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RESEARCH OF THE DYNAMICS OF TRADE PERFORMANCE IN SERBIA USING THE PIPECRIA-S AND MARCOS METHODS

Abstract: Abstract text, up to 500 words (Style: SM-Abstract) Abstract: It is of great importance to measure the dynamics of Serbian trade performance using different methods of multi-criteria decision-making. In this way, a more realistic performance picture of trade in Serbia is obtained. Because several criteria are taken into account, the importance of which is determined mathematically. In this study, with this in mind, a study of the dynamics of trade performance in Serbia was carried out using the PIPECRIA-S (Pivot Pairwise Relative Criteria Importance Assessment) and MARCOS (Measurement Alternatives and Ranking according to Compromise Solution) methods. The results of the research show that trade in Serbia achieved the best performance in 2023. Next: 2022, 2021, 2020, 2019, etc. Efficient management of human capital, assets, capital, sales, and profit contributed to this. Also the increasingly favorable macroeconomic trends, as well as the increasing digitization of the entire business.

Keywords: performance, Serbian trade, PIPECRIA-S, MARCOS

1. INTRODUCTION

There is no doubt that the application of multi-criteria decision-making methods in the evaluation of store performance is of great importance (Ersoy, 2017). Using them, the performance of the store can be seen more realistically from different perspectives as alternatives (by individual countries, regions, sales channels, stores, suppliers, etc.). Because they use several criteria to measure store performance. The significance of the criteria is determined mathematically. In this study, the research on the dynamics of trade performance in Serbia is carried out using the PIPECRIA-S and MARCOS methods to improve it in the future. This reflects the goal and the main research hypothesis in this study. Recently, there has been an increasingly rich literature dedicated to the application of multi-criteria decision-making methods in the analysis of various problems in trade (Ersoy, 2017; Lukić, 2023b). In this study, all relevant literature serves as a theoretical, methodological, and empirical basis for a more complex investigation of the treated problem using the PIPECRIA-S and MARCOS methods. The analysis of the results obtained in this study is based on scientific interpretation and verification of validity. This enables their international comparison.

2. METHODOLOGY

The research methodology of the treated problem in this study, following the subject, the goal, and the defined main research hypothesis, is based on the application of multi-criteria decision-making methods, specifically PIPECRIA-S and MARCOS, the characteristics of which are shown below. This method originates from the PIPECRIA (Pivot

Pairwise Relative Criteria Importance Assessment) method (Stanujkić et al., 2017), which improves the computational aspects. Contrary to the PIPRECIA method, the comparison with the simple **PIPRECIA-S** method is made only about the first criterion, thereby facilitating the decision-making process. Like the PIPRECIA method, the simple PIPRECIA-S method does not require prior sorting of criteria according to expected significance, which makes it suitable for application in the case of group decision-making. The Simple PIPRECIA-S method is used to define the weight of criteria and solve decision-making problems in different areas of business (Aytekin, 2022; Sulistiani et al., 2023; Mladenović et al., 2023; Setiawansyah et al., 2024). The calculation procedure of the PIPRECIA-S method takes place through the following steps (Stanujkić et al., 2021; Mirčetić et al., 2024):

Step 1. Defining a set of evaluation criteria.

Step 2. Calculation of the relative importance s_j of each criterion, except the first one, as follows:

$$s_j = \begin{cases} 1 & \text{if } c_j > c_1 \\ 1 & \text{if } c_j = 1 \\ 1 & \text{if } c_j < 1 \end{cases} \quad (1)$$

Where $j \neq 1$. Similar to the PIPRECIA method, the value of s_j is equal to 1, while the values of c_j belong to the interval (1, 1.9] when $c_1 > c_j$, and to the interval [0.1, 1) when $c_1 < c_j$.

