Application of Fuzzy SIWEC And Rough MABAC Methods in the Evaluation of Trade Performance Dynamics in Serbia

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DOI: 10.24818/mer/2025.02-11

ABSTRACT

The issue of trade performance evaluation is very challenging, primarily when it is based on multi-criteria analysis. The goal of this study is to determine as realistically as possible the dynamics of trade performance in Serbia using multicriteria analysis, that is, Fuzzy SIWEC (Simple Weight Calculation) and Rough MABAC (Multi-attributive Border Approximation area Comparison) methods. According to the results of this study, the overall performance of the Serbian trade has been continuously improving. The best was in 2023. This was influenced by the effective management of human capital, assets, capital, sales, and profit. As well as effective control of all relevant macro and micro factors. Let's mention only some of them. Foreign direct investments (i.e., foreign retail chains with new business models) had a positive effect on the continuous improvement of trade performance in Serbia. The digitisation of the entire business is a function of improving Serbia's trade performance. Adequate adaptation to changes in the complex business environment had a positive effect on improving the performance of trade in Serbia.

KEYWORDS: *performance, trade, Serbia, Fuzzy SIWEC, Rough MABAC.*

JEL CLASSIFICATION: *L81, M31, M41, O32.*

1. INTRODUCTION

In today's complex business conditions, the issue of analysis and evaluation of trade performance is becoming more and more important. Especially in the case of applying multicriteria analysis (Aytekin, 2020, 2021, 2022; Ersoy, 2027). The application of multicriteria analysis provides a realistic assessment of trade performance since it is based on a mathematical approach (Lukić, 2021a,b, 2022, 2023a,b). Given that, the goal of this study is to see as realistically as possible the dynamics of Serbia's trade performance based on the Fuzzy SIWEC (Simple Weight Calculation) and Rought MABAC (Multi-attributive Border Approximation area Comparison) methods to improve them in the future by applying relevant measure. In the world, there is an increasingly rich literature devoted to multicriteria analysis of trade performance. This is also the case with the literature in Serbia. All relevant literature serves as a guide in this study for the most realistic evaluation of the dynamics of trade performance in Serbia based on the Fuzzy SIWEC and Rough MABAC methods. In Serbia, high-quality empirical data is available for the analysis and evaluation of trade performance based on a mathematical approach. At the same time, relevant foreign sources can also be used for these purposes. Available relevant literature and available qualitative empirical data contribute to the quality of the analysis of the issue addressed in this study.

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2. METHODOLOGY

The research question in this study is analysed based on the Fuzzy SIWEC and Rough MABAC methods. Using the first method, the significance of the criteria is determined. Using the second method, the ranking of alternatives is performed. The characteristics of these methods are shown below. The specificity of the Fuzzy SIWEC (Simple Weight Calculation) method is that the grades are in the form of linguistic values (Tešić et al., 2024). These values are easier for the decision maker to determine because it is not necessary to determine which criterion should receive a certain grade, whether it is four, five, or three. The question is what to do if, according to the decision maker, the criterion has an intermediate rating, so it is difficult to decide which rating should be given. For this reason, linguistic evaluations are introduced that are closer to the decision maker's thinking. Decision makers give ratings in the form of a linguistic scale that goes, for example, from very poor to very good ratings. In this way, it is easier for decision-makers to give ratings because they can more easily judge whether it is good or not, instead of deciding what numerical value to give. Based on this, the steps of the Fuzzy SIWEC method are as follows (Puska et al., 2024):

Step 1. Determining the importance of the criteria using the decision maker's linguistic ratings. In this step, decision-makers choose a certain linguistic value that determines the importance of the criteria in their opinion.

