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Performance Analysis of Public Enterprises in Serbia Based on PIPRECIA-S and MARCOS Methods

Summary: *By their nature, the operations of public enterprises are specific, as they provide services to both citizens and other entities. Evaluating their performance is a challenging, complex, and significant task. This study analyzes the performance of public enterprises in Serbia using two multi-criteria decision-making methods: PIPRECIA-S and MARCOS. The results indicate that the top five public enterprises in terms of performance are: JP Putevi Srbije Beograd, JP Srbijagas Novi Sad, JP Pošta Srbije Beograd, Javno preduzeće za gazdovanje šuma "Srbijašume" sa p.o. Beograd, and JKP Beogradski vodovod i kanalizacija Beograd. The best-performing company is JP Putevi Srbije Beograd, while the lowest-ranked is JVP Srbijavode Beograd. The performance of public enterprises in Serbia can be improved through more efficient management of business assets, capital, losses, revenues, net results, and human resources. This requires adequate adaptation to the highly dynamic and complex business environment.*

Keywords: *public enterprises, performance analysis, PIPRECIA-S, MARCOS, Serbia*

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INTRODUCTION

In every country, including Serbia, public companies play an important role. They have a specific character. They provide public services to entities (enterprises and institutions) and citizens. The assessment of the quality of their business is given by the entire society. That is why the analysis of the performance of public companies is very challenging (1, 19). In this study, the performance of public companies in Serbia is analyzed based on the PIPRECIA-S and MARCOS methods. The study aims to rank public companies in Serbia as realistically as possible to improve the positioning, especially of the lower-ranked ones, and to improve the quality of public services provided to entities and citizens at affordable prices. Multi-criteria decision-making methods play a significant role in this (5, 11). The main research hypothesis is also reflected in the defined aim of the study.

Two types of literature were used in this study: literature related to public enterprises and literature dealing with the optimization problem. All relevant literature in this study serves as a theoretical, methodological, and empirical basis for the most complex research of the analyzed problem (16, 22, 3).

Relevant original empirical data for the analysis of the performance of public companies in Serbia were collected from the Agency for Economic Registers of the Republic of Serbia. The data is internationally comparable.

METHODOLOGY

The research methodology used in this study, in line with the subject, goal, and defined hypothesis, is based on the application of multi-criteria decision-making methods, specifically PIPRECIA-S and MARCOS, the characteristics of which are shown below.

PIPRECIA-S method

This method originates from the PIPRECIA (PIvot Pairwise Relative Criteria Importance Assessment) method (24), which improves the computational aspects. Contrary to the PIPRECIA method, the comparison with the simple PIPRECIA-S method is made only for the first criterion, thereby facilitating the decision-making process. Like the PIPRECIA method, the simple PIPRECIA-S method does not involve prior sorting of criteria according to expected importance, 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 various areas of business (2, 22, 15, 21). The calculation procedure of the PIPRECIA-S method takes place through the following steps (24, 13):

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:

$$s_j = \begin{cases} 1 \; if \; c_j > c_1 \\ 1 \; if \; c_j = 1 \\ 1 \; if \; c_j < 1 \end{cases} \tag{1}$$

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:

$$k_j = \begin{cases} 1 \quad if \; j = 1 \\ 2 - s_j \; if \; j > 1. \end{cases} \tag{2}$$

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

$$q_j = \begin{cases} 1 \; if \; j = 1 \\ \dfrac{1}{k_j} \; if \; j > 1. \end{cases} \tag{3}$$

Step 5: Define the relative weight of the criteria as follows:

$$q_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{4}$$

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

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

$$w_j = GM_j \Big/ \sum_{l=1}^{n} GM_l \tag{6}$$

Where GM_j is the geometric mean of the weighting coefficients obtained by the decision-makers involved in the assessment of criterion j, wj denotes the weighting coefficient of criterion j, and K_{is} the number of decision-makers.

