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THE ROLE OF MULTI-CRITERIA DECISION-MAKING IN IMPROVING CIRCULAR ECONOMY PERFORMANCES: EUROPEAN CONTEXT

Abstract

This paper evaluates circular-economy performance across selected European countries using Eurostat indicators: resource productivity, waste generation (excluding major mineral wastes), waste per capita, recycling rate, and municipal waste per capita using two MCDM methods: PROMETHEE and ARAS. The methodological design enables ranking of alternatives, visualization of trade-offs among criteria, and identification of dominance directions. Findings consistency has shown Sweden as the top performer (maximum utility and the highest aggregate score), whereas Western Balkan countries lag due to lower recycling rates and higher per-capita waste. Several mid-developed economies exhibit stable profiles and can serve as reference models. Policy implications emphasize scaling recycling capacity, improving resource productivity, strengthening waste-management systems, and aligning with the EU framework through targeted funding and improved institutional coordination.

Key words: *circular economy, performances, MCDM, PROMETHEE, ARAS*

JEL classification: *C44, Q33, Q56*

УЛОГА ВИШЕКРИТЕРИЈУМСКОГ ОДЛУЧИВАЊА У ПОБОЉШАЊУ ПЕРФОРМАНСИ ЦИРКУЛАРНЕ ЕКОНОМИЈЕ: ЕВРОПСКИ КОНТЕКСТ

Апстракт

Овај рад процењује перформансе циркуларне економије у одабраним европским земљама користећи Евростат индикаторе: продуктивност ресурса, генерисање отпада (без главних минералних отпада), отпад по глави становника, стопу рециклаже и комунални отпад по глави становника употребом две методе вишекритеријумског одлучивања: PROMETHEE и ARAS. Методолошки оквир омогућава рангирање алтернатива, визуелизацију компромиса међу критеријумима и идентификацију смерова доминације.

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Конзистентност резултата указује на то да је Шведска водећа земља (максимална корисност и највиши збирни скор), док земље Западног Балкана заостају због ниже стопе рециклаже и већег отпада по глави становника. Средње развијене економије показују стабилне перформансе и могу послужити као референтни модели. Импликације за креаторе политика укључују јачање рециклажних капацитета, повећање продуктивности ресурса, унапређење управљања отпадом и усклађивање са оквиром ЕУ кроз циљано финансирање и бољу институционалну координацију.

Кључне речи: *циркуларна економија, перформансе, вишекритеријумско одлучивање, PROMETHEE, ARAS*

Introduction

The circular economy (CE) represents a fundamental shift away from the linear "take–make–dispose" model of production and consumption. Instead, it prioritizes keeping products, materials, and components in use for as long as possible through closed-loop systems. The innovative approach of circular economy (CE) involves the reuse and recycling of resources, which return the waste materials to the production flows in order to optimize products, services, processes, and functions within a system. Core principles include (Awan & Sroufe, 2022; Obiuto et al., 2024; Solomon et al., 2024): (a) designing for durability to prevent premature obsolescence, (b) minimizing waste at the design stage, (c) extending product lifetimes via refurbishment, renovation, modification, or performance upgrades and remanufacturing, restoring used goods to near-new condition through disassembly, (d) cleaning, part replacement, and testing.

Far from being purely conceptual, these principles provide a practical blueprint for businesses to transition toward more sustainable models by reframing "waste" as a resource and embedding circular thinking across the entire life cycle. This system's approach aligns with broader sustainability agendas, especially the UN SDGs, such as SDG 12 (Responsible Consumption and Production) and SDG 9 (Industry, Innovation, and Infrastructure) which promote innovation to recover resources and reduce environmental harm (Papamichael et al., 2024; Raman et al., 2024). Integrating CE principles into industrial processes is now essential amid rising environmental pressures, supply-chain volatility, and more discerning consumers, where one of the biggest challenges can be identified as the necessity of meeting the growing needs of the urban population while ensuring economic, environmental and social sustainability of the society. As firms confront resource scarcity and climate change, circular strategies offer new ways to create, deliver, and capture value, most notably by reducing reliance on virgin, non-renewable inputs. Practices like remanufacturing recapture value from returns and end-of-life products, while green manufacturing embeds environmentally beneficial methods to lower energy use, emissions, and waste, leading to vital economic growth. Policymakers must identify appropriate instruments to target existing problems and constraints. Even resource-intensive sectors such as mining are applying circular methods to address long-standing sustainability issues (Ghaithan et al., 2023; Remeikienė et al., 2025).