Step 2. Transformation of linguistic values into fuzzy numbers. In this step, the linguistic values are transformed into corresponding fuzzy numbers using the membership function. The value of the fuzzy numbers is derived through the membership function. Using the example of a fuzzy number triangle, the value of a fuzzy number can be written as follows:

$$\tilde{x}_{ij} = \left(x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u}\right) \tag{1}$$

Where x_{ij}^{l}denotes the first fuzzy number, $x_{ij}^{m}$the second fuzzy number, and $x_{ij}^{u}$the third fuzzy number.

Step 3. Formation of the fuzzy initial decision matrix. In this step, the initial decision matrix is formed based on fuzzy numbers.

$$\tilde{A} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \cdots & \cdots & \ddots & \cdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{2}$$

Where $\tilde{x}_{ij}$it represents the ranking of decision-makers for certain criteria in the form of fuzzy numbers.

Step 4. Normalisation of the initial fuzzy decision matrix. In this step, all fuzzy values are divided by the maximum value of the third fuzzy number $\left(\max\ x_{ij}^{u}\right)$for all criteria and decision-makers.

$$\tilde{n}_{ij} = \frac{x_{ij}^{l}}{max\,x_{ij}^{u}}, \frac{x_{ij}^{m}}{max\,x_{ij}^{u}}, \frac{x_{ij}^{u}}{max\,x_{ij}^{u}} \tag{3}$$

Step 5. Calculation of the standard deviation value for the decision maker $(st.dev_j)$. Here, the value of the standard deviation is calculated for all values of fuzzy numbers for an individual decision-maker.

Step 6. Multiplying normalised scores with standard deviation values.

$$\tilde{v}_{ij} = \tilde{n}_{ij} \; x \; st.dev_j \tag{4}$$

Step 7. Calculation of the sum of weights of individual criteria. Here, the values of all criteria for all fuzzy numbers are added together.

$$\tilde{S}_{ij} = \sum_{j=1}^{n} \tilde{v}_j \tag{5}$$

Step 8. Calculation of fuzzy values of criterion weights. Individual values $\tilde{S}_{ij}$are is divided by the sum of all values. In such a calculation, it is necessary to take into account that the first fuzzy number can be equal to or less than the second fuzzy number, while the second fuzzy number can be less than or equal to the third fuzzy number.

$$\tilde{w}_{ij} = \frac{s_{ij}^{l}}{\sum_{j=1}^{n} s_{ij}^{u}}, \frac{s_{ij}^{m}}{\sum_{j=1}^{n} s_{ij}^{m}}, \frac{s_{ij}^{u}}{\sum_{j=1}^{n} s_{ij}^{l}} \tag{6}$$

The weight value obtained in this way can be used in fuzzy form or defuzzification performed in crips form, depending on how it will be used in the further calculation. If the ranking of the alternatives will be done using the fuzzy method, these weights will be used, and if only the values of the weights are calculated, it is necessary to perform the desification of the weights. This is done as follows:

$$w_{j_{def}} = \frac{w_{ij}^{l} + 4 \; x \; w_{ij}^{m} + w_{ij}^{l}}{6} \tag{7}$$

MABAC (Multi-attributive Border Approximation area Comparison) is a newly developed and widely accepted multi-criteria decision-making method (Pamučar & Ćirović, 2015), which primarily ranks a set of alternatives based on their distance from the border approximation area for each criterion. However, it has been modified over time to develop expedient hybrid models. In this study, MABAC is interpolated with rough numbers that are further fed into a DoE (design of experiments) model (Chattopadhyay et al., 2022; Božanić et al., 2024) to provide a generalized metamodel for evaluating and ranking a set of alternatives (e.g., supplier). Considering a decision problem that has n alternatives $(A_1, A_2, \dots, A_i, \dots, A_n)$ and criteria $(C_1, C_2, \dots, C_j, \dots, C_m)$, the procedural steps of the **Rough MABAC** method are listed below (Chakraborty et al., 2020; Božanić et al., 2024):