MARCOS Method

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) (4, 14, 17, 20, 25, 28). Based on the defined relationships, the utility functions of the alternatives are determined and a compromise ranking is made between ideal and anti-ideal solutions. Decision preferences are defined based on a utility function. Utility functions represent the position of alternatives with

respect to 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- ideal reference point. The MARCOS method proceeds through the following steps (26, 7, 8, 9, 10, 11, 12):

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 set of *r* experts is formed who evaluate the alternatives to the criteria. In that case, the expert evaluation matrices are aggregated into the initial group decision matrices.

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

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \end{array} \tag{7}$$

The anti-ideal solution (*AA*) 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:

$$AAI = \min_i x_{ij} \ if \ j \in B \ and \ \max_i x_{ij} \ if \ j \in C \tag{8}$$

$$AI = \max_i x_{ij} \ if \ j \in B \ and \ \min_i x_{ij} \ if \ j \in C \tag{9}$$

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

Step 3: Normalization of the extended initial matrix (*X*). The elements of the normalized matrix $N = [n_{ij}]_{mxn}$ are obtained by applying the following equations:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \ if \ j \in C \tag{10}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \ if \ j \in B \tag{11}$$

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

Step 4: Defining the weighting matrix $V = [v_{ij}]_{mxn}$. 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:

$$v_{ij} = n_{ij} x w_j \tag{12}$$

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

$$K_i^- = \frac{S_i}{S_{aai}} \tag{13}$$

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{14}$$

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

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{15}$$

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 by the following equation:

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

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:

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

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

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.

RESULTS AND DISCUSSION

Six relevant criteria for evaluating the performance of public companies in Serbia were used in this study. The alternatives are the twelve largest public companies by total assets in Serbia in 2023. Table 1 shows the criteria, alternatives, and original empirical data of the analyzed public companies in Serbia for 2023.

Table 1. Performance indicators – Public enterprises in Serbia, 2023 (Million dinars)

		Business property	Capital	Loss	Business income	Net result	Number of employees
		C1	C2	C3	C4	C5	C6
A1	JP PUTEVI SRBIJE BEOGRAD	559893	383542	96197	63720	-6819	2190
A2	JP SRBIJAGAS NOVI SAD	356702	132242	0	174239	12030	910
A3	JAVNO PREDUZEĆE ZA GAZDOVANJE ŠUMA SRBIJAŠUME SA PO BEOGRAD	138903	132589	0	11128	726	3168
A4	JUGOIMPORT-SDPR JP BEOGRAD	118722	24781	292	14434	602	355
A5	JKP BEOGRADSKI VODOVOD I KANALIZACIJA BEOGRAD	93884	85623	18921	13280	14	2706
A6	JKP BEOGRDSKE ELEKTRANE BEOGRAD	66398	39839	589	31390	27	1958
A7	JVP VODE VOJVODINE NOVI SAD	51815	40306	2636	7142	5	480
A8	JP VOJVODINA ŠUME PETROVARADIN	47842	44170	0	7156	68	1445
A9	JVP SRBIJAVODE BEOGRAD	44006	1723	6	3192	16	164
A10	JP POŠTA SRBIJE BEOGRAD	35113	25710	0	31196	3174	14307
A11	JKP GSP BEOGRAD	27511	8777	34941	21599	-820	5700
A12	JKP NOVOSADSKA TOPLANA NOVI SAD	25402	18705	0	9653	30	321

Note: Amounts are in million of dinars. The number of employees is expressed in whole numbers.

Source: Report on the hundred most... economic companies in 2023.
Agency for Economic Registers of the Republic of Serbia

The evaluation of the analyzed criteria was performed using the PIPRECIA-S method (Table 2, Figure 1). (In this study, all calculations and results are done by the authors.)

