SUSTAINABLE TRANSPORTATION MODE SELECTION FROM THE FREIGHT FORWARDER'S PERSPECTIVE IN TRADING WITH WESTERN EU COUNTRIES

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Abstract: *The transportation mode selection problem is one of the most significant problems that logistics companies and freight forwarders face. The complexity of this problem is reflected in a large number of factors that affect the choice of an adequate mode of transport. In order to facilitate the decision-making process when choosing, the aim of this paper is to propose an approach for selecting sustainable transportation mode when trading with western EU countries using the Multi-Criteria Decision-Making (MCDM) methods, i.e., SWARA (Stepwise Weight Assessment Ratio Analysis) and MARCOS (Measurement Alternatives and Ranking according to Compromise Solution) methods. SWARA was used to determine the weights of the criteria, while MARCOS was used for the final ranking of the alternatives. In this paper, 9 criteria and 5 alternatives for the realization of transport from Serbia to Germany were observed. The results of the described methodology showed that road transport (via the Horgoš border crossing) proved to be the alternative with the best value, while road transport via the Batrovci border crossing proved to be the alternative with the worst value.*

Keywords*: mode selection, transport, sustainable logistics, SWARA, MARCOS*

1. INTRODUCTION

The organization of the international commodity flows is a complex task due to a large number of activities, participants, and documents. As this process requires knowledge of customs procedures, many companies leave this task to freight forwarders. One of the key problems that freight forwarders face on that occasion is the choice of transportation mode that will be used to realize the observed flow. The choice of an adequate transportation mode is influenced by a number of factors, such as the transportation time, costs, impact on the environment, infrastructure, retention at the border crossing, etc. Given that the awareness of environmental protection is at a high level in recent years, an increasing number of freight forwarders are striving for more environmentally friendly

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solutions for the realization of transport. On the other hand, in addition to this, freight forwarders can have an impact on the sustainability of a company's business, given that they are responsible for foreign and international trade with foreign company's partners. In addition to this impact, the choice of an adequate transportation mode can also have an impact on the company's competitiveness in terms of time and costs. For all previously mentioned reasons, freight forwarders pay great attention to solving the problem of choosing a transportation mode for the realization of commodity flows.

Given that the choice of an adequate transportation mode can have a crucial impact on the efficiency of a flow but also on the competitiveness of a company, the aim of this paper is to propose an approach based on Stepwise Weight Assessment Ratio Analysis-Measurement Alternatives and Ranking according to Compromise Solution (SWARA-MARCOS) methods for selecting a sustainable transportation mode from the perspective of freight forwarders in trade with western EU countries. The proposed model represents some kind of Decision Support System (DSS) tool for practitioners and also the basis for future research in the literature. In order to evaluate and select an appropriate transportation mode, evaluation criteria must be defined first. In this paper, 9 criteria were defined which were then used to evaluate 5 transportation modes. Since every criterion is not of the same importance, a SWARA method was used in order to determine the weight of each criterion. Obtained criteria weights were then used in the MARCOS method in order to determine the final ranking. The SWARA method is useful when there is a need to determine the weight of each criterion based on the experience and knowledge of the experts. In order to determine weights, experts' must first rank criteria from the most significant to the least significant. MARCOS method is based on defining the relationship between alternatives and reference values which are ideal and anti-ideal values. Next, utility functions of alternatives are determined as well as compromise ranking which is made in relation to ideal and anti-ideal values. The utility function is determined because it represents the position of alternative in relation to the ideal and anti-ideal solutions. The alternative that is closest to the ideal and at the same time furthest from the anti-ideal solution is the best according to this method.

The paper is organized as follows. After the introduction, a description of the problem is given as well as a review of the literature. In the next section of the paper, the methodology used in this paper is presented, which refers to the SWARA and MARCOS methods. The following section presents the results of the application of the described methodology. The last section provides concluding remarks as well as directions for future research.