Step 1. The decision matrix *X* is constructed using rough numbers while taking into account the judgment of a team of experts/decision-makers when evaluating the relative performance of alternatives (for example suppliers) in terms of evaluation criteria:

$$X = \begin{array}{c} A_1 \\ A_2 \\ M \\ A_n \end{array} \begin{bmatrix} RN(x_{11}) & RN(x_{12}) & \wedge & RN(x_{1m}) \\ RN(x_{21}) & RN(x_{22}) & \wedge & RN(x_{2m}) \\ M & M & M & M \\ RN(x_{n1}) & RN(x_{n2}) & K & RN(x_{nm}) \end{bmatrix} \tag{8}$$

$$= \begin{array}{c} A_1 \\ A_2 \\ M \\ A_n \end{array} \begin{bmatrix} [x_{11}^-, x_{11}^+] & [x_{12}^-, x_{12}^+] & \wedge & [x_{1m}^-, x_{1m}^+] \\ [x_{21}^-, x_{21}^+] & [x_{22}^-, x_{22}^+] & \wedge & [x_{2m}^-, x_{2m}^+] \\ M & M & M & M \\ [x_{n1}^-, x_{n1}^+] & [x_{n2}^-, x_{n2}^+] & K & [x_{nm}^-, x_{bm}^+] \end{bmatrix}$$

where $RN(x_{ij}) = [x_{ij}^-, x_{ij}^+]$.

Step 2. Depending on the type of criteria, the initial decision matrix X is normalised to obtain the corresponding normalised decision matrix $N = [n_{ij}^-, n_{ij}^+]_{n\,x\,m}$.

$$RN(n_{ij}) = \begin{Bmatrix} \left[\frac{x_{ij}^- - x_{ij}^+}{x_j^+ - x_j^-}, \frac{x_{ij}^+ - x_{ij}^-}{x_j^+ - x_j^-}\right]; if\ j \in B, \\ \left[\frac{x_{ij}^+ - x_j^+}{x_j^- - x_j^+}, \frac{x_{ij}^- - x_j^+}{x_j^- - x_j^+}\right]; if\ j \in C, \end{Bmatrix} \quad (9)$$

Where $x_j^+ = \max_i(x_{ij}^+), x_j^- = \min_i(x_{ij}^-)$, B is the set of utility criteria and C is the set of cost criteria.

Step 3. Determine the weight assigned to each criterion $W = (w_1, w_2, \ldots, w_j, \ldots, w_m)$so that $\sum_{j=1}^m w_j = 1$. The weight-normalised decision matrix $Y = [y_{ij}^-, y_{ij}^+]_{n\,x\,m\mathcal{M}}$is now calculated using equation (3):

$$y_{ij}^- = (n_{ij}^- + 1)w_j; y_{ij}^+ = (n_{ij}^+ + 1)w_j, i = 1,2, \ldots, n, j = 1,2, \ldots, m \quad (9)$$

Step 4. The Boundary Approximation Area (BAA) matrix is derived based on the geometric aggregation of the rough numbers.

$$Q = [RN(q_1)\ \ RN(q_2)\ \ \wedge\ \ RN(q_m)]$$

$$q_j^- = \left(\prod_{i=1}^n y_{ij}^-\right)^{1/n}, j = 1,2, \ldots, m \quad (10)$$

$$q_j^+ = \left(\prod_{i=1}^n y_{ij}^+\right)^{1/n}, j = 1,2, \ldots, m$$

Step 5. The Euclidean distance of the alternative from the BAA is estimated based on the difference between the boundary approximation area and the weighted normalised matrix and is presented$K = [RN(k_{ij})]_{n\,x\,m}$.

$$k_{ij} = D(y_{ij}, q_j) = \sqrt{\frac{1}{2}\left((y_{ij}^- - q_j^-)^2 + (y_{ij}^+ - q_j^+)^2\right)}\ if\ RN(y_{ij}) > RN(q_j) \quad (11)$$

$$k_{ij} = -D(y_{ij}, q_j) = -\sqrt{\frac{1}{2}\left((y_{ij}^- - q_j^-)^2 + (y_{ij}^+ - q_j^+)^2\right)}\ if\ RN(y_{ij}) < RN(q_j)$$