Operators are using Industry 4.0, enabled smart logistics and IoT sensors, AI, and real-time analytics, to trace materials, optimize operations, and facilitate the reuse and recycling of valuable by-products even developing digital (smart) agriculture (Kamali Saraji et al. 2025; Vaezinejad et al. 2025). These intelligent systems both improve efficiency and shrink carbon footprints by reducing energy demand and enabling more efficient resource flows and finally could improve export which is the most important for the country's competitiveness (Han et al., 2023; Chi et al, 2023). By designing loops that return materials and components to production, companies can curb depletion of finite resources, preserve capital, and strengthen environmental credibility. The EU's circular economy frameworks emphasize linking digitalization with well-structured policies to reduce single-use materials and encourage product-service models (Popović et al, 2025). The convergence of CE principles with digital technologies thus signals a transformative move toward industrial systems that are more sustainable, low-carbon, and resource-efficient (Woschank & Zsifkovits, 2021). The assessment of the performance of the circular economy in this research will be based on the application of MCDM methods in the case of the ranking of selected European countries (Peyravi et al, 2024; Mesa, 2023). Namely, after certain literature findings, the research methodology will be presented based on the analysis of circular economy indicators as the main criteria in the performance ranking of European countries (Figueiredo & Figueiredo, 2025). A comparative presentation of MCDM methods such as PROMETHEE and ARAS, along with their advantages and limitations, will analyze the leading countries in the field of circular economy, their influence on policymakers, as well as their importance in the implementation of circular economy postulates.

1. Theoretical Background

The transition to a circular economy and the associated challenges require rapid, innovative solutions that ultimately contribute to an environmentally sustainable future, given that the amalgamation of the circular economy and the Industry 4.0 concept has produced an entirely new economic environment (Xie et al., 2022). The necessary shift to a circular economy is widely recognized as a complex and immense challenge that stimulates intensive debate and diverse approaches to transformation. Cities and regions, key drivers of the circular economy, must urgently reconsider how to accelerate and improve this transition process. As part of this comprehensive transition, innovative approaches to process evaluation, capacity building, financing, and regulation are essential for optimizing the current linear system. Such optimization may include the adoption of green and clean production techniques, changes in value-chain relationships, the identification of relevant synergies, and the optimization of cross-sectoral processes. These technologies can help develop durable and sustainable products, drive new circular business models, and support the infrastructure needed to scale up the circular economy (Walzberg et al., 2020). Multi-criteria decision-making (MCDM) is a way to help decision-makers rationally choose among multiple options where several conflicting objectives are present. It is often used when: (a) There is a combination of criteria that are clearly not directly comparable; and (b) Multiple stakeholder perspectives influence the decision being made.

The qualitative element of multi-criteria analysis concerns working with stakeholders to explore their perspectives. The quantitative element concerns the use of models to represent stakeholder preferences and the performance of different options. MCDM is described as a normative, or prescriptive, approach to decision analysis, rather than a descriptive one. It indicates which decision should be made if the decision-maker is consistent with the stated preferences. MCDA seldom captures all modifications associated with a decision. This means it should be viewed as a support tool for decision-makers, not as a comprehensive solution to decision-making. The views of different stakeholders must be taken into account in order to make good decisions within organizations. This means that one of the first actions is to identify an adequate set of stakeholders who provide the necessary diversity of perspectives relative to the complexity of the problem. Preferences are inherently subjective, which means that precautions must be taken to ensure a valid MCDM outcome (Meng et al., 2025). A particularly useful technique is to examine how seemingly impartial positions relate to relevant strategic objectives. All criteria in an MCDM problem can be classified into two categories. Criteria to be maximized fall into the category of "benefit" (or performance) criteria, though they need not literally be profit measures, while criteria to be minimized fall into the category of "cost" criteria.

