Study of Criteria for Evaluating the Development of Intermodal Services of the Type "Car on the Train" by Applying SWOT Analysis and Best-Worst Method

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Abstract

This paper aims to propose a methodology for assessing the criteria for the effectiveness of transportation of intermodal services "car on the train" named also motorail trains. 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 study proposes a methodology based on the combination of Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis and multi-criteria Best-Worst method (BWM) to evaluate different criteria for assessment the motorail transportation. The methodology of the research includes two steps. The first step includes the SWOT analysis to identify strengths, weaknesses, opportunities, and threats related to passenger railway transport. The sub-criteria for each SWOT group has been defined. A total of 31 sub-criteria are included in this study. The second step includes the determination of the weights of the main criteria and sub-criteria. The Best Worst Method (BWM) which is based on a linear programming method has been applied. It was found that the main importance for SWOT group has the strengths group criteria. The methodology could be applied to evaluate different alternatives of development of passenger railway transport based on defined criteria, sub-criteria and their weights.
KEY WORDS: *SWOT analysis, BWM, multi-criteria analysis, passenger, car, train, motorail, railway transport*

1. Introduction

The intermodal services of the type "car on the train" are also called a car shuttle train, car-carrying train or auto trains. This technology allows passengers to transport from door to door their car. This service is common in many countries. The motorail services are available for both domestic and international transport in many European countries. Some regular day and night trains include car-carrier wagons.

It is important to evaluate the effectiveness of the introduction of this technology by analyzing predefined criteria. The intermodal service of the type "car on the train" offers a number of advantages for users such as: passenger comfort, opportunity to use free time, safety and security, environmental protection.

This paper aims to propose and assess the criteria for evaluating the service "car on the train".

The SWOT analysis as a strategic planning technique to identify strengths, weaknesses, opportunities, and threats related to the investigated system. The strengths and weaknesses are internal parameters, while the opportunities and threats focus on the external environment. The SWOT analysis is an appropriate means to study the sub-criteria related to the four parameters.

The SWOT analysis has been used by authors to make research on different purposes. The SWOT analysis has been applied to select a logistic strategy [1], public transport [2], and other research fields and decision-making activities [3-5]. The scenario for rail freight development, based on a detailed SWOT has been studied in [6]. SWOT analysis is used to analyse inner and external factors of intercity mass transit, [7]. Thirteen sub-criteria have been defined in SWOT groups and assessed by using AHP method. In [8] the Bus Rapid Transit transport has been analysed based on SWOT analysis. The questionnaires have been applied and the results have been modelled based on SWOT technique.

It should be noted that some authors only define the criteria in SWOT groups, while other authors additionally determine the weights of the criteria using multicriteria analysis methods.

The novel contribution of this paper is the elaboration of a methodology for assessing the effectiveness of the development of motorail service. The methodology consists of two steps. In the first step, the criteria in each SWOT group have been defined. In the second step, the weights of criteria have been assessed based on Best – Worst Method.

2. Methodology

This paper proposes a new integrated approach based on the combination of SWOT analysis and Best-Worst method for multicriteria analysis.

The methodology includes the following steps:

- Step 1: Defining the criteria for decision making. This step of methodology uses SWOT analysis as a strategic planning technique to identify strengths, weaknesses, opportunities, and threats related to the investigated system. This study proposes the following sub-criteria for each SWOT group:
  - Internal strengths (IS): IS1 - Opportunity to use a restaurant; IS2 -Availability of free Time; IS3-Ability

to use the Toilet; IS4 - Ability to use travel time for other activities; IS5 - Opportunity to sleep and rest; IS6 - Ability to move during the trip; IS7- Security and safety of travel; IS8-Eco-friendly transport.

- Internal weaknesses (IW): IW1- Availability of loading and unloading operations; IW2 - Option for theft; IW3 -Lack of specialized wagons; IW4 - Poor customer reputation; IW5 - Increase in total transport time due to additional handling operations; IW6 - Extra fees; IW7 - Low frequency of the trains; IW8 - Transportation only in certain months.
- External opportunities (EO): EO1- Priority development of rail transport in the European Union; EO2 - Make rail transport a national priority; EO3 - Increasing competitiveness of rail transport generated by the technological development of the sector; EO4 - Development of intercity train services; EO5 - Increasing the speed of trains after the reconstruction of the railway infrastructure; EO6- High toll road taxis.
- External threats (ET): ET1 - Increased motorway speed (shorter journey); ET2 - Improving the condition of the road infrastructure; ET3 - Increasing the share of bus and coach transport; ET4 -Permanent decline in fuel prices; ET5 - Poor condition of the railway infrastructure and delays in the implementation of infrastructure projects; ET6 - Existing rail infrastructure does not allow the development of speeds that make the service offered competitively; ET7 - High rental rates for specialized cars; ET8 – The reduced financial opportunity to purchase specialized wagons; ET9 - Insufficient interest in customer service.

