ranking the alternatives. This method is based on ratio system. The MOORA method is utility-based method and consists the following steps, [30]:

Step 1: Determination the decision matrix $\left(x_{ij}\right)_{nxm}$ consisting of n alternatives and m criteria.

Step 2: The ratio represented the normalized performances x_{ij}^* of i-th alternative on j-th criterion is determined as follows:

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}, i = 1, \dots, n; j = 1, \dots, m; 0 \le x_{ij}^* \le 1 \tag{13}$$

Step 3: Determination the normalized performances in the case of maximation (for beneficial criteria) and the normalized performances in the case of minimization (for non-beneficial criteria). The optimal alternative based on the ratio system has the highest assessment value. The y_i value can be positive or negative. When the criteria weights are taken into account, they are added in the Eq. (13).

$$y_i = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{m} x_{ij}^* \tag{14}$$

Where: y_i is the total assessment of alternative j which can be positive or negative; g is the number of criteria to be maximized, $(n - g)$ is the number of criteria to be minimized.

3.7 COPRAS method

The COPRAS method uses simple evaluating procedure to determine the influence of maximizing and minimizing criteria on ranking the alternatives. The best alternative is based on both the ideal and the anti-ideal solutions. The COPRAS method is utility-based method and consists the following steps, [31]:

Step 1: Determination the decision matrix $\left(x_{ij}\right)_{nxm}$consisting of n alternatives and m criteria.

Step 2: Normalization of the decision matrix. The elements are calculated as follows:

$$\overline{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{15}$$

Step 3: Determination of the weighted normalized matrix $\left(\hat{x}_{ij}\right)_{nxm}$. For this purpose, the elements of the normalized matrix are multiplicated by the weight to the corresponding criterion.

Step 4: Determination of the maximizing index $P_i$and minimizing index R_i

$$P_i = \sum_{i=1}^{k} \hat{x}_{ij}; R_i = \sum_{i=k+1}^{n} \hat{x}_{ij} \tag{16}$$

Where: k is the number of criteria which is to be maximized, $(n - k)$ is the number of criteria to be minimized.

Step 5: Determination of the relative weights of each alternative. The best alternative is based on the highest the relative weights.

$$Q_i = P_i + \frac{\sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \frac{1}{R_i}} \tag{17}$$

3.8 PROMETHEE method

The Preference ranking organization method for enrichment evaluation (PROMETHEE) method is outranking approach in multi-criteria analysis. The explanation and mathematical calculation steps of the PROMETHEE method are summarized below [28]:

Step 1: This step computes, for each pair of possible decisions and for each criterion, the value of the preference degree.

Step 2: This step consists of aggregating the preference degrees of all criteria for each pair of possible decisions.

Step 3: This step includes the computing of the outranking flows. For each possible decision the positive outranking flow $\varphi^{+}(a_i)$ and the negative outranking flow $\varphi^{-}(a_i)$ are computed. The positive outranking flow expresses how much each alternative is outranking all the others. The negative outranking flow expresses how much each alternative is outranked by all the others.

Step 4: In this step the net outranking flows $\varphi(a_i)$ of a_i in the alternatives set m of a possible decision are determined as a difference between $\varphi^{+}(a_i)$ and $\varphi^{-}(a_i)$. The optimal alternative is determined by the maximum value of net outranking flows, which corresponds to the alternative with highest priority.

For net outranking flow, the following conditions are valid:

$$\varphi(a_i) \in [-1; 1]; \sum_{i=1}^{n} \varphi(a_i) = 0 \tag{18}$$

3.9 Combination the PESTLE analysis with other analysis for strategic planning

The fifth stage of methodology consists a combination of the PESTLE analysis with other analysis for strategic planning as SWOT technique. In this chapter is