2. PROBLEM DESCRIPTION AND LITERATURE REVIEW

Foreign trade is one of the most important branches of a country. On that occasion, two types of international trade can be distinguished, namely import and export. Numerous companies hire freight forwarders who have adequate knowledge and resources for organizing import-export commodity flows. After the engagement, the task of the freight forwarder is to determine the most efficient way of realizing that flow in order to keep the total costs as low as possible, with the shortest possible time of realization, in order to ensure the company's competitiveness in the market. When organizing a flow, one of the key things is to choose the appropriate transportation mode that will be used to perform the transport. On that occasion, it is necessary to take into account several elements that may affect the cost and time of realization of the flow. In addition to these impacts, in recent years more and more importance is given to the impact of a certain type of transportation mode on the environment, given that transport is one of the largest sources of pollution. Namely, although trucks account for less than 2% of the vehicles in Europe, they made up to 23% of the CO2 emissions from road transport in 2019. On the other side, the fastest-growing source of CO2 emissions from transport is vans, which now account for 13% of road transport carbon pollution in the EU (Transport Environment, 2022). For this reason, certain logistics companies are investing in new environmentally-friendly vehicles (such as vans that run on electricity). As the goal is to reduce the emission of harmful gases as well as the pollution caused by transport, this paper also defines the sustainability criteria that were used to evaluate the alternatives.

The problem of choosing a sustainable transportation mode has been recognized in the literature where there are papers that deal with this problem. Kundu et al. (2017) proposed a fuzzy multi-criteria group decision-making method based on ranking interval type-2 fuzzy variables for transportation mode selection. Hoen et al. (2014) determined the effect of carbon emission regulations on transport mode selection under stochastic demand, where they took into account emission costs as well. Also, Fulzele et al. (2019) proposed a model for the selection of transportation modes in the context of sustainable freight transportation. The authors in this paper used an integrated grey relational analysis based intuitionistic fuzzy multi-criteria decision-making process and fuzzy multi-objective linear programming model. Zheng et al. (2016) in their paper observed both optimum pricing and order quantities, considering consumer demand and the selection of transportation modes by retailers, in terms of carbon emissions sensitivity and price sensitivity under the conditions of a cap-and-trade policy and uncertain market demand. A multi-objective optimization model for green supply chain network design for transportation mode selection was proposed in the paper by Gong et al. (2017). Namely, the proposed model considered both cost and environmental protection when the authors designed a multi-objective optimization model. In their paper, the authors considered four transportation modes, road, rail, air, and sea. Andrejić et al. (2013) in their paper estimated the energy efficiency of transport modes in Serbia by applying data envelopment analysis (DEA). Based on the literature review, it was determined that there are no papers that take the time of customs clearance as one of the criteria when evaluating different types of transportation modes. For that reason, in this paper, this criterion was used during the evaluation. Also, the goal was to propose a model for choosing a sustainable transportation mode but from the perspective of freight forwarders.

The aim of this paper was to select a sustainable transportation mode taking into account 9 criteria, of which 8 were taken from the literature and one was defined by the authors. On that occasion, the choice of mode from the perspective of freight forwarders in trade with western EU countries was observed, given that trade is very pronounced with western EU countries, which can be seen from the data presented in Table 1. Based on data it can be seen that the largest trade in the previous 7 months was realized with Germany, and for that reason, this country is considered as the destination country of the flow that was considered in this paper. For the realization of this flow, 5 alternatives were considered, of which 1 is realized by air transport, 2 by road, 1 by inland waterways, and 1 by rail.

The criteria used in this paper in order to rank alternatives are costs (C1), transportation time (C2), customs clearance time (C3), lead time (C4), transport energy consumption (C5), greenhouse gas emissions as CO_2 (C6), flexibility (C7), capacity (C8) and traffic congestion (C9).

Table 1. Foreign trade (Statistical office of the Republic of Serbia, 2022)

Period	Export (in mil €)				
	Germany	Italy	Bosnia and Herzegovina	Romania	Hungary
Aug-21	1718.6	1146	969.8	835.1	708.8
Sep-21	1971.3	1339	1120.2	930.6	800.9
Oct-21	2233.6	1524	1269.8	1020.6	903.6
Nov-21	2512.4	1696	1412.3	1111.3	1001.2
Dec-21	2743.3	1840	1562	1189	1088.9
Jan-22	243.7	148.1	108.9	-	92.6
Feb-22	516.2	315.3	257.7	162.4	193.4