- Step 2: Determination of the weights of criteria.

This study applied the BWM method to calculate the weights of criteria. This approach uses a pairwise comparison of the criteria. The decision maker identifies the most important criterion called best, and the criterion with the opposite role called worst. The method uses linear programming to define the criteria weights. The methodology of BWM consist of the following steps, [9, 10]:

- Determination of the best and worst criteria.
- Determination of the preference of the best criterion over all the other criteria.
- Determination of the preference of each of the other criteria over the worst criterion.
- Determination of the weights.

The experts give their preferences by using a linguistic scale for pairwise comparison for BWM. The scale includes numbers between 1 and 9. Score 1 shows that the compared criteria have the same importance. The value 9 presents extreme importance. Table 1 presents the linguistic scale.

Table 1

Linguistic scale for pairwise comparison for BWM

Scale	Score	Scale	Score
Equally important	1	Strongly more important	5
Equal to moderately more important	2	Strongly to very strongly important	6
Moderately more important	3	Very strongly more important	7
Moderately to strongly important	4	Very strongly to extremely more important	8
		Extremely more important	9

The results Best-to-Others vector is as follow:

$$A_B = (a_{B1}, a_{B2}, ..., a_{Bn}), \tag{1}$$

where a_{Bj} – preference of the best criterion *B* over criterion *j*. In this case, a_{BB}=1.

The results Others-to-Worst vector is as follow:

$$A_W = (a_{1W}, a_{2W}, ..., a_{nW})^T, \tag{2}$$

where a_{jW} – preference of the criterion *j* over the worst criterion *W*. In this case, a_{WW}=1.

The following minimax model is formulated to determine the weights of criteria:

$$\min_j \max \left\{ \left| w_B - a_{Bj}.w_j \right|, \left| w_j - a_{jW}.w_W \right| \right\}; \tag{3}$$

$$\sum_{j=1}^{n} w_j = 1; \tag{4}$$

$$w_j \geq 0, \text{ for all } j = 1, ..., n, \tag{5}$$

where w_j – weights of criteria, $j = 1,...,n$.

The model given by formulas (3) – (5) is solved by transferring to linear optimization model as follow:

$$\min \xi^L; \tag{6}$$

$$\left| w_B - a_{Bj}.w_j \right| \le \xi^L, \text{ for all } j; \tag{7}$$

$$\left| w_j - a_{jW}.w_W \right| \le \xi^L, \text{ for all } j; \tag{8}$$

$$\sum_{j=1}^{n} w_j = 1; \tag{9}$$

$$w_j \ge 0, \text{ for all } j = 1,\ldots,n. \tag{10}$$

The model given by formulas (6) – (10) is linear and has a unique solution. The optimal weights $(w_1^*, w_2^*,\ldots,w_n^*)$ and optimal value ξ^* are obtained. The value ξ^* is defined as the consistency ratio of the system. A value closer to zero is desired for consistency.

3. Results and Discussion

The BWM method has been applied to determine the weights of SWOT criteria and sub-criteria. Six experts, two specialists from academia and four specialists from BDZ Passengers service LTD, have been made group assessment of criteria using scale 1-9, (Tab.1)

The assessment starts with the main SWOT criteria. The criterion Internal strengths (IS) have been selected by the experts as the best criterion. The criterion External opportunities (EO) has been determined as the worst criterion. Table 2 and Table 3 present the pairwise comparison for the best and the worst criterion.

Table 2

Pairwise comparison vector for the best criterion for main criteria

Best to Others	Internal strengths (IS)	Internal weaknesses (IW)	External opportunities (EO)	External threats (ET)
Internal strengths (IS)	1	2	3	3

Table 3

Pairwise comparison vector for the worst criterion for main criteria

Others to the Worst	External opportunities (EO)
Internal strengths (IS)	3
Internal weaknesses (IW)	2
External opportunities (EO)	1
External threats (ET)	2

For the main group Internal strengths (IS), the sub-criterion Security and safety of travel (IS7) has been determined as the best; the sub-criterion Opportunity to use a restaurant (IS1) has been determined as the worst. Table 4 and Table 5 presents the pairwise comparison.