PESTLE	Criteria	S	W	O	T	PESTLE	Criteria	T	E	T	E
	P1			x			P1	x			
	P2			x			P2	x			
P	P3			x		**P**	P3	x			
	P4				x		P4	x			
	P5				x		P5		x		
	P6			x			P6			x	
	P7			x			P7			x	
E	EC1		x			**E**	EC1		x		
	EC2		x				EC2		x		
S	S1	x				**S**	S1	x			
	S2	x					S2	x			
	S3		x				S3			x	
	S4		x				S4			x	
	S5		x				S5			x	
	S6			x			S6			x	
T	T1		x			**T**	T1			x	
	T2		x				T2			x	
	T3		x				T3			x	
	T4		x				T4			x	
	T5		x				T5			x	
	T6			x			T6			x	
L	L1			x		**L**	L1	x			
E	EN1	x				**E**	EN1				x
	EN2			x			EN2				x

Table 1.
Interactions between PESTLE, SWOT and TETE analysis.

studied also the integration between PESTLE and technical, economic, technological and environmental (TETE) group criteria. This serves to determine the weights of the main groups criteria of the compared types of analysis. **Table 1** represents the interactions between PESTLE and SWOT analysis on the one hand and between PESTLE and TETE analysis on the other hand. The symbol "x" indicate that the criterion of PESTLE is also a criterion in SWOT or TETE analysis.

4. Results and discussion

The proposed methodology is applied for Bulgarian railway network. The following categories of intercity passenger trains have been studied: fast trains, accelerated fast trains and express trains. The fast trains serve intermediate stations between cities, big transport and important administrative centers. The accelerated fast trains have mandatory seat reservations and serve major cities and transport nodes. The direct express trains have a lower number of stops in comparison to accelerated fast trains. They also have mandatory seat reservations. The alternative A1 consists two categories of trains – fast and accelerated fast trains, while alternatives A2 and A3 offers three categories of trains – fast trains, accelerated fast trains and direct express trains.

Alternative A1 is close to the current situation in which some reconstructions in railway lines are carried out according to the operational program transport for Bulgaria. The trains are composed of wagons, only some intercity trains are electric multiple units. In current situation the average technical speed of movement of passenger trains in Bulgarian railway network is one of the lowest in Europe. The movement of trains is achieved at 75 ÷ 80 km/h, and in certain areas it is limited to 40–60 km/h in order to ensure traffic safety. The express trains and accelerated fast trains in alternatives A2 and A3 are composed of novel electric multiple unit trains. Alternative A3 offer new service with motorail trains in direction Sofia - Plovdiv – Burgas (this is part of the core TEN-T network). In this case, new rolling stooks for carriage of cars are taken into account.

4.1 Application of the SIMUS procedure

4.1.1 Ranking the alternatives

The third stage of methodology includes application the SUMUS method to select the appropriate alternative. **Table 2** consists two parts. The first part represents the initial decision matrix for SIMUS procedure. This matrix consists the values of quantitative and qualitative criteria in PESTLE groups. The values of criteria P5, P6, P7, EC1, S6, T3, T4, T6 and L1 are determined using scale 0, 1. The values of criteria P1, P2, P3, S1-S5 and T5 are determined using a scale of 0, 1, 2, 3.

The number of trains for alternatives A2 and A3 increases due to the replacement of old rolling stock with new one. The alternative A2 and A3 there are an increase in electricity consumption due to increased maximum speed 100–120 km/h in the direction Sofia - Plovdiv – Burgas (this is part of the core TEN-T network). The carbon dioxide emissions for the production of electricity by the power plants also decrease.

The second part of **Table 2** shows the normalized matrix, the type of actions for each criterion, the type of the operator for the restrictive conditions, the limits called "Right Hand Side" (RHS). The normalization has been performed by using the Sum of All Values method. In general, the normalization could be made based on some of different ways. The values of the RHS are obtained from the left normalized values and the type of action. In the case of minimum, RHS is equal to