Table 2. Evaluation of criteria

	sj	kj	qj	wj
C1		1	1.00	0.14
C2	1.5	0.5	2	0.28
C3	1	1	1.00	0.14
C4	0.6	1.4	0.71	0.10
C5	1.1	0.9	1.11	0.16
C6	1.2	0.8	1.25	0.18
			7.08	1.00

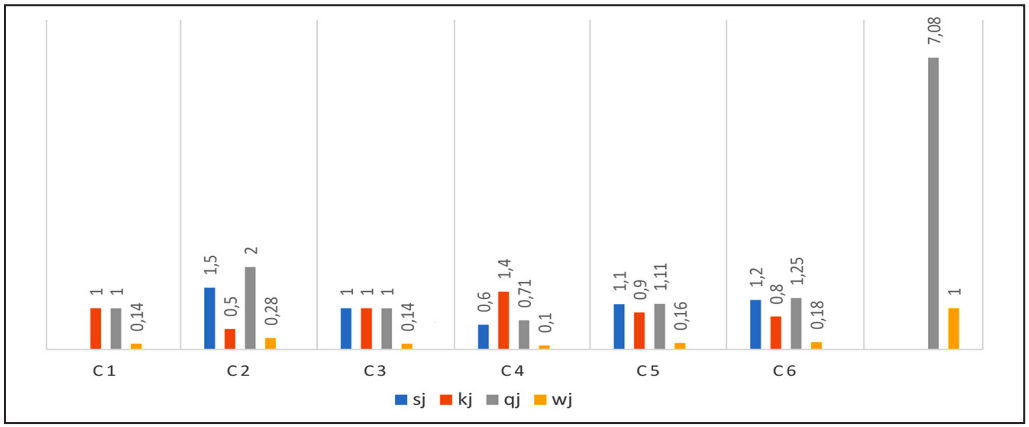

Figure 1. Evaluation of criteria

Source: Author's image

In the specific case, the ranking of the criteria is C2>C6>C5>C1 =C3 >C4. The most important criterion is C2 - Capital. The target performance ranking of public companies in Serbia can therefore be achieved with the efficient management of financial capital. In that direction, it is important to manage the other criteria as efficiently as possible. The selected criteria are key factors influencing the performance positioning of public companies in Serbia.

The ranking of alternatives in this study was performed using the MARCOS method. Tables 3 - 7 present the calculation procedure and results of the MARCOS method.

Table 3. Initial Matrix

Initial Matrix						
Weight of criteria	0.14	0.28	0.14	0.1	0.16	0.18
Kind of criteria	1	1	-1	1	1	1
	C1	C2	C3	C4	C5	C6
A1	559893	383542	96197	63720	-6819	2190
A2	356702	132242	0	174239	12030	910
A3	138903	132589	0	11128	726	3168
A4	118722	24781	292	14434	602	355
A5	93884	85623	18921	13280	14	2706
A6	66398	39839	589	31390	27	1958
A7	51815	40306	2636	7142	5	480
A8	47842	44170	0	7156	68	1445
A9	44006	1723	6	3192	16	164
A10	35113	25710	0	31196	3174	14307
A11	27511	8777	34941	21599	-820	5700
A12	25402	18705	0	9653	30	321
MAX	559893	383542	96197	174239	12030	14307
MIN	25402	1723	0	3192	-6819	164

Table 4. Extended Initial Matrix

Weight of criteria	0.14	0.28	0.14	0.1	0.16	0.18
Kind of criteria	1	1	-1	1	1	1
	C1	C2	C3	C4	C5	C6
AAI	25402	1723	96197	3192	-6819	164
A1	559893	383542	96197	63720	-6819	2190
A2	356702	132242	0	174239	12030	910
A3	138903	132589	0	11128	726	3168
A4	118722	24781	292	14434	602	355
A5	93884	85623	18921	13280	14	2706
A6	66398	39839	589	31390	27	1958
A7	51815	40306	2636	7142	5	480
A8	47842	44170	0	7156	68	1445
A9	44006	1723	6	3192	16	164
A10	35113	25710	0	31196	3174	14307
A11	27511	8777	34941	21599	-820	5700
A12	25402	18705	0	9653	30	321
AI	559893	383542	0	174239	12030	14307