The ideal solution to an MCDM problem would maximize all benefit criteria and minimize all cost criteria. There are two types of MCDM methods, compensatory and non-compensatory:

a) Compensatory methods allow trade-offs among criteria. A slight decrease in one criterion is acceptable if it is offset by an improvement in one or more other criteria.
b) Non-compensatory methods do not allow trade-offs among criteria. An unfavorable value on one criterion cannot be compensated by favorable values on other criteria; each criterion must stand on its own. Comparisons are therefore made on a criterion-by-criterion basis.

The purpose of MCDM is to help decision-makers select the most suitable alternative from a set of options while considering multiple criteria simultaneously (Theilig et al., 2024). This approach recognizes that decisions are rarely based on a single factor and aims to provide a comprehensive analysis that reflects the complexity and multidimensional nature of decision problems. The purpose of MCDM is to acknowledge that decision problems often involve conflicting objectives and to provide a structured framework for evaluating and comparing alternatives based on their performance against the identified criteria. The key objectives of MCDM can be summarized as follows:

- Comprehensive evaluation - MCDM aims to provide a holistic assessment of alternatives by considering multiple criteria. It takes into account both quantitative and qualitative factors relevant to the decision problem, ensuring a more comprehensive and balanced evaluation.
- Trade-off analysis - MCDM recognizes that decision problems often involve trade-offs among criteria. By explicitly considering trade-offs, decision-makers can gain insight into the implications of different choices and make informed decisions aligned with their goals and preferences.
- Stakeholder involvement - MCDM methods often involve the participation of stakeholders in the decision-making process. By incorporating the

preferences and perspectives of different stakeholders, MCDM promotes inclusiveness, transparency, and accountability in decision-making.

- Structured decision process - MCDM provides a structured framework and systematic approach to decision-making. It involves a sequence of steps, problem formulation, criteria identification, alternative evaluation, and ranking, that help decision-makers navigate complex decision problems logically and coherently.
- Decision support - MCDM methods serve as decision-support tools, providing decision-makers with valuable insights, information, and analyses to facilitate the decision process. They help decision-makers make more informed and rational choices by considering a broader range of factors and perspectives.

By providing a systematic approach and incorporating stakeholder preferences, MCDM methods enable decision-makers to navigate complex decision problems and choose alternatives that are best aligned with their objectives and priorities, thereby shaping balanced and optimized circular models (Walzberg et al., 2020). Using MCDM methods, decision-makers can manage complex decision problems more effectively, leading to more informed and balanced decisions. The multi-criteria decision-making process typically involves several key steps that guide decision-makers through the evaluation and selection of alternatives based on multiple criteria. Although specific details may vary depending on the chosen MCDM method, the following steps provide a general overview of the MCDM process (Wang et al., 2024):

1. Problem formulation - Clearly define and articulate the decision problem. This includes identifying the objectives, criteria, and constraints of the decision. The decision-maker should have a clear understanding of what needs to be achieved and the context in which the decision is being made.
2. Criteria identification - Identify and define the criteria to be used in evaluating alternatives. Criteria may be quantitative or qualitative and should be relevant to the decision problem. It is important to ensure that the criteria are comprehensive, non-redundant, and mutually exclusive.
3. Alternative generation - Generate a set of feasible alternatives that could potentially solve the decision problem. Creativity and domain knowledge are essential for identifying a diverse range of alternatives. The number of alternatives should be manageable yet sufficiently representative to allow meaningful comparison.
4. Evaluation and measurement of criteria - Evaluate and measure each criterion for every alternative. This step involves collecting data or information regarding the performance of alternatives on each criterion. The data may be quantitative (numerical values) or qualitative (scores or rankings). Various techniques, such as surveys, expert judgment, or data-analysis methods, can be used for quantification.
5. Weighting and normalization - Once criteria have been evaluated, assign weights representing the relative importance of each criterion. Weighting reflects the decision-maker's preferences and priorities. Normalization may also be performed to standardize criterion values, ensuring they are on the

same scale and comparable.