Criterion	Initial matrix			Normalized matrix			Action	Type	RHS
	A1	A2	A3	A1	A2	A3			
P1	1.00	2.00	2.00	0.20	0.40	0.40	max	≤	0.40
P2	1.00	2.00	2.00	0.20	0.40	0.40	max	≤	0.40
P3	1.00	2.00	3.00	0.17	0.33	0.50	max	≤	0.50
P4	1.00	0.00	0.00	1.00	0.00	0.00	min	≥	0.00
P5	0.00	1.00	1.00	0.00	0.50	0.50	min	≥	0.00
P6	0.00	1.00	1.00	0.00	0.50	0.50	max	≤	0.50
P7	0.00	1.00	1.00	0.00	0.50	0.50	max	≤	0.50
EC1	50807.00	51957.00	61491.00	0.31	0.32	0.37	min	≥	0.31
EC2	0.00	0.00	1.00	0.00	0.00	1.00	min	≥	0.00
S1	1.00	2.00	3.00	0.17	0.33	0.50	max	≤	0.50
S2	1.00	2.00	3.00	0.17	0.33	0.50	max	≤	0.50
S3	1.00	2.00	3.00	0.17	0.33	0.50	max	≤	0.50
S4	0.00	1.00	2.00	0.00	0.33	0.67	max	≤	0.67
S5	1.00	2.00	3.00	0.17	0.33	0.50	max	≤	0.50
S6	0.00	0.00	1.00	0.00	0.00	1.00	min	≥	0.00
T1	36.00	38.00	40.00	0.32	0.33	0.35	max	≤	0.35
T2	65.00	80.00	80.00	0.29	0.36	0.36	max	≤	0.36
T3	0.00	1.00	1.00	0.00	0.50	0.50	max	≤	0.50
T4	0.00	0.00	1.00	0.00	0.00	1.00	min	≥	0.00
T5	0.00	0.00	3.00	0.00	0.00	1.00	max	≤	1.00
T6	0.00	0.00	1.00	0.00	0.00	1.00	max	≤	1.00
L1	0.00	1.00	1.00	0.00	0.50	0.50	max	≤	0.50
EN1	23511.00	25225.00	25225.00	0.32	0.34	0.34	min	≥	0.32
EN2	0.00	0.00	2808000.00	0.00	0.00	1.00	max	≤	1.00

Table 2.
Initial decision matrix. Normalized "sum" matrix.

the minimum value of the row; in the case of maximum, the RHS value is equal to the maximum value of the row in normalized matrix. The type of operator depends on the type of objective function. In the case of maximum, the operator is "≤"; in the case of minimum, the operator is "≥".

The linear optimization models are performed by using the data in **Table 2**. For example, the first optimization linear model is formed for the first objective Z1 (criterion P1) as follows:

$$Z1 = 0.20x_1 + 0.40x_2 + 0.40x_3 \rightarrow \text{Min}, \tag{19}$$

where: x_i represents the score of each alternative, i = 1,2,3.

The restrictive conditions for the optimization model are formed by using the others rows of the ERM matrix. For example, for criterion P2, the restrictive condition is:

$$0.20x_1 + 0.40x_2 + 0.40x_3 \leq 0.40 \tag{20}$$

The restrictive conditions are formed successively using all other rows in the Normalized Sum Matrix. The final restrictive condition for the first optimization model is performed by criterion EN2 (objective Z24) based on the data in the last row in the Normalized Sum Matrix, as follows:

$$1.00x_1 + 0.00x_2 + 0.00x_3 \geq 0.00 \tag{21}$$

For all variables the following condition is set:

$$0 \leq x_1, x_2, x_3 \leq 1 \tag{22}$$

Similar optimization linear models are performed for all other criteria. The results for the scores are recorded in Efficient Results Matrix. The next step of the SIMUS procedure includes the normalization of the ERM matrix. Then two approaches are used for ranking the alternatives - weighted sum method and outranking approach. In the first approach the sum method has been applied to normalize the ERM matrix. The results are presented in the first part of **Table 3**. The second part shows the steps of the ranking. First the sum of column is determined. The number of satisfactions of each alternative by each objective are determined and recorded as participation factors (PF). The normalization of the participation factor is carried out by dividing the number of criteria. The final results of the alternatives are calculated by multiplying the sum of the columns by the normalized participation factor. The alternatives are ranked in descending order. **Table 4** shows the ERM matrix and the determination of the weights of criteria. The first part of the table indicates the ERM matrix and the values of the objective function for each optimization. The second part of **Table 4** shows haw to calculate the weights of criteria. For this purpose, first the maximum value of the row for ERM matrix$\left(\max_j ERM_{ij}\right)$ is determined. The global weights (w_i) are determined by dividing the maximum value $\left(\max_j ERM_{ij}\right)$ by sum of all maximum values. These values indicate the importance of each objective. The results show very close values of the criteria. The weights of the main groups $\left(w_g\right)$ criteria are presented in the last column of the **Table 4**. It can be seen that the main importance has the criteria in political (0.29), social (0.25) and technological (0.25) groups.