Step 3. Determining the value of the coefficient k_j as follows:

$$k_j = \begin{cases} 1 & \text{if } j = 1 \\ 2 - s_j & \text{if } j > 1. \end{cases} \quad (2)$$

Step 4. Calculating the weight of the coefficient q_j again as follows:

$$q_j = \begin{cases} 1 & \text{if } j = 1 \\ \frac{1}{k_j} & \text{if } j > 1. \end{cases} \quad (3)$$

Step 5. Defining the relative weight of the criteria as follows:

$$q_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (4)$$

Step 6: In the case of group decision-making, the total weight coefficient of each criterion is determined using the following equation:

$$GM_j = \left(\prod_{k=1}^K w_j^k \right)^{1/K} \quad (5)$$

$$w_j = GM_j / \sum_{i=1}^n GM_i \quad (6)$$

Where GM_j is the geometric mean of the weighting coefficients obtained by the decision-makers included in the evaluation of criterion j , w_j denotes the weighting coefficient of criterion j , and K is the number of decision-makers.

The **MARCOS** (Measurement Alternatives and Ranking according to Compromise Solution) method is based on defining the relationship between alternatives and reference values (ideal and anti-ideal alternatives) (Đalić, 2020; Kovač, 2021; Miškić, 2021; Nedeljković, 2021; Puška, 2021; Stević, 2020a, b; Stanković, 2020; Trung, 2021). Based on the defined relationships, the utility functions of alternatives are determined and a compromise ranking is made about ideal and anti-ideal solutions. Decision preferences are defined based on a utility function. Utility functions represent the position of the alternative about ideal and anti-ideal solutions. The best alternative is the one that is closest to the ideal and at the same time furthest from the anti-deal reference point. The MARCOS method proceeds through the following steps (Stević, 2020a, b; Lukić, 2022a,b,c, 2023a,b,c):

Step 1: Formation of the initial decision-making matrix. A multi-criteria model involves defining a set of n criteria and m alternatives. In the case of group decision-making, a group of r experts is formed who evaluate the

alternatives in relation to the criteria. In this case, the matrices of expert evaluation are aggregated into initial matrices of group decision-making.

Step 2: Forming the expanded initial matrix. In this step, the expansion initial matrix is defined with ideal (*AI*) and anti-ideal (*AAI*) solutions.

$$X = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} AAI \\ A_1 \\ A_2 \\ \dots \\ A_m \\ AI \end{matrix} & \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{matrix} \quad (7)$$

The anti-ideal solution (*AAI*) is the worst alternative. The ideal solution (*AI*) is, on the contrary, the alternative with the best characteristics. Depending on the nature of the criteria, *AAI* and *AI* are defined using the following equations:

$$AAI = \min x_{ij} \text{ if } j \in B \text{ and } \max x_{ij} \text{ if } j \in C \quad (8)$$

$$AI = \max x_{ij} \text{ if } j \in B \text{ and } \min x_{ij} \text{ if } j \in C \quad (9)$$

Where *B* represents the benefit and *C* the cost group of criteria.

Step 3: Normalization of the expanded initial matrix (*X*). The elements of the normalized matrix $N = [n_{ij}]_{m \times n}$ were obtained by applying the following equations:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C \quad (10)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \quad (11)$$

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

Step 4: Defining the weighting matrix $V = [v_{ij}]_{m \times n}$. The weighting matrix *V* is obtained by multiplying the normalized matrix *N* with the weighting coefficients of the criteria w_j using the following equation:

$$v_{ij} = n_{ij} \times w_j \quad (12)$$

Step 5: Determining the level of usefulness of alternatives K_i . The degree of usefulness of alternatives to anti-ideal and ideal solutions is determined using the following equations:

$$K_i^- = \frac{S_i}{S_{aa}} \quad (13)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (14)$$

Where S_i ($i=1,2,\dots,m$) represents the sum of the elements of the weight matrix *V*, shown in the following equation:

$$S_i = \sum_{j=1}^n v_{ij} \quad (15)$$

Step 6: Determining the utility function of alternatives $f(K_i)$. The utility function is the compromise of the observed alternative about ideal and anti-ideal solutions. The utility function of alternatives is defined with the following equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \quad (16)$$

Where $f(K_i^-)$ represents the utility function of the anti-ideal solution and $f(K_i^+)$ represents the utility function of the ideal solution.

Utility functions about ideal and anti-ideal solutions are determined using the following equations:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (17)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (18)$$

Step 7: Ranking of alternatives. The ranking of alternatives is based on the final value of the utility function. The alternative that has the highest possible value of the utility function is preferred.