The cost of the organization and the transport of goods on the route Serbia-Germany was observed under the costs. Transport time represents the time that elapses from the moment of dispatch of goods to the moment of delivery, not counting the time of detention of vehicles at the border crossing. Customs clearance time represents the time that elapses from the arrival of the vehicle at the border crossing until the end of all export customs procedures. Given that these times are different for each transportation mode, and that they can significantly affect the competitiveness of individual modes, the authors decided to take into account this criterion as well. In this paper lead time is defined as the sum of the average time the vehicle spends waiting in line at the border and dispatch of goods (the time that elapses from the moment of completion of export customs procedure to the moment of further dispatch of goods). Transport energy consumption and greenhouse gas emissions as CO_2 are criteria that are considered as a form of sustainability. Flexibility implies the possibility of adapting a certain type of transport to the new demands. Traffic congestion implies all congestion that is a consequence of a certain type of transport that can affect the increase in lead time, and for this reason, it was observed in this paper. The last criterion is the capacity of one vehicle in a certain type of transport, i.e., the amount of goods that can be transported by the vehicle during one delivery.

3. METHODOLOGY

In order to select the appropriate sustainable transportation mode, MARCOS method was used in this paper. In order to determine the weights of the observed criteria, a SWARA method was used (which were then used in the MARCOS method). The methodological steps of the application of these methods are presented below.

3.1. SWARA method

The procedure for the determination of weights by SWARA method includes the following steps (Radović and Stević, 2018; Pajić et al., 2021a):

Step 1 – All criteria should be sorted in descending order based on their significance evaluated by experts.

Step 2 – Starting from the second criterion, experts express the relative importance of criterion *j* in relation to the *j+1* criterion. This way the comparative importance of average value (S_j) is determined for each criterion.

Step 3 – Determine the coefficient k_j as follows:

$$k_j = \begin{cases} 1 & , j = 1 \\ s_j + 1 & , j > 1 \end{cases} \tag{1}$$

Step 4 – Determine the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & , j = 1 \\ \frac{q_{j-1}}{k_j} & , j > 1 \end{cases} \tag{2}$$

Step 5 – Calculate the weight values of criteria as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{3}$$

where w_j represents the relative weight value of the criterion *j*.

3.2. MARCOS method

The procedure for the determination of the final ranking of variants by the MARCOS method includes the following steps (Stević et al., 2020):

Step 1: Formation of an initial decision-making matrix including *n* criteria and *m* alternatives.

Step 2: Formation of an extended initial matrix by defining the ideal (*AI*) and anti-ideal (*AAI*) solution.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \dots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{array} \tag{4}$$

The anti-ideal solution (*AAI*) is the worst alternative while the ideal solution (*AI*) is an alternative with the best characteristics. Depending on the criteria nature, *AAI* and *AI* are determined using equations (5) and (6):

$$AAI = \min_i x_{ij} \text{ if } j \in B \text{ and } \max_i x_{ij} \text{ if } j \in C \tag{5}$$

$$AI = \max_i x_{ij} \text{ if } j \in B \text{ and } \min_i x_{ij} \text{ if } j \in C \tag{6}$$

where *B* represents benefit criteria while *C* represents cost criteria.

Step 3: Normalization of the extended initial matrix by applying equations (7) and (8):

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C \quad (7)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \quad (8)$$

where elements x_{ij} and x_{ai} represent the elements of the matrix X.

Step 4: Determination of the weighted matrix $V=[v_{ij}]_{mxn}$ by multiplying the normalized matrix N with the weight coefficients of the criterion (9).

$$v_{ij}=n_{ij} \times w_j \quad (9)$$

Step 5: Calculation of the utility degree of alternatives K_i by applying equations (10) and (11) in relation to the anti-ideal and ideal solution.

$$K_i^- = \frac{S_i}{S_{aai}} \quad (10)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (11)$$

where S_i ($i=1, 2, \ldots, m$) represents the sum of the elements of the weighted matrix V, equation (12).

$$S_i = \sum_{i=1}^{n} V_{ij} \quad (12)$$

Step 6: Determination of the utility function of alternatives $f(K_i)$. The utility function is the compromise of the observed alternative in relation to the ideal and anti-ideal solution and is calculated by applying equation (13).

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad (13)$$

where $f(K_i^-)$ represents the utility function in relation to the anti-ideal solution, while $f(K_i^+)$ represents the utility function in relation to the ideal solution, equations (14) and (15).