Step 6. The considered alternatives are finally ranked in descending order according to $S_{\,and}$ value.

$$S_i = \sum_{j=1}^m k_{ij}\ \ (i = 1,2,\wedge, n) \quad (12)$$

3. RESULTS AND DISCUSSION

When analysing the performance of trade in Serbia using the Fuzzy SIWEC and Rough MABAC methods, the following indicators were used as criteria: C1 – number of employees, C2 – assets, C3 – capital, C4 – sales, and C5 – net profit. It is considered that they are a good measure of the trade's performance, that is, they are in line with the nature of its business. The activities are in the following years: A1 – 2018, A2 – 2019, A3 – 2020, A4 – 2021, A5 – 2022, and A6 – 2023. The necessary empirical data for researching the issue addressed in this study were collected from the Agency for Business Registers of the Republic of Serbia, and are shown in Table 6. (The number of employees is expressed in whole numbers, and the other variables in millions of dinars). The data were created by the relevant international standards and, considering that the results obtained in this study can be compared internationally, i.e. there are no restrictions in this regard. The significance of the criteria in this study was determined using the Fuzzy SIWEC method. The procedure and results of this method are shown in Tables 1-5. (In this study, all calculations and results are the authors' own.)

Table 1. Linguistic decision-making matrix

	C1	C2	C3	C4	C5
DM1	EG	P	G	AG	AG
DM2	AG	AG	G	EG	AG
DM3	AG	EG	G	AG	AG
DM4	P	EG	G	EG	AG
DM5	AG	AG	AG	EG	AG
DM6	AG	P	EG	EG	EG
DM7	AG	P	G	EG	AG

Table 2. Fuzzy linguistic evaluation scale

Linguistic terms	Membership function
Absolutely bad (AB)	*(1,1,1)*
Very bad (VB)	*(1,2,3)*
Bad (B)	*(2,3,4)*
Medium-bad (MB)	*(3,4,5)*
Equal (E)	*(4,5,6)*
Medium-good (MG)	*(5,6,7)*
Good(G)	*(6,7,8)*
Extremely good (EG)	*(7,8,9)*
Absolutely good (AG)	*(8,9,10)*
Perfect (P)	*(9,10,10)*

Table 3. Normalised fuzzy decision-making matrix

	C1			C2			C3			C4			C5			St dev $_j$
DM1	0.7	0.8	0.9	0.9	1.0	1.0	0.6	0.7	0.8	0.8	0.9	1.0	0.8	0.9	1.0	0.125
DM2	0.8	0.9	1.0	0.8	0.9	1.0	0.6	0.7	0.8	0.7	0.8	0.9	0.8	0.9	1.0	0.118
DM3	0.8	0.9	1.0	0.7	0.8	0.9	0.6	0.7	0.8	0.8	0.9	1.0	0.8	0.9	1.0	0.118
DM4	0.9	1.0	1.0	0.7	0.8	0.9	0.6	0.7	0.8	0.7	0.8	0.9	0.8	0.9	1.0	0.123
DM5	0.8	0.9	1.0	0.8	0.9	1.0	0.8	0.9	1.0	0.7	0.8	0.9	0.8	0.9	1.0	0.094
DM6	0.8	0.9	1.0	0.9	1.0	1.0	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9	0.106
DM7	0.8	0.9	1.0	0.9	1.0	1.0	0.6	0.7	0.8	0.7	0.8	0.9	0.8	0.9	1.0	0.125

Table 4. Obtaining final values of the criteria by using the Fuzzy SIWEC method

	C1			**C2**			**C3**			**C4**			**C5**					
$\tilde{S}_{ij}$	0.65	0.73	0.80	0.66	0.74	0.79	0.52	0.60	0.68	0.59	0.67	0.75	0.64	0.72	0.80	3.05	3.45	3.81
$\tilde{w}_{ij}$	0.17	0.211	0.261	0.173	0.214	0.258	0.135	0.173	0.222	0.155	0.195	0.247	0.167	0.208	0.262			