3. RESULTS AND DISCUSSION

In this study, the relevant criteria for measuring the performance of the store were chosen, due to their nature. These are number of employees (C1), assets (C2), capital (C3), sales (C4) and net profit (C5). Alternatives were observed from 2002 to 2023 (A1, A2,..., A22). Relevant data for researching the treated problem in this study are presented in Table 1.

Table 1: Initial data, 2002-2023

		(I) Number of employees	(I) Assets	(I) Capital	(O) Sale	(O) Net profit
		C1	C2	C3	C4	C5
A1	2002	159881	408777	155219	538446	7291
A2	2003	173615	511466	176372	678953	12444
A3	2004	173529	739522	214201	956885	23540
A4	2005	179895	1267296	582530	1220051	45310
A5	2006	187028	1440435	676899	1531190	70878
A6	2007	205215	1832673	790197	1971676	90281
A7	2008	215540	2101239	796758	2364978	84995
A8	2009	208595	2206975	803361	2243762	74201
A9	2010	202585	2080584	596110	2495934	80709
A10	2011	199718	2152946	664968	2689107	91637
A11	2012	193954	2354259	716558	2979785	93687
A12	2013	193210	2160474	746992	2891518	89730
A13	2014	191621	2157564	761305	2594602	86955
A14	2015	159621	2197931	805009	2731999	95265
A15	2016	206092	2324843	859749	3009651	105238
A16	2017	208020	2375290	920992	3172393	122727
A17	2018	219373	2524897	1007972	3361094	121816
A18	2019	222049	2682931	1073056	3608329	139409
A19	2020	227618	2837599	1183026	3664505	171010
A20	2021	234727	3166529	1318126	4754169	170703
A21	2022	234011	3490398	1426553	5511864	214917
A22	2023	239429	3882976	1600734	5737589	234843
	Statistics					
	Mean	201605.7273	2131709.2730	812576.6818	2759476.3640	101253.9091
	Median	203900.0000	2179202.5000	793477.5000	2710553.0000	90959.0000
	Std. Deviation	23194.66915	871468.56640	369228.77390	1382857.50700	58423.61117
	Minimum	159621.00	408777.00	155219.00	538446.00	7291.00
	Maximum	239429.00	3882976.00	1600734.00	5737589.00	234843.00
	Friedman Test					
	Mean Rank	2.05	4.05	2.95	4.95	1.0

	Test Statistics ^a					
	Chi-Square	86,473				
	df	4				
	Asymp. Sig.	.000				
	a. Friedman Test					

Note:(I) input, (O) output. The number of employees is expressed in whole numbers. Other data are expressed in millions of dinars. Author's statistical calculations.

Source: Agency for Economic Registers of the Republic of Serbia

As in the specific case of Asymp. Sig. = 0.000 < 0.05, the hypothesis is rejected that the differences between the variables (measurements) (C1, C2, C3, C4, and C5) are equal to zero, that is, the differences between them are statistically significant. Table 2 shows the correlation of statistical variables.

Table 2: Correlation

Correlations		C1	C2	C3	C4	C5
C1	Pearson Correlation	1	.854 **	.871 **	.837 **	.861 *
	Sig. (2-tailed)		.000	.000	.000	.000
	N	22	22	22	22	22
C2	Pearson Correlation	.854 **	1	.967 **	.975 **	.961 **
	Sig. (2-tailed)	.000		.000	.000	.000
	N	22	22	22	22	22
C3	Pearson Correlation	.871 **	.967 **	1	.954 **	.978 **
	Sig. (2-tailed)	.000	.000		.000	.000
	N	22	22	22	22	22
C4	Pearson Correlation	.837 **	.975 **	.954 **	1	.977 **
	Sig. (2-tailed)	.000	.000	.000		.000
	N	22	22	22	22	22
C5	Pearson Correlation	.861 **	.961 **	.978 **	.977 **	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	22	22	22	22	22

** . Correlation is significant at the 0.01 level (2-tailed).

In this case, there is therefore a strong correlation between the variables at the level of statistical significance. The weighting coefficients of the criteria calculated using the PIPRECIA-S method are shown in Table 3 and Figure 1.