6. Selection of a decision method - Choose an appropriate MCDM method or approach. The choice depends on the nature of the decision problem, the available data, and the decision-maker's preferences. Common MCDM methods include the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).
7. Alternative ranking and selection - Using the chosen MCDM method, rank or prioritize the alternatives based on their performance across the criteria. The method aggregates criterion evaluations, taking into account the assigned weights and preferences. The outcome is a ranked list of alternatives indicating their relative suitability or preference.
8. Sensitivity analysis - Conduct sensitivity analysis to assess the robustness and stability of results. This involves examining the impact of changes in criterion weights or alternative scores on the ranking. Sensitivity analysis helps to understand the influence of uncertainty and variability on the final decision.
9. Decision implementation - After alternatives have been ranked and selected, proceed with implementing the chosen alternative. This may include further planning, resource allocation, and monitoring to ensure that decisions are effectively put into practice.

This may include further planning, resource allocation, and monitoring to ensure effective implementation. It is important to note that the MCDM process is iterative and may involve revisiting steps to refine the problem formulation, criteria, or evaluations based on feedback and additional analyses. MCDM methods offer several advantages that make them valuable decision-making tools, but they also have limitations that should be considered. Key advantages and limitations include (Taherdoost & Madanchian, 2023):

- Consideration of multiple criteria - MCDM methods allow decision-makers to consider and evaluate multiple criteria simultaneously, enabling a more comprehensive and holistic assessment of alternatives that reflect the different dimensions of the decision problem.
- Transparency and accountability - MCDM methods provide a transparent and documented process for decision-making. Criteria, weights, and evaluation procedures are explicitly defined, allowing decision-makers to justify and communicate their decisions to stakeholders.
- Flexibility and adaptability - MCDM methods can be adapted to different decision contexts and tailored to specific evaluation needs. They can handle both quantitative and qualitative criteria, enabling decision-makers to incorporate diverse types of information into the decision process.
- Sensitivity analysis - MCDM methods often support sensitivity analysis, allowing decision-makers to assess the robustness of results. Sensitivity analysis helps identify the impact of changes in criterion weights, scores, or preferences on the final ranking, improving understanding of uncertainty and decision stability.
- Subjectivity and bias - MCDM methods rely on subjective judgments and preferences of decision-makers. The accuracy and consistency of these

judgments may vary, leading to potential biases and subjectivity in the decision process.

- Data availability and quality - MCDM methods heavily depend on data for criterion evaluation. Obtaining accurate and reliable data for all criteria can be challenging, particularly in complex decision problems. Incomplete or inaccurate data can affect the validity and reliability of results.
- Complex decision contexts - MCDM methods may struggle with decision problems involving a very large number of criteria and alternatives. The complexity of computations and interpretation of results can be challenging, requiring additional effort and expertise.
- Simplifying assumptions - MCDM methods often require simplifying assumptions to facilitate computation and comparison. These assumptions may oversimplify the decision problem, overlooking important combinations and interactions among criteria and potentially affecting result accuracy.
- Limited treatment of uncertainty - MCDM methods generally do not explicitly account for uncertainty and risk. While sensitivity analysis can provide insights into robustness, it may not capture all sources of uncertainty, limiting the ability to make fully informed decisions in uncertain environments.
- Lack of a universal method - No single MCDM method is universally applicable to all decision problems. The choice of a method depends on the characteristics of the decision problem, available data, the decision-maker's preferences, and the desired level of complexity. Selecting an appropriate method requires careful consideration and expertise.