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (14)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (15)$$

Step 7: Ranking the alternatives based on the values of utility functions where alternative with the highest value is the most desirable.

4. RESULTS

In order to determine the final ranking of alternatives, first, it is necessary to determine the weight of each of the observed criteria. Criteria were first ranked according to the importance by experts (from the most important to the least important), after which the other steps of the SWARA method were implemented. In the evaluation of the criteria, 10 experts were involved (including experts with years of experience in trading with western EU countries as well as professors). In order to get one value for every criterion, the geometric mean of the judgments was used (Pajić et al., 2021b). The results of the application of the SWARA method are presented in Table 2.

Table 2. Results of the SWARA method

Criteria	S_j	$K_j = S_j+1$	Q_j	w_j
Costs	-	1	1	0.162
Transportation time	0.03	1.03	0.971	0.157
Customs clearance time	0.07	1.07	0.907	0.147
Lead time	0.11	1.11	0.817	0.132
Transport energy consumption	0.32	1.32	0.619	0.100
Greenhouse gas emissions as CO2	0.05	1.05	0.590	0.096
Flexibility	0.17	1.17	0.504	0.082
Capacity	0.14	1.14	0.442	0.072
Traffic congestion	0.37	1.37	0.323	0.052
Σ			6.174	

Based on the results of Table 2, it can be concluded that costs and transportation time with a weight of 0.162 and 0.157 respectively are the two most significant criteria, while capacity and traffic congestion are the two least significant criteria with a weight of 0.072 and 0.052 respectively. After determining the weights of the criteria, the MARCOS method was applied in accordance with equations (4)-(15). In this paper, as mentioned, 5 alternatives were observed. The first alternative involves air transport (A1), the second road transport (via the border crossing Horgoš – A2), and the third also involves road transport (but in this case via the border crossing Batrovci – A3). The fourth alternative involves inland waterway transport (A4), while the last alternative involves rail transport (A5). The values of alternatives by criteria were determined as follows. The costs (C1) are defined on a scale from 1 to 5 in accordance with a certain mode of transport (where the costs of the realization of the flow, i.e., transport) were observed. For that reason, A1 has the highest value (thus it is the worst value). On the other hand, A2 and A4 have the best values according to this criterion, considering that the costs according to these alternatives are the lowest. The values of criterion C2 are determined on the basis of transport time from Belgrade to Frankfurt. The values of criteria C3 and C4, for alternatives A1, A2 and A3, were determined based on the data of the study which was provided by the Customs administration, which measured the time required for import-export procedures, where in this case the time required for export procedures were only observed (Customs Administration, 2021). The values for alternatives A4 and A5 were determined based on the assessment of experts in the field of inland waterway and railway transport. The values for criteria C5 and C6 were determined on the basis of data on transport energy consumption and greenhouse gas emissions as CO2 on the route Serbia-Germany (Ecotransit, 2022). Values for the last 3 criteria (C7-C9) were also determined on a scale of 1-5. In terms of flexibility (C7), alternatives A2 and A3 have the best values since they represent road transport, while alternative A4 has the worst value. The values of the capacity criterion (C8) are determined on the basis of data on the quantity of goods that can be transported by one vehicle in one delivery, where it was estimated that alternatives A4 and A5 have the best value and alternatives A2 and A3 have the worst. The values for the last criterion (traffic congestion – C9) are determined on the basis of congestion that can occur in a certain mode of transport (both during transport and customs clearance) where alternative A2 has the worst value while the A1 has the best (Table 3).

Table 3. An extended initial matrix

	C1	C2 (min)	C3 (min)	C4 (min)	C5 (megajoule)	C6	C7	C8	C9
type	**min**	**min**	**min**	**min**	**min**	**min**	**max**	**max**	**min**
AAI	5	12971	320	1450	1449419	107.14	2	1	5
A1	5	110	77	1370	1449419	107.14	4	3	1
A2	1	791	143	162	132408	9.55	5	1	5
A3	2	890	244	210	148979	10.74	5	1	4
A4	1	12971	320	1450	68347	4.9	2	5	2
A5	3	1055	300	1120	56500	2.51	3	5	3
AI	1	110	77	162	56500	2.51	5	5	1

After determining the extended initial matrix using equations (5) and (6), equations (7) and (8) were applied to determine the normalized matrix which was then used in the further steps of the MARCOS method (Table 4).