Table 5. Defuzzified value of the weights of criteria

	C1	**C2**	**C3**	**C4**	**C5**
W_j	0.2125	0.2145	0.1746	0.1967	0.2101

In this particular case, the most important criterion is C2 - assets. Criterion C1 follows – number of employees. The ranking of the criteria is as follows: C2>C1>C5>C4>C3. To realise the target performance of trade in Serbia, it is therefore necessary to effectively manage investments and human capital. Effective control of the other analysed criteria is also a function of this. Tables 6 - 12 show the procedure and results of applying the Rough MABAC method.

Table 6. Initial decision matrix

	Initial decision matrix											
		0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101	2.0168
		maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	
		C1		C2		C3		C4		C5		
2018	A1	219373	219373	2524897	2524897	1007972	1007972	3361094	3361094	121816	121816	
2019	A2	222049	222049	2682931	2682931	1073056	1073056	3608329	3608329	139409	139409	
2020	A3	227618	227618	2837599	2837599	1183026	1183026	3664505	3664505	171010	171010	
2021	A4	234727	234727	3166529	3166529	1318126	1318126	4754169	4754169	170703	170703	
2022	A5	234011	234011	3490398	3490398	1426553	1426553	5511864	5511864	214917	214917	
2023	A6	239429	239429	3882976	3882976	1600734	1600734	5737589	5737589	234843	234843	

Table 7. Quantified initial decision matrix

Quantified initial decision matrix										
w	0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101
	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
	C1		C2		C3		C4		C5	
A1	219373.000	219373.000	2524897	2524897	1007972.000	1007972.000	3361094	3361094	121816.000	121816.000
A2	222049.000	222049.000	2682931	2682931	1073056.000	1073056.000	3608329	3608329	139409.000	139409.000
A3	227618.000	227618.000	2837599	2837599	1183026.000	1183026.000	3664505	3664505	171010.000	171010.000
A4	234727.000	234727.000	3166529	3166529	1318126.000	1318126.000	4754169	4754169	170703.000	170703.000
A5	234011.000	234011.000	3490398	3490398	1426553.000	1426553.000	5511864	5511864	214917.000	214917.000
A6	239429.000	239429.000	3882976	3882976	1600734.000	1600734.000	5737589	5737589	234843.000	234843.000
minimum	219373.000	219373.000	2524897.000	2524897.000	1007972.000	1007972.000	3361094.000	3361094.000	121816.000	121816.000
maximum	239429.000	239429.000	3882976.000	3882976.000	1600734.000	1600734.000	5737589.000	5737589.000	234843.000	234843.000

Table 8. Normalised matrix

Normalised matrix										
	0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101
	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
	C1		C2		C3		C4		C5	
A1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A2	0.133	0.133	0.116	0.116	0.110	0.110	0.104	0.104	0.156	0.156
A3	0.411	0.411	0.230	0.230	0.295	0.295	0.128	0.128	0.435	0.435
A4	0.766	0.766	0.472	0.472	0.523	0.523	0.586	0.586	0.433	0.433
A5	0.730	0.730	0.711	0.711	0.706	0.706	0.905	0.905	0.824	0.824
A6	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table 9. Weighted matrix

Difficult matrix										
	0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101
	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
	C1		C2		C3		C4		C5	
A1	0.213	0.213	0.215	0.215	0.175	0.175	0.197	0.197	0.210	0.210
A2	0.241	0.241	0.239	0.239	0.194	0.194	0.217	0.217	0.243	0.243
A3	0.300	0.300	0.264	0.264	0.226	0.226	0.222	0.222	0.302	0.302
A4	0.375	0.375	0.316	0.316	0.266	0.266	0.312	0.312	0.301	0.301
A5	0.368	0.368	0.367	0.367	0.298	0.298	0.375	0.375	0.383	0.383
A6	0.425	0.425	0.429	0.429	0.349	0.349	0.393	0.393	0.420	0.420