Table 5 shows the results of ranking according the outranking approach of SIMUS method. The number of columns and the rows in PDM is equal to the number of alternatives. The ERM matrix is used for compiling PDM ranking. Starting from the highest value in the first row the difference between values in the same row of normalized ERM is calculated. The procedure is repeated with all the values. The net dominance is calculated as the difference between row sum and column sum. The alternatives are ranked according to the maximal value of the net dominance. The results presented in **Tables 3** and **5** show that the ranking formed using both procedures is the same. Alternative A1 is the most suitable.

The main advantages of the SIMUS method are that it does not use expert's assessment and does not use the weights of criteria for ranking the alternatives. There is no subjectivism in decision making. SIMUS applied Linear Programming that does not use any type of weights, that's why they are not needed in the SIMUS procedure. The results of optimization are Pareto efficient. The weights of criteria can be determined in the end of optimization to determine its impact on the studied system. Two approaches are used to rank the alternatives; thus, verifying the results.

Criterion	Objective	Alternatives		
		A1	A 2	A3
P1	Z1			1.00
P2	Z2			1.00
P3	Z3			1.00
P4	Z4			1.00
P5	Z5	1.00		
P6	Z6			1.00
P7	Z7			1.00
EC1	Z8		1.00	
EC2	Z9		1.00	
S1	Z10			1.00
S2	Z11			1.00
S3	Z12			1.00
S4	Z13			1.00
S5	Z14			1.00
S6	Z15		1.00	
T1	Z16	1.00		
T2	Z17	0.11	0.89	
T3	Z18			1.00
T4			1.00	
T5	Z19			1.00
T6	Z20			1.00
L1	Z21			1.00
EN1	Z22			1.00
EN2	Z23			1.00
Sum of Column (SC)		2.11	4.89	17.00
Participation Factor (PF)		3	5	17
Norm. Participation Factor (NPF)		0.13	0.21	0.71
Final Result (SC x NPF)		0.26	1.02	12.04
ERM Ranking			A3 - A2 - A1	

Table 3.
Normalized efficient results matrix. Ranking. (The values equal to 0 are not shown).

4.2 Application of the TOPSIS, EDAS, MOORA, COPRAS and PROMETHEE methods

The fourth stage of methodology includes ranking by application the following multi-criteria methods: distance based: TOPSIS and EDAS, utility based: MOORA and COPRAS; and outranking approach PROMETEE. All these methods require the weights of the criteria to be set. What because, the weights determined on the basis of the ERM matrix of the SIMUS method are used as input to the studied methods. The results of the criteria weights show that they have almost equal values. For this

	Criterion	Objective	A 1	A 2	A 3	Objective function values	$\max_j \text{ERM}_{ij}$	SIMUS w_i	SIMUS w_g
P	P1	Z1	0.00	0.00	1.00	0.40	1.00	0.042	0.29
	P2	Z2	0.00	0.00	1.00	0.40	1.00	0.042	
	P3	Z3	0.00	0.00	1.00	0.50	1.00	0.042	
	P4	Z4	0.00	0.00	0.93	0.00	0.93	0.039	
	P5	Z5	1.00	0.00	0.00	0.00	1.00	0.042	
	P6	Z6	0.00	0.00	1.00	0.50	1.00	0.042	
	P7	Z7	0.00	0.00	1.00	0.50	1.00	0.042	
E	EC1	Z8	0.00	0.93	0.00	0.29	0.93	0.039	0.08
	EC2	Z9	0.00	0.98	0.00	0.00	0.98	0.041	
S	S1	Z10	0.00	0.00	1.00	0.50	1.00	0.042	0.25
	S2	Z11	0.00	0.00	1.00	0.50	1.00	0.042	
	S3	Z12	0.00	0.00	1.00	0.50	1.00	0.042	
	S4	Z13	0.00	0.00	1.00	0.67	1.00	0.042	
	S5	Z14	0.00	0.00	1.00	0.50	1.00	0.042	
	S6	Z15	0.00	0.98	0.00	0.00	0.98	0.041	
T	T1	Z16	1.23	0.00	0.00	0.39	1.23	0.052	0.26
	T2	Z17	0.12	0.94	0.00	0.37	0.94	0.040	
	T3	Z18	0.00	0.00	1.00	0.50	1.00	0.042	
	T4	Z19	0.00	0.98	0.00	0.00	0.98	0.041	
	T5	Z20	0.00	0.00	1.00	1.00	1.00	0.042	
	T6	Z21	0.00	0.00	1.00	1.00	1.00	0.042	
L	L1	Z22	0.00	0.00	1.00	0.50	1.00	0.042	0.04
E	EN1	Z23	0.00	0.00	0.83	0.28	0.83	0.035	0.08
	EN2	Z24	0.00	0.00	1.00	1.00	1.00	0.042	
Total							23.80	1.00	1.00

