Analysis of the circular economy of Serbia based on the Cobra method

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Abstract

Recently, the problem of the circular economy has been very topical. In the literature, it is investigated from different angles. This study analyzes the problem of the circular economy in Serbia based on the COBRA method. The results of the COBRA method show that the best performance of the circular economy in Serbia was in 2021. The worst was in 2016. Recently, generally speaking, the performance of the circular economy in Serbia has been improving. To improve the performance of the circular economy in Serbia, it is necessary to have a continuous, adequate action plan to manage the recycling of municipal waste, production of municipal waste, dependence on the import of materials, resource productivity, and energy from renewable sources as efficiently as possible. Likewise, other relevant factors. There is no doubt that the increasing application of the circular economy principle contributes significantly to the preservation of the environment in Serbia.

Keywords

performance, circular economy, Serbia, COBRA method

JEL classification

M10, M21

1.Introduction

The issue of the circular economy has been very challenging lately. Due to its character in the relevant literature, special attention is paid to the analysis of the problem of applying the circular economy principle. The issue of the circular economy is widely researched. Here we will point out only some aspects relevant to the analysis of the treated problem in this study. In the literature, significant attention is paid to the effects of applying the circular economy principle (Alivojvodic & Kokalj, 2024). in the countries of the European Union (Mazur-Wierzbicka, 2021; Friant et al., 2021; Alberich et al., 2023; Marković et al., 2023; Radovan et al., 2023; The Word Bank - Squaring the Circle: Policies From Europe's Circular Economy Transition, 2022). The problems of applying the principle of circular economy in Serbia also receive significant attention in the literature (Ilić & Nikolić, 2016; Kosanović et al., 2021; Abramović et al., 2024; Mihajlov et al., 2021; Radovanov et al., 2023; Stiljkovic et al., 2023; Vukelič et al., 2023). This issue is analyzed from different angles. Significant attention in the literature is devoted to the sectoral analysis of the circular economy problem (Amicarelli et al., 2024; Krstić et al., 2024; Stošić & Šmelcerović, 2023). In the literature, special attention is paid to the specifics of the application of the circular economy principle in the countries of the Western Balkans (Bjelić et al., 2024). When analyzing the circular economy problem, in addition to classic analysis, DEA models are also applied in the literature (Radovanov et al., 2023). Likewise, multi-criteria decision-making methods are increasingly being applied in the literature (Marković et al., 2023). The application of mathematical multi-criteria analysis provides more accurate results of research into the circular economy problem. Therefore, mathematical multicriteria analysis is increasingly used in the literature devoted to the circular economy. Consequently, in this study, we will analyze the problem of the circular economy in Serbia based on the COBRA method.

2.Research Methodology

The research on the circular economy problem in Serbia in this study is based on the AHP-COBRA approach. Therefore, we will briefly indicate their mathematical characteristics.

Analytic Hierarchy Process (AHP) method

Given that the weighting coefficients of the coefficients of the application of the COBRA method are determined using the AHP method, we will briefly refer to its theoretical and methodological characteristics.

The Analytical Hierarchy Process (AHP) method takes place through the following steps (Saaty, 2008):

Step 1. Formation of the matrix of comparison pairs

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

Step 2. Normalization of the comparison pair matrix

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, i, j = 1, \dots, n \quad (2)$$

Step 3. Determination of relative character, i.e. vector weights

$$w_i = \frac{\sum_{i=1}^{n} a_{ij}^*}{n}, i, j = 1, \dots, n \quad (3)$$

The consistency index - CI (consistency index) represents a measure of the deviation *of* *n* from λ_{max} and can be represented by the following formula:

$$CI = \frac{\lambda_{max} - n}{n} \quad (4)$$

If CI < 0.1 of the estimated value of coefficient a_{ij} is consistent, the deviation of λ_{max} from *n* is negligible. This means, in other words, that the AHP method accepts an inconsistency of less than 10%.

Using the consistency index, the consistency ratio CR = CI/RI can be calculated, where RI is the random index.

COBRA method

COBRA (Comprehensive Distance Based Ranking) is a relatively new multi-criteria decision-making method (Popović et al., 2022). The budget steps of the COBRA method are shown below (Krstić et al., 2022).

Step 1. Formation of the decision matrix.

The decision matrix is created in the following way

$$D = [d_{ij}]_{mxn} = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} i = 1,2, \dots, m, j = 1,2, \dots, n \quad (1)$$

Where d_{ij} represents the degree of performance of alternative *i* about criterion *j*. Opinions *m* alternatives and *n* criteria.