Table 3: Weighting coefficients of criteria - PIPRECIA-S method

		sj	kj	what	wj
C1	Number of employees		1	1.00	0.10
C2	Assets	1.7	0.3	3.333333	0.33
C3	Capital	1.6	0.4	2.50	0.25
C4	Sale	1.5	0.5	2.00	0.20
C5	Net profit	1.2	0.8	1.25	0.12
				10.08	1.00

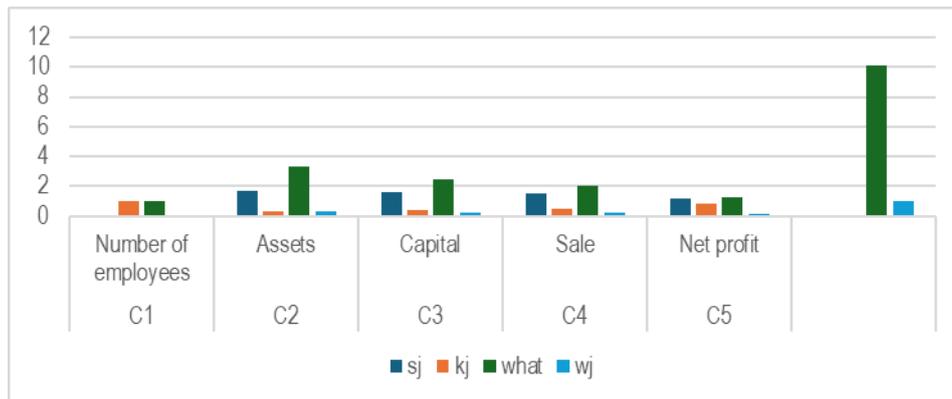


Figure 1: Weighting coefficients of criteria

Source: Author's picture

The most important criterion in the analyzed case is, therefore, assets. Assets in trade represent investment investments. An increase in investment per employee can have a significant impact on the realization of the desired profit in the trade of Serbia. Table 4 shows the process and results of the MARCOS method.

Table 4: Process and results of the MARCOS method

Initial Matrix					
weights of criteria	0.1	0.33	0.25	0.2	0.12
kind of criteria	1	1	1	1	1
	C1	C2	C3	C4	C5
A1	159881	408777	155219	538446	7291
A2	173615	511466	176372	678953	12444
A3	173529	739522	214201	956885	23540
A4	179895	1267296	582530	1220051	45310
A5	187028	1440435	676899	1531190	70878
A6	205215	1832673	790197	1971676	90281
A7	215540	2101239	796758	2364978	84995
A8	208595	2206975	803361	2243762	74201
A9	202585	2080584	596110	2495934	80709
A10	199718	2152946	664968	2689107	91637
A11	193954	2354259	716558	2979785	93687
A12	193210	2160474	746992	2891518	89730
A13	191621	2157564	761305	2594602	86955
A14	159621	2197931	805009	2731999	95265
A15	206092	2324843	859749	3009651	105238
A16	208020	2375290	920992	3172393	122727
A17	219373	2524897	1007972	3361094	121816
A18	222049	2682931	1073056	3608329	139409
A19	227618	2837599	1183026	3664505	171010
A20	234727	3166529	1318126	4754169	170703
A21	234011	3490398	1426553	5511864	214917
A22	239429	3882976	1600734	5737589	234843
MAX	239429	3882976	1600734	5737589	234843
MIN	159621	408777	155219	538446	7291

Extended Initial Matrix					
weights of criteria	0.1	0.33	0.25	0.2	0.12
kind of criteria	1	1	1	1	1
	C1	C2	C3	C4	C5
AAA	159621	408777	155219	538446	7291
A1	159881	408777	155219	538446	7291
A2	173615	511466	176372	678953	12444
A3	173529	739522	214201	956885	23540
A4	179895	1267296	582530	1220051	45310
A5	187028	1440435	676899	1531190	70878