Table 4.
Efficient results matrix (ERM). Weights of criteria.

Dominant alternatives	A1	A2	A3	Row sum	Net dominance
A1	—	2.0	2.1	4.1	−17.7
A2	4.8	—	4.9	9.7	−9.3
A3	17.0	17.0	—	34.0	27.0
Column sum	21.8	19.0	7.0	—	—
PDM Ranking			A3 - A2 - A1		

Table 5.
Project dominance matrix (PDM). Ranking.

reason, they may not be taken into account. **Table 6** shows the results of application the distance based multi-criteria methods: TOPSIS and EDAS methods. Eqs. (1–12) have been applied. It can be seen that the ranking of alternatives is similar to those

Alternative	TOPSIS				EDAS					
	D_i^+	D_i^-	C_i	Rank	SP_i	NSP_i	SN_i	$NSNl$	ASi	Rank
A1	2.910	1.843	0.388	3	4.135	0.318	13.486	0.000	0.159	3
A2	2.198	2.323	0.514	2	6.518	0.501	3.505	0.475	0.488	2
A3	1.843	2.910	0.612	1	13.019	1.000	6.681	0.000	0.500	1

Table 6.
TOPSIS, EDAS – results.

Alternative	MOORA				COPRAS			
	$\sum_{j=1}^{g} x_{ij}^*$	$\sum_{j=g+1}^{m} x_{ij}^*$	y_i	Rank	P_i	R_i	Q_i	Rank
A1	3.048	2.074	0.974	3	3.048	2.074	10.262	3
A2	8.472	1.833	6.639	2	8.472	1.833	15.686	2
A3	13.285	4.963	8.322	1	13.285	4.963	20.500	1

Table 7.
MOORA, COPRAS - results.

Alternative	$\varphi(a_i)$	$\varphi^+(a_i)$	$\varphi^-(a_i)$	Rank
A1	0.292	0.500	0.208	3
A2	0.104	0.292	0.188	2
A3	−0.396	0.188	0.583	1

Table 8.
PROMETHEE - results.

by SIMIS method. **Table 7** represents the results of MOORA and COPRAS methods. Eqs. (13–17) have been used. The ranking is also similar to those received by SIMUS approach.

Table 8 shows the net outranking flows, the positive outranking flow $\varphi^+(a_i)$ and the negative outranking flow $\varphi^-(a_i)$. The preference function for the criteria assessed by 0 or 1 is usual function. Other criteria have linear preference function. The ranking is the same as others procedures. The PROMETHEE method use preference functions for the criteria, type of their optimization and outranking approach. This makes it more effective in decision making compared to distance-based and utility-based approaches. Since the decision maker has to set the weights of the criteria, this makes the discussed distance-based, utility-based and outranking methods also dependent on subjective evaluation. Of course, the cases where the weights are determined by Shannon entropy or another method based on the information of data, must to be excluded.

The most suitable alternative according all represented approached is alternative A3. This means that introduction of new service "car on the train" named also motorail trains is proposed. This strategy takes also into account the reconstruction of railway infrastructure.