Table 10. GAO

											0.047
GAO											
	0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101	
	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	
	C1		C2		C3		C4		C5		
GAO	0.246	0.246	0.232	0.232	0.184	0.184	0.213	0.213	0.237	0.237	

Table 11. Distance from GAO

Distance from GAO										
	0.2125	0.2125	0.2145	0.2145	0.1746	0.1746	0.1967	0.1967	0.2101	0.2101
	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum	maximum
	C1		C2		C3		C4		C5	
A1	-0.033	-0.033	-0.018	-0.018	-0.010	-0.010	-0.016	-0.016	-0.027	-0.027
A2	-0.005	-0.005	0.007	0.007	0.010	0.010	0.004	0.004	0.006	0.006
A3	0.054	0.054	0.032	0.032	0.042	0.042	0.009	0.009	0.065	0.065
A4	0.129	0.129	0.084	0.084	0.082	0.082	0.099	0.099	0.064	0.064
A5	0.122	0.122	0.135	0.135	0.114	0.114	0.162	0.162	0.146	0.146
A6	0.179	0.179	0.197	0.197	0.165	0.165	0.181	0.181	0.183	0.183

Table 12. Rank

						Rank				
2018	A1	-0.103	-0.103	-0.10339	-0.208	6		[-0.103,-0.103]	-0.208	6
2019	A2	0.022	0.022	0.02226	-0.081	5		[0.022,0.022]	-0.081	5
2020	A3	0.201	0.201	0.201477	0.100	4		[0.201,0.201]	0.100	4
2021	A4	0.458	0.458	0.458166	0.359	3		[0.458,0.458]	0.359	3
2022	A5	0.679	0.679	0.678571	0.581	2		[0.679,0.679]	0.581	2
2023	A6	0.905	0.905	0.90501	0.809	1		[0.905,0.905]	0.809	1
		-0.103								
			0.905							

As a whole, the performance of Serbia's trade has been continuously improving lately. The best was in 2023. The result is efficient management of human capital, assets, capital sales, and profit. Effective control of all relevant macro and micro factors is certainly a function of this. Foreign direct investments have had a positive effect on the continuous improvement of trade performance in Serbia. Digitisation of the entire business is in the function of improving the performance of trade in Serbia. Adequate adaptation to changes in the business environment had a positive effect on the performance of trade in Serbia.

4. CONCLUSIONS

The application of multicriteria analysis in the evaluation of trade performance is very challenging, as confirmed by the results of this study. It provides a realistic picture of trade performance because it is based on a modern mathematical approach. Of all the analysed indicators as criteria in this particular case, the most important criterion is C2 – assets. Criterion C1 follows – number of employees. The ranking of the criteria is as follows: C2>C1>C5>C4>C3. Therefore, to realise the target performance of trade in Serbia, it is necessary to effectively manage investments and human capital. Effective control of other observed criteria is also a function of this. The results of this study show that the performance of trade in Serbia has been continuously improving recently. The best was in 2023. The result is efficient management of human capital, assets, capital, sales, and profits. Effective control of all relevant macro and micro factors is certainly a function of this. Foreign direct investments (foreign retail chains) had a positive effect on the continuous improvement of trade performance in Serbia. Digitisation of the entire business is in the function of improving the performance of trade in Serbia. The increasing application of the concept of sustainable development (economic, social, and environmental dimensions) is a function of the continuous improvement of trade performance in Serbia. Adequate adaptation to a very complex business environment (geopolitical situation, energy crisis, pandemic of the coronavirus virus COVID-19, etc.) had a positive effect on the continuous improvement of trade performance in Serbia.

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