Step 2. Normalized decision matrix.

It is formed using the equation

$$\Delta = [a_{ij}]_{mxn} \quad (2)$$

$$a_{ij} = \frac{a_{ij}}{\max_i a_{ij}} \quad (3)$$

Step 3. Weight-normalized matrixΔ_w

The weight-normalized matrix is determined using Eq

$$\Delta_w = \left[w_j x a_j\right]_{mxn} \quad (4)$$

Where w_j represents the relative weight of criterion *j*.

Step 4. The positive ideal solution (PIS_j), the negative ideal solution (NIS_j), and the average solution (AS_j) for each criterion are determined using equations

$$PIS_j = \max_i\left(w_j x a_{ij}\right), \forall_j = 1, \dots, m \; for \; j \in B \quad (5a)$$

$$PIS_j = \min_i\left(w_j x a_{ij}\right), \forall_j = 1, \dots, m \; for \; j \in C \quad (5b)$$

$$NIS_j = \min_i\left(w_{jx} x a_{ij}\right), \forall_j = 1, \dots, m \; for \; j \in B \quad (6a)$$

$$NIS_j = \max_i\left(w_j x a_{ij}\right), \forall_j = 1, \dots, m \; for \; j \in C \quad (6b)$$

$$S_j = \frac{\sum_{i=1}^{n}\left(w_j x a_{ij}\right)}{n}, \forall_j = 1, \dots, m \; j \; for \; \in B, C \quad (7)$$

Where *B* represents the benefit set and *C* is the cost set.

d (PIS_j)) and negative ideal (*d* (NIS_j)) solutions are determined. The distance from the average solution is also identified for positive (*d* (AS_j^+)) and negative (*d* (AS_j^-)) solutions.

$$d\left(S_j\right) = dE\left(S_j\right) + \sigma \; x \; dE\left(S_j\right) \; x \; dT\left(S_j\right), \forall_j = 1, \dots, m \quad (8)$$

For any solution S_j (PIS_J, NIS_j, or AS_j) the correction coefficient σ is calculated using the equation

$$\sigma = \max_i dE\left(S_j\right)_i - \min_i dE\left(S_j\right)_i \quad (9)$$

The symbols $dE(S_j)_i$ and $dE(S_j)_i$ represent the Euclidean and Taxicab distances, respectively. Accordingly, the differences between the positive and negative ideal solutions are shown by Eqs.

$$dE(PIS_j)_i = \sqrt{\sum_{j=1}^{m}(PIS_j - w_j\ x\ a_{ij})^2}, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (10)$$

$$dT(PIS_j)_i = \sum_{j=1}^{m}|PIS_j - w_j\ x\ a_{ij}|, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (11)$$

$$dE(NIS_j)_i = \sqrt{\sum_{j=1}^{m}(PIS_j - w_j\ x\ a_{ij})^2}, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (12)$$

$$dT(NIS_j)_i = \sum_{j=1}^{m}|NIS_j - w_j\ x\ a_{ij}|, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (13)$$

Euclidean and Taxicab distances for positive and negative deviations from the average solution are calculated by equations

$$dE(AS)_i^+ = \sqrt{\sum_{j=1}^{m}\tau^+(AS_j - w_j\ x\ a_{ij})^2}, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (14)$$

$$dT(AS)_i^+ = \sum_{j=1}^{m}\tau^+|AS_j - w_j\ x\ a_{ij}|, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (15)$$

$$\tau^+ = \begin{cases} 1 & AS_j < w_j\ x\ a_{ij} \\ 0 & AS_j > w_j\ x\ a_{ij} \end{cases} \quad (16)$$

$$dE(AS)_i^- = \sqrt{\sum_{j=1}^{m} \tau^-\left(AS_j - w_j\ x\ a_{ij}\right)^2}, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (17)$$

$$dT(AS)_i^- = \sum_{j=1}^{m} \tau^-\left|AS_j - w_j\ x\ a_{ij}\right|, \forall_i = 1, \dots, n, \forall_j = 1, \dots, m \quad (18)$$

$$\tau^- = \begin{cases} 1 & AS_j > w_j\ x\ a_{ij} \\ 0 & AS_j < w_j\ x\ a_{ij} \end{cases} \quad (19)$$