4.3 Combination the PESTLE analysis with SWOT analysis and TETE

In this chapter is studied the integration between PESTLE and SWOT analysis and also the integration between PESTLE and TETE analysis. This serves to determine the weights of the main groups criteria of the compared types of analysis. **Table 9** represents the dependencies between the criteria. The weights of predefined criteria in PESTLE group are recorded in the relevant places in SWOT or TETE group. Thus, the weights are determined for SWOT and TETE criteria. Finally, the main criteria for groups are calculated. It can be seen that the main importance for SWOT groups have Weakness (0.42) and Opportunities (0.38) groups criteria. The main impact for TETE groups criteria has technical (0.29) and technological (0.51) groups criteria.

Figure 2 illustrates the impact of the criteria according compared analysis. The established dependencies between the criteria in the use of different types of strategic analyzes help the decision maker to expand the analysis of the influence of factors on the studied system.

		SIMUS w_i	S	W	O	T			Te	Ec	Tn	En
P	P1	0.042	—	—	0.042	—	**P**	P1	0.042	—	—	—
	P2	0.042	—	—	0.042	—		P2	0.042	—	—	—
	P3	0.042	—	—	0.042	—		P3	0.042	—	—	—
	P4	0.039	—	—	—	0.039		P4	0.039	—	—	—
	P5	0.042	—	—	—	0.042		P5	—	0.042	—	—
	P6	0.042	—	—	0.042	—		P6	—		0.042	—
	P7	0.042	—	—	0.042	—		P7	—		0.042	—
	EC1	0.039	—	0.039	—	—		EC1	—	0.039	—	—
E	EC2	0.041	—	0.041	—	—	**E**	EC2	—	0.041	—	—
S	S1	0.042	0.042	—	—	—	**S**	S1	0.042		—	—
	S2	0.042	0.042	—	—	—		S2	0.042		—	—
	S3	0.042	—	0.042	—	—		S3	—		0.042	—
	S4	0.042	—	0.042	—	—		S4	—	—	0.042	—
	S5	0.042	—	0.042	—	—		S5	—	—	0.042	—
	S6	0.041	—	—	0.041	—		S6	—	—	0.041	—
T	T1	0.052	—	0.052		—	**T**	T1	—	—	0.052	—
	T2	0.040	—	0.04		—		T2	—	—	0.040	—
	T3	0.042	—	0.042		—		T3	—	—	0.042	—
	T4	0.041	—	0.041		—		T4	—	—	0.041	—
	T5	0.042	—	0.042		—		T5	—	—	0.042	—
	T6	0.042	—	—	0.042	—		T6	—	—	0.042	—
L	L1	0.042	—	—	0.042	—	**L**	L1	0.042	—	—	—
	EN1	0.035	0.035	—		—		EN1	—	—	—	0.035
E	EN2	0.042		—	0.042	—	**E**	EN2	—	—	—	0.042
		1.00	0.12	0.42	0.38	0.08			0.29	0.12	0.51	0.08

Table 9.
PESTLE – SWOT – TETE relations and weights.

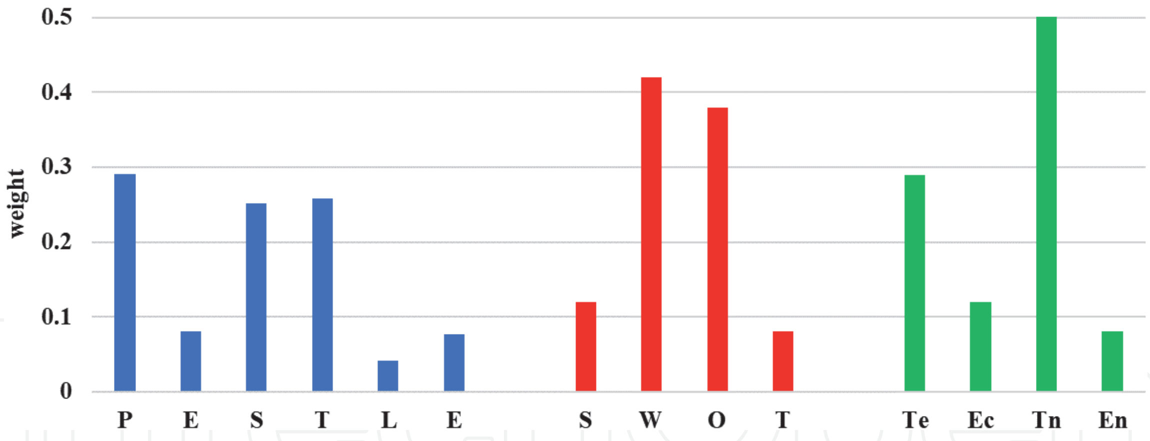

Figure 2.
PESTLE, SWOT, TETE weights.