A6	205215	1832673	790197	1971676	90281
A7	215540	2101239	796758	2364978	84995
A8	208595	2206975	803361	2243762	74201
A9	202585	2080584	596110	2495934	80709
A10	199718	2152946	664968	2689107	91637
A11	193954	2354259	716558	2979785	93687
A12	193210	2160474	746992	2891518	89730
A13	191621	2157564	761305	2594602	86955
A14	159621	2197931	805009	2731999	95265
A15	206092	2324843	859749	3009651	105238
A16	208020	2375290	920992	3172393	122727
A17	219373	2524897	1007972	3361094	121816
A18	222049	2682931	1073056	3608329	139409
A19	227618	2837599	1183026	3664505	171010
A20	234727	3166529	1318126	4754169	170703
A21	234011	3490398	1426553	5511864	214917
A22	239429	3882976	1600734	5737589	234843
AI	239429	3882976	1600734	5737589	234843

Normalized Matrix					
weights of criteria	0.1	0.33	0.25	0.2	0.12
kind of criteria	1	1	1	1	1
	C1	C2	C3	C4	C5
AAA	0.666674	0.105274	0.096967	0.093845	0.031046
A1	0.6678	0.1053	0.0970	0.0938	0.0310
A2	0.7251	0.1317	0.1102	0.1183	0.0530
A3	0.7248	0.1905	0.1338	0.1668	0.1002
A4	0.7514	0.3264	0.3639	0.2126	0.1929
A5	0.7811	0.3710	0.4229	0.2669	0.3018
A6	0.8571	0.4720	0.4936	0.3436	0.3844
A7	0.9002	0.5411	0.4977	0.4122	0.3619
A8	0.8712	0.5684	0.5019	0.3911	0.3160
A9	0.8461	0.5358	0.3724	0.4350	0.3437
A10	0.8341	0.5545	0.4154	0.4687	0.3902
A11	0.8101	0.6063	0.4476	0.5193	0.3989
A12	0.8070	0.5564	0.4667	0.5040	0.3821
A13	0.8003	0.5556	0.4756	0.4522	0.3703
A14	0.6667	0.5660	0.5029	0.4762	0.4057
A15	0.8608	0.5987	0.5371	0.5245	0.4481
A16	0.8688	0.6117	0.5754	0.5529	0.5226
A17	0.9162	0.6502	0.6297	0.5858	0.5187
A18	0.9274	0.6909	0.6704	0.6289	0.5936
A19	0.9507	0.7308	0.7391	0.6387	0.7282
A20	0.9804	0.8155	0.8235	0.8286	0.7269
A21	0.9774	0.8989	0.8912	0.9607	0.9152
A22	1.0000	1.0000	1.0000	1.0000	1.0000
AI	1	1	1	1	1

Weighted Normalized Matrix					
	C1	C2	C3	C4	C5
AAA	0.066667	0.03474	0.024242	0.018769	0.003726
A1	0.0668	0.0347	0.0242	0.0188	0.0037
A2	0.0725	0.0435	0.0275	0.0237	0.0064
A3	0.0725	0.0628	0.0335	0.0334	0.0120
A4	0.0751	0.1077	0.0910	0.0425	0.0232
A5	0.0781	0.1224	0.1057	0.0534	0.0362
A6	0.0857	0.1558	0.1234	0.0687	0.0461
A7	0.0900	0.1786	0.1244	0.0824	0.0434

A8	0.0871	0.1876	0.1255	0.0782	0.0379
A9	0.0846	0.1768	0.0931	0.0870	0.0412
A10	0.0834	0.1830	0.1039	0.0937	0.0468
A11	0.0810	0.2001	0.1119	0.1039	0.0479
A12	0.0807	0.1836	0.1167	0.1008	0.0459
A13	0.0800	0.1834	0.1189	0.0904	0.0444
A14	0.0667	0.1868	0.1257	0.0952	0.0487
A15	0.0861	0.1976	0.1343	0.1049	0.0538
A16	0.0869	0.2019	0.1438	0.1106	0.0627
A17	0.0916	0.2146	0.1574	0.1172	0.0622
A18	0.0927	0.2280	0.1676	0.1258	0.0712
A19	0.0951	0.2412	0.1848	0.1277	0.0874
A20	0.0980	0.2691	0.2059	0.1657	0.0872
A21	0.0977	0.2966	0.2228	0.1921	0.1098
A22	0.1000	0.3300	0.2500	0.2000	0.1200
AI	0.1	0.33	0.25	0.2	0.12