Step 6. The alternatives are ranked based on the comprehensive distance (dC_i)

$$dC_i = \frac{d\left(PIS_j\right)_i - d\left(NIS_j\right)_i - d\left(AS_j\right)_i^+ + d\left(AS_j\right)_i^-}{4}, \forall_i = 1, \dots, n \quad (20)$$

3.Results and discussion

Developed with numerous circular economy indicators (Eurostat, The Word Bank, OECD statistics). They are used as criteria in the multi-criteria decision-making method. In this study, the multi-criteria analysis of the circular economy problem in Serbia based on the COBRA method is based on the following criteria:

C1 - Recycling rate of municipal waste, Percentage

C2 - Generation of municipal waste per capita, Kilograms per capita

C3 - Material import dependency, Percentage

C4 - Resource productivity, Euro per kilogram

C5 - Overall share of energy from renewable sources, (% of gross final energy consumption)

In Serbia in the period 2012 - 2022, a strong correlation between the production of municipal waste and the recycling rate of municipal waste (.894) was recorded at the level of statistical significance (.000). There is a strong correlation between the production of municipal waste and the use of energy from renewable sources (.812) at the level of statistical significance (.002). Likewise, there is a strong correlation between energy from renewable sources and the recycling rate of municipal waste (.947) at the level of statistical significance (.000). All this in itself leads to the conclusion that efficient management of these statistical variables can significantly influence the achievement of the target performance of the circular economy in Serbia. (The correlation analysis was performed on the Eurostat database.)

The alternatives are:

A1 – 2013

A2 – 2014

A3 – 2015

A4 – 2016

A5 – 2017

A6 – 2018

A7 – 2019

A8 – 2020

A9 – 2021

A10 – 2022

The necessary empirical data for the analysis of the circular economy problem in Serbia were collected from Eurostat. (In this study, the calculations and results are the author's.)

The decision matrix is shown in Table 1.

Table 1 Decision Matrix

w	0.2635	0.3177	0.1721	0.117	0.1298
	C1	C2	C3	C4	C5
A1	1	336	9.8	0.3352	21,095
A2	0.7	299	11.1	0.346	22,864
A3	0.8	259	12.4	0.3278	21,989
A4	0.3	268	12.5	0.3096	21,147
A5	0.3	306	14.2	0.3458	20,287
A6	0.3	319	14	0.3629	20.32

A7	0	338	14.1	0.3656	21,443
A8	15.4	427	12.7	0.3564	26,297
A9	16.8	442	13.5	0.4015	25,255
A10	17.6	472	0	0	27,077
MAX	17.6	472	14.2	0.4015	27,077

The weighting coefficients of the criterion were determined using the AHP method (Table 2).

Table 2 Weight coefficients of the criterion

		1	2	3	4	5	**WEIGHTS**	
		C1	C2	C3	C4	C5		
1	C1	1.00	1.00	1.50	2.00	2.00	**0.2635**	
2	C2	1.00	1.00	2.00	2.50	3.00	**0.3177**	
3	C3	0.67	0.50	1.00	2.00	1.00	**0.1721**	
4	C4	0.50	0.40	0.50	1.00	1.00	**0.1170**	
5	C5	0.50	0.33	1.00	1.00	1.00	**0.1298**	
							1.0000	
							Consistency Ratio	**0.0130**

Generation of municipal waste per capita, Kilograms per capita) is highly ranked. Adequate management of municipal waste production per capita (kilograms per capita) can influence the achievement of the target performance of the circular economy in Serbia. In this direction, it is important to improve the productivity of the resource.

The ranking of alternatives based on the COBRA method is shown in Table 3 and Figure 1.

Table 3 Results of the COBRA method

		D(PIS)	D(NIS)	d(as+)	d(as-)	dC		rank
2013	A1	0.07704	0.027282459	0.005952	0.071924	0.028932546	0.028933	7
2014	A2	0.082739	0.030026097	0.009189	0.0804485	0.030993172	0.030993	8
2015	A3	0.088793	0.032708685	0.012629	0.0951485	0.034650782	0.034651	9
2016	A4	0.091507	0.031906843	0.01326	0.0977785	0.036029854	0.03603	10
2017	A5	0.083852	0.041964564	0.03616	0.0851626	0.0227225	0.022722	6
2018	A6	0.081679	0.042863632	0.035554	0.082298	0.021389865	0.02139	5
2019	A7	0.08109	0.044766858	0.037074	0.0840075	0.020814041	0.020814	4
2020	A8	0.002541	0.107181538	0.17786	0	-0.070625174	-0.07063	2