Table 4

Pairwise comparison vector for the best criterion for Internal strengths (IS)

Criteria Best to Others	IS1	IS2	IS3	IS4	IS5	IS6	IS7	IS8
IS7-Security and safety of travel	3	3	4	2	2	2	1	2

Table 5

Pairwise comparison vector for the worst criterion for Internal strengths (IS)

Criteria Others to the Worst	IS1- Opportunity to use a restaurant
IS1- Opportunity to use a restaurant	1
IS2 - Availability of free Time	4
IS3 - Ability to use the Toilet	1
IS4 -Ability to use travel time for other activities	4
IS5 - Opportunity to sleep and rest	4
IS6 - Ability to move during the trip	3
IS7- Security and safety of travel	4
IS8 - Eco-friendly transport	3

For the main group Internal weaknesses (IW), the sub-criterion Lack of specialized wagons (IW3) has been determined as the best; the sub-criterion Extra fees (IW6) has been determined as the worst. Table 6 and Table 7

presents the pairwise comparison. For the main group External opportunities (EO), the sub-criterion Increasing the speed of trains after the reconstruction of the railway infrastructure (EO5) has been determined as the best; the sub-criterion High toll road taxis (EO6) has been determined as the worst. Table 8 and Table 9 presents the pairwise comparison. For the main group External threats (ET), the sub-criterion Increased motorway speed (ET1) has been determined as the best; the sub-criterion Increasing the share of bus and coach transport (ET3) has been determined as the worst. Table 10 and Table 11 presents the pairwise comparison.

Table 6

Pairwise comparison vector for the best criterion for Internal weaknesses (IW)

Criteria Best to Others	IW1	IW2	IW3	IW4	IW5	IW6	IW7	IW8
IW3 - Lack of specialized wagons	3	4	1	3	3	3	2	2

Table 7

Pairwise comparison vector for the worst criterion for Internal weaknesses (IW)

Criteria: Others to the Worst	IW6 - Extra fees
IW1- Availability of loading and unloading operations	1
IW2 - Option for Theft	1
IW3 - Lack of specialized wagons	3
IW4 - Poor customer reputation	2
IW5 - Increase in total transport time due to additional handling operations	3
IW6 - Extra fees	1
IW7 - Low frequency of the trains	4
IW8 - Transportation only in certain months	2

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Table 8

Pairwise comparison vector for the best criterion for External opportunities (EO)

Criteria Best to Others	EO1	EO2	EO3	EO4	EO5	EO6
EO5 - Increasing the speed of trains after the reconstruction of the railway infrastructure	1	1	3	1	1	3

Table 9

Pairwise comparison vector for the best criterion for External opportunities (EO)

Criteria Others to the Worst	EO6 - High toll road taxis
EO1 - Priority development of rail transport in the European Union	3
EO2 - Make rail transport a national priority	3
EO3 - Increasing competitiveness of rail transport generated by technological development of the sector	2
EO4 - Development of intercity train services	3
EO5 - Increasing the speed of trains after the reconstruction of the railway infrastructure	4
EO6 - High toll road taxis	1

Table 10

Pairwise comparison vector for the best criterion for External threats (ET)

Criteria Best to Others	ET1	ET2	ET3	ET4	ET5	ET6	ET7	ET8	ET9
ET1 - Increased motorway speed (shorter journey)	1	1	2	3	2	2	3	3	3

Table 11

Pairwise comparison vector for the best criterion for External threats (ET)

Others to the Worst	ET3 - Increasing the share of bus and coach transport
ET1 - Increased motorway speed (shorter journey)	3
ET2 - Improving the condition of the road infrastructure	3
ET3 - Increasing the share of bus and coach transport	4
ET4 - Permanent decline in fuel prices	1
ET5 - Poor condition of the railway infrastructure and delays in the implementation of infrastructure projects	4
ET6 - Existing rail infrastructure does not allow the development of speeds that make the service offered competitive	4
ET7 - High rental rates for specialized cars	3
ET8 - Reduced financial opportunity to purchase specialized wagons	3
ET9 - Insufficient interest in customer service	3

The values of Consistency ξ^* for the main criteria and sub-criteria are shown in Table 12. It can be seen that these values are closer to zero, which shows a high degree of consistency.