Table 5. Normalized Matrix

Weight of criteria	0.14	0.28	0.14	0.1	0.16	0.18
Kind of criteria	1	1	-1	1	1	1
	C1	C2	C3	C4	C5	C6
AAI	0.045369	0.004492	0	0.01832	-0.56683	0.011463
A1	1.0000	1.0000	0.0000	0.3657	0.0000	0.1531
A2	0.6371	0.3448	0.0000	1.0000	1.0000	0.0636
A3	0.2481	0.3457	0.0000	0.0639	0.0603	0.2214
A4	0.2120	0.0646	0.0000	0.0828	0.0500	0.0248
A5	0.1677	0.2232	0.0000	0.0762	0.0012	0.1891
A6	0.1186	0.1039	0.0000	0.1802	0.0022	0.1369
A7	0.0925	0.1051	0.0000	0.0410	0.0004	0.0336
A8	0.0854	0.1152	0.0000	0.0411	0.0057	0.1010
A9	0.0786	0.0045	0.0000	0.0183	0.0013	0.0115
A10	0.0627	0.0670	0.0000	0.1790	0.2638	1.0000
A11	0.0491	0.0229	0.0000	0.1240	0.0000	0.3984
A12	0.0454	0.0488	0.0000	0.0554	0.0025	0.0224
AI	1	1	0	1	1	1

Table 6. Weighted Normalized Matrix

	C1	C2	C3	C4	C5	C6
AAI	0.006352	0.001258	0	0.001832	0	0.002063
A1	0.1400	0.2800	0.0000	0.0366	0.0000	0.0276
A2	0.0892	0.0965	0.0000	0.1000	0.1600	0.0114
A3	0.0347	0.0968	0.0000	0.0064	0.0097	0.0399
A4	0.0297	0.0181	0.0000	0.0083	0.0080	0.0045
A5	0.0235	0.0625	0.0000	0.0076	0.0002	0.0340
A6	0.0166	0.0291	0.0000	0.0180	0.0004	0.0246
A7	0.0130	0.0294	0.0000	0.0041	0.0001	0.0060
A8	0.0120	0.0322	0.0000	0.0041	0.0009	0.0182
A9	0.0110	0.0013	0.0000	0.0018	0.0002	0.0021
A10	0.0088	0.0188	0.0000	0.0179	0.0422	0.1800
A11	0.0069	0.0064	0.0000	0.0124	0.0000	0.0717
A12	0.0064	0.0137	0.0000	0.0055	0.0004	0.0040
AI	0.14	0.28	0	0.1	0.16	0.18

Table 7. Results of the MARCOS Method

		Si	Ki-	Ki+	f(K-)	f(K+)	f(K)		Ranking
	AAI	0.0115							
JP PUTEVI SRBIJE BEOGRAD	A1	0.4841	42.0799	0.5629	0.0132	0.9868	0.5628	0.5628	1
JP SRBIJAGAS NOVI SAD	A2	0.4572	39.7383	0.5316	0.0132	0.9868	0.5315	0.5315	2
JAVNO PREDUZEĆE ZA GAZDOVANJE ŠUMA SRBIJAŠUME SA PO BEOGRAD	A3	0.1874	16.2911	0.2179	0.0132	0.9868	0.2179	0.2179	4
JUGOIMPORT-SDPR JP BEOGRAD	A4	0.0685	5.9570	0.0797	0.0132	0.9868	0.0797	0.0797	8
JKP BEOGRADSKI VODOVOD I KANALIZACIJA BEOGRAD	A5	0.1278	11.1115	0.1486	0.0132	0.9868	0.1486	0.1486	5
JKP BEOGRDSKE ELEKTRANE BEOGRAD	A6	0.0887	7.7094	0.1031	0.0132	0.9868	0.1031	0.1031	7
JVP VODE VOJVODINE NOVI SAD	A7	0.0526	4.5707	0.0611	0.0132	0.9868	0.0611	0.0611	10
JP VOJVODINA ŠUME PETROVARADIN	A8	0.0674	5.8584	0.0784	0.0132	0.9868	0.0784	0.0784	9
JVP SRBIJAVODE BEOGRAD	A9	0.0164	1.4228	0.0190	0.0132	0.9868	0.0190	0.0190	12
JP POŠTA SRBIJE BEOGRAD	A10	0.2677	23.2656	0.3112	0.0132	0.9868	0.3112	0.3112	3
JKP GSP BEOGRAD	A11	0.0974	8.4656	0.1133	0.0132	0.9868	0.1132	0.1132	6
JKP NOVOSADSKA TOPLANA NOVI SAD	A12	0.0300	2.6063	0.0349	0.0132	0.9868	0.0349	0.0349	11
	AI	0.8600							