2021	A9	0.000702	0.126998567	0.207061	0	-0.083339304	-0.08334	1
2022	A10	0.044399	0.094762587	0.224164	0.1794501	-0.023769321	-0.02377	3

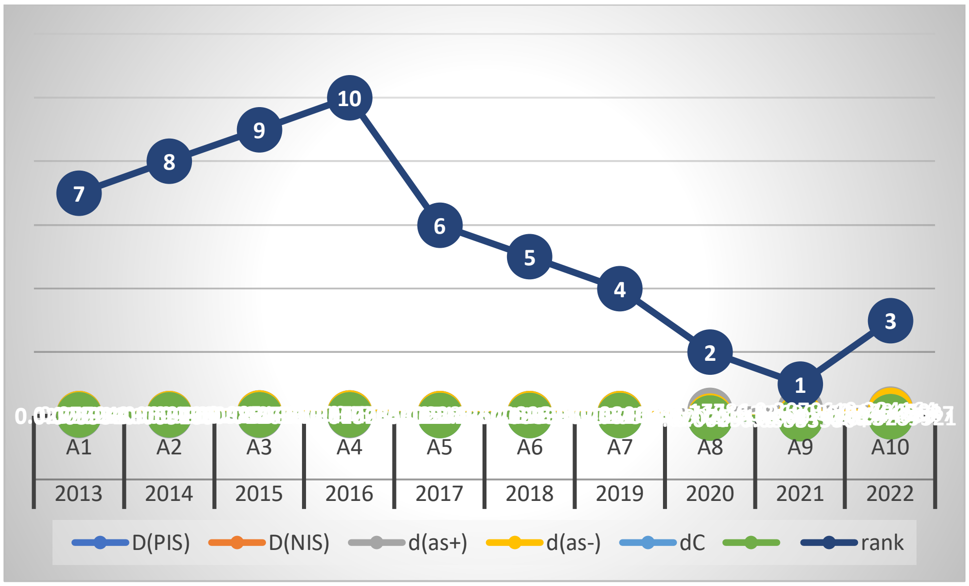

Figure 1 Ranking of alternatives according to the COBRA method

Source: Author's picture

The data in Table 3 show that the best performance of the circular economy in Serbia was in 2021. The worst was in 2016. Recently, the performance of the circular economy in Serbia has been improving. To improve the performance of the circular economy in Serbia, it is necessary to manage the recycling of municipal waste, production of municipal waste, dependence on the import of materials, resource productivity, and energy from renewable sources as efficiently as possible with an adequate action plan. This also applies to other relevant factors. The increasing application of the circular economy principle contributes significantly to the preservation of the environment in Serbia.

4.Conclusion

In this local study, we can conclude the following: the results of the COBRA method show that in the period 2013 - 2022, the best performances of the circular economy in Serbia were in 2021. The worst was in 2016. Generally speaking, the performance of the circular economy has been improving recently in Serbia. In the direction of continuous improvement of the performance of the circular economy in Serbia, it is certainly necessary, with an adequate action plan, to manage the recycling of municipal waste, production of municipal waste, dependence on the import of materials, resource productivity and energy from renewable sources, and other relevant factors as efficiently as possible. In principle, the increasing application of the circular economy principle contributes significantly to the preservation of the environment in Serbia.

References

1 Alberich, J.P., Pansera, M., & Hartley, S.(2023). Understanding the EU's circular economy policies through futures of circularity. *Journal of Cleaner Production*, 385, 135723. https://doi.org/10.1016/j.jclepro.2022.135723.

2 Abramović, F., Popović, M.P., Simić, V., Matović, V., & Šerović, R. (2024). Characterization and Environmental Evaluation of Recycled Aggregates from Construction and Demolition Waste in Belgrade City Area (Serbia). *Materials*, *17*, 820. https://doi.org/10.3390/ma17040820

3 Alivojvodic, V., & Kokalj, F. (2024). Drivers and Barriers for the Adoption of Circular Economy Principles towards Efficient Resource Utilisation. *Sustainability*, *16*, 1317. https://doi.org/10.3390/su16031317

4 Amicarelli, V., Bux, C., & Fiore, M. (2024). Guest editorial: Circular economy in the agri-food, tourism, and hospitality industries in the post-pandemic era. *British Food Journal*, 126(1), 1-12. https://doi.org/10.1108/BFJ-01-2024-369