Table 4. Normalized matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
AAI	0.2	0.008	0.241	0.112	0.039	0.023	0.4	0.2	0.2
A1	0.2	1	1	0.118	0.039	0.023	0.8	0.6	1
A2	1	0.139	0.538	1	0.427	0.263	1	0.2	0.2
A3	0.5	0.124	0.316	0.771	0.379	0.234	1	0.2	0.25
A4	1	0.008	0.241	0.112	0.827	0.512	0.4	1	0.5
A5	0.333	0.104	0.257	0.145	1	1	0.6	1	0.333
AI	1	1	1	1	1	1	1	1	1
w_j	0.162	0.157	0.147	0.132	0.100	0.096	0.082	0.072	0.052

Values from the normalized decision-making matrix were then multiplied with the weight coefficients of the criteria, by applying equation (9), in order to determine the weighted normalized matrix. Obtained values are presented in Table 5.

Table 5. Weighted normalized matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
AAI	0.032	0.001	0.035	0.015	0.004	0.002	0.033	0.014	0.010
A1	0.032	0.157	0.147	0.016	0.004	0.002	0.065	0.043	0.052
A2	0.162	0.022	0.079	0.132	0.043	0.025	0.082	0.014	0.010
A3	0.081	0.019	0.046	0.102	0.038	0.022	0.082	0.014	0.013
A4	0.162	0.001	0.035	0.015	0.083	0.049	0.033	0.072	0.026
A5	0.054	0.016	0.038	0.019	0.100	0.096	0.049	0.072	0.017
AI	0.162	0.157	0.147	0.132	0.100	0.096	0.082	0.072	0.052

Afterward, values presented in Table 5, were used in equations (10)-(15) in order to determine the utility functions of each alternative as well as the final rank of the alternatives (Table 6).

Table 6. Final ranking

	Si	Ki-	Ki+	f(Ki-)	f(Ki+)	f(Ki)	Final rank
AAI	0.14747503						
A1	0.519	3.519	0.519	0.129	0.871	0.509	**2**
A2	0.570	3.863	0.570	0.129	0.871	0.559	**1**
A3	0.418	2.837	0.418	0.129	0.871	0.411	**5**
A4	0.476	3.226	0.476	0.129	0.871	0.467	**3**
A5	0.461	3.127	0.461	0.129	0.871	0.453	**4**
AI	1						

Final ranking of the alternatives can be shown as A2 > A1 > A4 > A5 > A3. Based on the results presented in Table 6, it can be concluded that A2 represents the best variant according to the MARCOS method.

5. CONCLUSION

A review of the literature established that there is a need for DSS tools regarding the observed problem. The importance of the correct choice of mode becomes even more important when the impact of a certain mode on the environment is included. For this reason, the subject of this research was to propose an approach for selecting sustainable transportation mode in trading with western EU countries, given that it was found that most of the exported quantity is with these countries. In order to rank the 5 observed alternatives using 9 criteria (costs, transportation time, customs clearance time, lead time, transport energy consumption, greenhouse gas emissions as CO_2, flexibility, capacity, and traffic congestion), SWARA and MARCOS methods were applied in this paper. Namely, as not all criteria are of equal importance, SWARA was applied to determine the weights of the criteria, which were then used in the MARCOS method for the final ranking of alternatives. The results of this paper showed that price and transportation time stood out as the two most significant criteria while capacity and traffic congestion stood out as the two least significant criteria. On the other hand, road transport (via the Horgoš border crossing) proved to be the alternative with the highest value, while road transport via the Batrovci border crossing proved to be the alternative with the worst value.

The proposed methodology of this research can be a good basis for people from practice when selecting sustainable transportation mode in trading with western EU countries. The application of the described methodology in trade with other countries and regions stands out as one of the directions for future research. In addition, the application of the proposed methodology for the selection of sustainable transportation mode for import also stands out as one of the directions of future research, given that in this paper only export from Serbia was observed. Also, the consideration of new alternatives, such as multimodal or intermodal transport when applying the proposed methodology, as well as developing new hybrid approaches suitable for solving these problems, also stand out as a direction for future research.

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