5. Conclusions

This chapter proposes a methodology for assessment of the strategies of development the railway passenger transport using integration of PESTLE and SWOT criteria and MCDM methods. Different multi-criteria methods, as linear programming-based, distance-based, utility-based and outranking have been applied to rank the alternatives. All studied methods except SIMUS use weights of criteria in the procedures of ranking the alternatives. The SIMUS method only applies linear optimization, while the other applied methods use formulas to determine the distance to the ideal solution or utility. It is also a hybrid MCDM method because the ranking is based on weighted sum method and outranking approach. SUMUS also give the weights of the criteria as a result by the optimization and thus there is no subjectivism. The defined weights are valid for the set data.

The main advantages of the PROMETHEE method as an outranking method compared to the distance-based, utility-based multi-criteria methods are the following: it uses a preference functions for each criterion; normalization of the initial decision matrix is not used; availability of software that allows easy sensitivity analysis; the type of optimization can be taken into account - maximum or minimum.

The main advantages of the EDAS method are that it does not use normalization of the initial matrix for decision making; the criteria can be of maximum or minimum, i.e., of costs or benefits. This method determines the best alternative using the distance from average solution instead of calculating the distance from ideal and negative ideal solutions as in the compromise MCDM methods such as TOPSIS. The method is quite comprehensible and easy to apply. The TOPSIS method uses criteria that must be of one type - benefits. The subtraction-based conversion procedure for non-beneficial criteria is needed, which converts criterion type using the differences between criterion values and the maximum value in the criterion column. Thus, can completely distort the results of the analysis. The utility-based methods MOORA and COPRAS also use matrix normalization for decision making, the criteria can be of costs or of benefits. COPRAS separately evaluates influence of maximized and minimized criteria. It could be concluded that the SIMUS method is the most suitable multi-criteria method as based on linear programming it can assessed different quantitative and qualitative criteria and alternatives considering all criteria. There is also software that can solve SIMUS procedure.

The research propose PESTLE – SWOT – SIMUS approach as the most suitable to assess the alternatives and criteria. The advantages of application the SIMUS technique with PESTLE – SWOT criteria consists in the lack of subjectivism in decision making because the weights of criteria are not used, consideration the criteria as objectives in Linear programming optimization models. The PESTLE criteria are presented as objectives and the ranking of the alternatives of strategic planning is conducted without the use of subjective expert evaluation. The results of SIMUS ranking are compared with distance based, utility based and outranking multi-criteria approaches to make decision. These methods use weights of criteria in their procedures. In this research these weights have been set based on the results given by SIMUS method. The weights of criteria in PESTLE groups have been determined based on the results given by linear optimization in SIMUS, and the set of alternatives to evaluate. This approach depends of the data, there is not a subjectivism. It was found that the most important are the political (0.29), social (0.25) and technological (0.25) groups in PESTLE analysis. By establishing dependencies between PESTLE and SWOT groups criteria, the weights of Strengths - Weaknesses – Opportunities – Threats has been determined. It was found that the main importance in SWOT groups have Weakness (0.42) and Opportunities (0.38) groups criteria. The independences between PESTLE criteria and technical, economic, technological and environmental (TETE) criteria were determined. It was found that the main impact for TETE groups criteria has technical (0.29) and technological (0.51) criteria. It could be summed based on PESTLE and TETE analysis that the technological criteria have of great importance when choosing a strategy for railway development. The most suitable strategy for Bulgarian railway passenger transport has been proposed, including the service with motorail trains.

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Conflict of interest

The author declares no conflict of interest.

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