5 Bjelić, D., Markić, D.N., Prokić, D. *et al.* (2024). "Waste to energy" as a driver towards a sustainable and circular energy future for the Balkan countries. *Energ Sustain Soc* 14. https://doi.org/10.1186/s13705-023-00435-y

6 Kosanović, S., Miletić, M., & Marković, L.(2021). Energy Refurbishment of Family Houses in Serbia in Line with the Principles of Circular Economy. *Sustainability*, *13*, 5463. https://doi.org/10.3390/su13105463

7 Krstic, M., Agnusdei, G.P., Miglietta, P.P., Tadic, S., Roso, V. (2022). Applicability of Industry 4.0 Technologies in the Reverse Logistics: A Circular Economy Approach Based on COmprehensive Distance RAnking (COBRA) Method. *Sustainability*, 14, 5632. https:// doi.org/10.3390/su14095632

8 Friant, M.C., Vermeulen, W.J.V., & Salomone, R. (2021). Analysing European Union circular economy policies: words versus actions. *Sustainable Production and Consumption*, 27, 337-353. https://doi.org/10.1016/j.spc.2020.11.001.

9 Ilić, M., & Nikolić, M. (2016). Drivers for development of circular economy – A case study of Serbia. *Habitat International*, 56, 191-200. https://doi.org/10.1016/j.habitatint.2016.06.003.

10 Krstić, M., Elia, V., Agnusdei, G.P., De Leo, F., Tadić, S., & Miglietta, P.P. (2024). Evaluation of the agri-food supply chain risks: the circular economy context. *British Food Journal*, 126(1), 113-133. https://doi.org/10.1108/BFJ-12-2022-1116

11 Mazur-Wierzbicka, E.(2021). Circular economy: advancement of European Union countries. *Environ Sci Eur*, 33, 111. https://doi.org/10.1186/s12302-021-00549-0

12 Marković, M., Popović, Z., & Marjanović, I. (2023).Towards a circular economy: evaluation of waste management performance in European Union countries. *Serbian journal of management* 18 (1), 45 – 57. Doi: 0.5937/sjm18-40073

13 Mihajlov, A., Mladenovic, A., & Jovanovic, F. (2021). Country in transition (Serbia) case: Circular economy starts from waste management. *Environmental Research and Technology*, 4(1), 83-88. https://doi.org/10.35208/ert.853792

14 Oğuz, A., & Satır, H. (2024). Analyzing profitability performance with the integrated MEREC-COBRA method: The case of BIST retail companies. *Business and Economics Research Journal*, 15(1), 33-50. http://dx.doi.org/10.20409/berj.2024.433

15 Popović, G., Pucar, Đ., & Smarandache, F. (2022). MEREC-COBRA approach in e-commerce development strategy selection. *Journal of Process Management and New Technologies*, 10(3-4), 66-74. https://doi.org/10.5937/jouproman2203066p

16 Radovanov, B., Horvat, A.M., Stojić, D., Sedlak, O., & Dušan Bobera, D. (2023). Assessing circular economy performance of European countries and Serbia using data envelopment analysis. *The European Journal of Applied Economics - EJAE*, 20(2), 1 – 11. DOI: 10.5937/EJAE20-44067

17 Saaty, T. L. (2008). Decision Making With The Analytic Hierarchy Process. *Int J Serv Sci*, 1(1), 83-98. https://doi.org/10.1504/IJSSCI.2008.017590

18 Stoiljkovic, B., Petkovic, N., Krstic, H., & Petrovic, V. (2023). Application of Circular Economy Principles to Architectural Design: A Case Study of Serbia. *Buildings*, 13, 1990. https://doi.org/10.3390/buildings13081990

19 Stošić, I., & Šmelcerović, M. (2023). The path towards the circular economy and sustainability in the construction industry: A case study of Serbia, *SCIENCE International Journal*, 2(3), 15-21. doi: 10.35120/sciencej0203015s UDK: 338.121:658.567]:69(497.11)

20 The Word Bank - Squaring the Circle: Policies From Europe's Circular Economy Transition, 2022.

21 Vukelić, I., Milošević, S., Đurđević, D. *et al.* (2023). Sustainable transition of the Republic of Serbia: measuring capacity for circularity in agriculture and rural areas. *Energ Sustain Soc*, 13, 34. https://doi.org/10.1186/s13705-023-00413-4