Results of the MARCOS Method									
	AAA	Si	Ki-	Ki+	f(K-)	f(K+)	f(K)		Ranking
2002	A1	0.1483	1.0007	0.1483	0.1290	0.8710	0.1455	0.1455	22
2003	A2	0.1736	1.1715	0.1736	0.1290	0.8710	0.1703	0.1703	21
2004	A3	0.2142	1.4456	0.2142	0.1290	0.8710	0.2101	0.2101	20
2005	A4	0.3395	2.2917	0.3395	0.1290	0.8710	0.3331	0.3331	19
2006	A5	0.3958	2.6720	0.3958	0.1290	0.8710	0.3884	0.3884	18
2007	A6	0.4797	3.2383	0.4797	0.1290	0.8710	0.4707	0.4707	17
2008	A7	0.5189	3.5027	0.5189	0.1290	0.8710	0.5092	0.5092	12
2009	A8	0.5163	3.4850	0.5163	0.1290	0.8710	0.5066	0.5066	14
2010	A9	0.4828	3.2588	0.4828	0.1290	0.8710	0.4737	0.4737	16
2011	A10	0.5108	3.4480	0.5108	0.1290	0.8710	0.5012	0.5012	15
2012	A11	0.5447	3.6771	0.5447	0.1290	0.8710	0.5345	0.5345	9
2013	A12	0.5276	3.5615	0.5276	0.1290	0.8710	0.5177	0.5177	10
2014	A13	0.5172	3.4910	0.5172	0.1290	0.8710	0.5075	0.5075	13
2015	A14	0.5231	3.5310	0.5231	0.1290	0.8710	0.5133	0.5133	11
2016	A15	0.5766	3.8923	0.5766	0.1290	0.8710	0.5658	0.5658	8
2017	A16	0.6059	4.0898	0.6059	0.1290	0.8710	0.5945	0.5945	7
2018	A17	0.6430	4.3406	0.6430	0.1290	0.8710	0.6310	0.6310	6
2019	A18	0.6854	4.6263	0.6854	0.1290	0.8710	0.6725	0.6725	5
2020	A19	0.7361	4.9688	0.7361	0.1290	0.8710	0.7223	0.7223	4
2021	A20	0.8260	5.5754	0.8260	0.1290	0.8710	0.8105	0.8105	3
2022	A21	0.9191	6.2042	0.9191	0.1290	0.8710	0.9019	0.9019	2
2023	A22	1.0000	6.7502	1.0000	0.1290	0.8710	0.9812	0.9812	1
	AI	1.0000							

The conclusion, according to the results of the study, is that trade in Serbia achieved the best performance in 2023. Next: 2022, 2021, 2020, 2019, etc. In 2002, the worst performance of trade in Serbia was achieved. Recently, overall, the performance of trade in Serbia has significantly improved. This was influenced by efficient management of human capital, assets, capital, sales, and profit. The increasingly favorable macroeconomic indicators of Serbia (inflation, interest, exchange rate, foreign direct investments, reduced unemployment rate, and/or increased employment rate, etc.) contributed significantly to this. Digitalization of the entire business certainly plays a significant role in this. Likewise, the application of new business concepts (management of costs, customers, product categories, inventory, private label, sale of organic products, etc.). In the future, to obtain a realistic performance picture of trade in Serbia, as a result of the results of this study, different methods of multi-criteria decision-making should be used as much as possible. There are no restrictions regarding the availability of empirical data.

4. CONCLUSION

In this study, the research results showed that the application of PIPRECIA-S and MARCOS methods provides a realistic performance picture of trade in Serbia. This is also the case with the use of other multi-criteria decision-making methods. Therefore, generally speaking, they should be used as much as possible in the analysis of trade performance in Serbia, using different criteria and alternatives. Recently, it can be said freely according to the results of this study, the performance of trade in Serbia is getting better. The improvement of trade performance in Serbia was the result of the most efficient management of human capital, assets, capital, sales, and profit. Increasingly favorable macroeconomic trends (gross domestic product growth rate, inflation, interest, exchange rate, foreign direct investments, employment, living standards of the population, etc.) also contributed to this. In the context of this, it should be mentioned that the increasing digitization of the entire business and the application of new business models.

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