The results of the analysis of the problem addressed in this study show that the following five public companies in terms of performance in Serbia are: JP PUTEVI SRBIJE BEOGRAD, JP SRBIJAGAS NOVI SAD, JP POŠTA SRBIJE BEOGRAD, JAVNO PREDUZEĆE ZA GAZDOVANJE ŠUMA SRBIJAŠUME SA PO BEOGRAD and JKP BEOGRADSKI VODOVOD I KANALIZACIJA BEOGRAD.Therefore, the best-positioned public company is JP PUTEVI SRBIJE BEOGRAD. The public company JVP SRBIJAVODE BEOGRAD is the worst-positioned. The performance positioning of public companies in Serbia can, among other things, be improved through the most efficient management of business assets, capital, losses, business income, net results, and human resources. For these purposes, adequate adaptation to very dynamic changes in the business environment is necessary. The digitization of the entire business process of public companies in Serbia plays a significant role in this.

CONCLUSION

The operations of public companies are specific. They provide their services to entities and citizens. They should operate as efficiently as possible. This enables public companies to provide entities and citizens with quality services at affordable prices. To that end, it is necessary to continuously analyze the performance of public companies. In this study, an analysis of the performance of public companies in Serbia was performed using multi-criteria decision-making methods, namely PIPRECIA-S and MARCOS methods. The obtained results show that among these five public companies in terms of performance in Serbia are: JP PUTEVI SRBIJE BEOGRAD, JP SRBIJAGAS NOVI SAD, JP POŠTA SRBIJE BEOGRAD, JAVNO PREDUZEĆE ZA GAZDOVANJE ŠUMA SRBIJAŠUME SA PO BEOGRAD and JKP BEOGRADSKI VODOVOD I KANALIZACIJA BEOGRAD. Therefore, the best-positioned public company is JP PUTEVI SRBIJE BEOGRAD. The public company JVP SRBIJAVODE BEOGRAD is the worst-positioned. Among other things, to improve the performance positioning of public companies in Serbia, it is necessary to manage business assets, capital, losses, business income, net result, and human resources as efficiently as possible. Likewise, adequate adaptation to very complex dynamic changes in the business environment at the global, regional, and national levels is necessary. Digitization of the entire business is key to achieving the target performance positioning of public companies in Serbia.

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Analiza učinka javnih preduzeća u Srbiji na osnovu PIPRECIA-S i MARCOS metoda

Rezime: Po prirodi stvari, poslovanje javnih preduzeća je specifično. Ona pružaju javne usluge entitetima i građanima. Istraživanje učinka javnih preduzeća je veoma izazovno, složeno, relevantno i značajno. Ova studija istražuje performanse javnih preduzeća u Srbiji korišćenjem višekriterijumskih metoda donošenja odluka, i to: PIPRECIA-S i MARCOS metode. Rezultati ove studije pokazuju da su pet javnih preduzeća sa najvećim performansama u Srbiji: JP PUTEVI SRBIJE BEOGRAD, JP SRBIJAGAS NOVI SAD, JP POŠTA SRBIJE BEOGRAD, JAVNO PREDUZEĆE ZA GAZDOVANJE ŠUMA SRBIJAŠUME SA PO BEOGRAD i JKP BEOGRADSKI VODOVOD I KANALIZACIJA BEOGRAD. Najbolje pozicionirano javno preduzeće je JP PUTEVI SRBIJE BEOGRAD. Javno preduzeće JVP SRBIJAVODE BEOGRAD je u najgorem položaju. Pozicioniranje javnih preduzeća u Srbiji može se poboljšati efikasnijim upravljanjem poslovnom imovinom, kapitalom, gubicima, poslovnim prihodima, neto rezultatima i ljudskim resursima. U ove svrhe neophodna je adekvatna adaptacija na veoma složene dinamičke promene u poslovnom okruženju.

Ključne reči: Učinak, pozicioniranje, javna preduzeća, Srbija, PIPRECIA-S, MARCOS