Table 12

Values of Consistency for main criteria and sub-criteria

Table	Main criteria	IS	IW	EO	ET
ξ^*	0.07	0.08	0.07	0.03	0.05

The weights of the main criteria and sub-criteria are determined according to linear optimization model (formulas 1-10) by using Solver in Excel. Table 13 shows the weights of the main SWOT group criteria, local weights for each group and the global weights of sub-criteria. The global weights present the priority of all sub-criteria taking into account the weights of the main criteria.

Table 13

Local and global weights of main criteria and sub-criteria

Main criteria	Weight	Sub-criteria	Local weight	Global weight	Main criteria	Weight	Sub-criteria	Local weight	Global weight
		IS1	0.044	0.019			EO1	0.207	0.026
		IS2	0.096	0.043			EO2	0.207	0.026
		IS3	0.072	0.032			EO3	0.080	0.010
		IS4	0.144	0.064			EO4	0.207	0.026
		IS5	0.144	0.064			EO5	0.241	0.030
		IS6	0.144	0.064	External		EO6	0.057	0.007
Internal		IS7	0.210	0.093	opportunities		-	-	-
strengths (IS)	0.444	IS8	0.144	0.064	(EO)	0.123	-	-	-
		IW1	0.057	0.015			ET1	0.183	0.032
		IW2	0.078	0.020			ET2	0.183	0.032
		IW3	0.241	0.063			ET3	0.118	0.020
		IW4	0.104	0.027			ET4	0.043	0.007
		IW5	0.104	0.027			ET5	0.118	0.020
		IW6	0.104	0.027			ET6	0.118	0.020
Internal		IW7	0.156	0.040			ET7	0.079	0.014
weaknesses		IW8	0.156	0.040	External threats		ET8	0.079	0.014
(IW)	0.259	-	-	-	(ET)	0.173	ET9	0.079	0.014

Fig. 1 illustrates the weights of the main SWOT group criteria. It can be seen that the main importance of SWOT group has IS - Internal strengths, (0.444).

Fig. 2 presents the global weights of all sub-criteria. It can be seen that the main importance have the criteria: IS7 - Security and safety of travel (0.093), IW3 - Lack of specialized wagons (0.063); IS4 - Ability to use travel time for other activities (0.064), IS5 - Opportunity to sleep and rest (0.064); IS6 - Ability to move during the trip (0.064); IS8 - Eco-friendly transport (0.064).

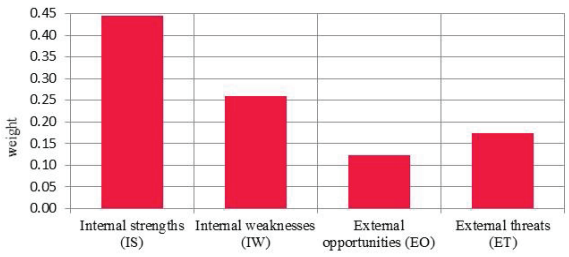

Fig. 1 Weights of main SWOT criteria

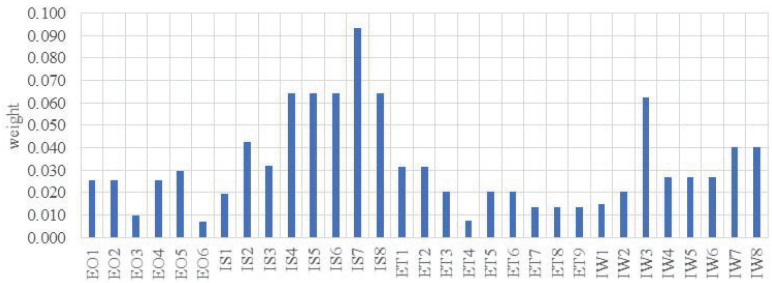

Fig. 2 Weights of the sub-criteria

3. Conclusions

In this research has been developed a methodology for evaluating the development of intermodal services of the type "car on the train" by applying SWOT analysis and Best-Worst method. The sub-criteria related to the strengths, weaknesses, opportunities and threats have been defined. Thirty-one sub-criteria have been defined in SWOT groups. It was found that the main importance of SWOT group has the IS - Internal strengths, (0.444). The main importance has the sub-criteria: IS7- Security and safety of travel (0.093), IW3 - Lack of specialized wagons (0.063); IS4 - Ability to use travel time for other activities (0.064), IS5 - Opportunity to sleep and rest (0.064); IS6 - Ability to move during the trip (0.064); IS8 - Eco-friendly transport (0.064). The received results for the weights of criteria could be used to rank the alternatives of transportation by motorail trains. In this case, an application of other multi-criteria methods is needed.

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