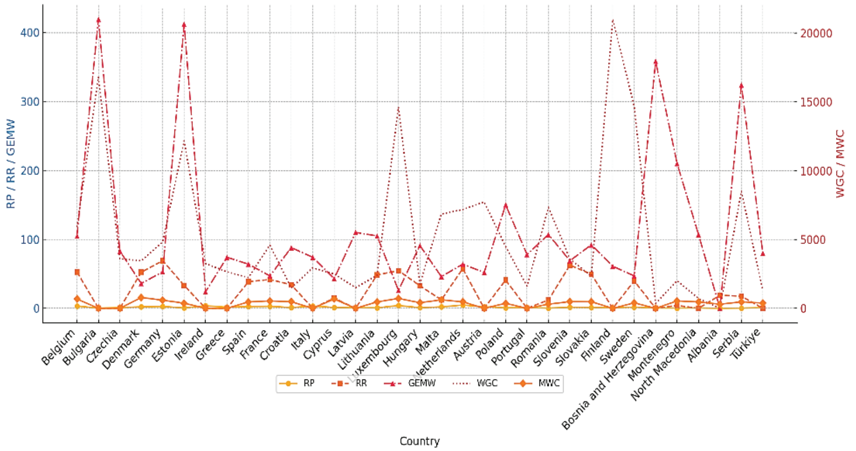
2. Research Design and Methodology

The diversity of multi-criteria decision-making (MCDM) methods provides an exceptionally valuable analytical framework for assessing indicator performance within the circular economy. These methods, grounded in the consideration of multiple criteria and objectives, enable decision-makers to systematically evaluate alternatives, set priorities, and formulate actions that foster a sustainable circular transition (Garcia-Bernabeu et al., 2020). Based on a review of the relevant literature, the author concludes that all indicators should carry equal importance in the subsequent analysis. Specifically, determining the weighting coefficients of the criteria (indicators) for further analysis is one of the key aspects of MCDM, as it evaluates each criterion's contribution to the construction of the multi-criteria model (Rađenović & Veselinović, 2017). Through a comparative analysis of two MCDM methods, the study will rank the country with the optimal environment for developing the postulates and principles of the circular economy and for improving existing performance. Accordingly, drawing on the experience of the top-ranked country, the other countries in the model should receive guidance for shaping their own trajectories in circular-economy development. The data required for this analysis were collected from the Eurostat database and refer to the performance values of circular economy indicators for the most recent year available. Based on the most recently available data from the Eurostat database, 33 countries were analyzed using the following circular economy indicators developed according to the methodology of the applied database:

- Resource productivity (Eurostat, a),
- Generation of waste excluding major mineral waste per GDP unit (Eurostat, b),
- Waste generation per capita (Eurostat, c),
- Recycling rate of municipal waste (Eurostat, d),
- Generation of municipal waste per capita (Eurostat, e).

Below is a descriptive statistics chart showing the trends of the above indicators for the most recent available years (Figure 1). The chart displays various indicators related to waste management and resource productivity. It points to significant oscillations in waste generation, while the parameters related to recycling and resource productivity are relatively stable. These fluctuations may stem from seasonal changes, economic activity, or regional differences in waste management. In interpreting the chart, indicators with optimal behavior are those that exhibit stability without large oscillations and remain within reasonable bounds.

Figure 1: Descriptive statistics for analyzed indicators according to last available data



*Note: RP- Resource productivity; GEMW- Generation of waste excluding major mineral wastes per GDP unit; WGC- Waste generation per capita; RR- Recycling rate of municipal waste; MWC- Generation of municipal waste per capita

Source: Authors' calculations

For this reason, in the multi-criteria model, identical weights are assigned to all indicators ($w_i = 0.2$), indicating their equal importance in contributing to the implementation of circular economy principles. One of the best-known methods within the MCDM approach is PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), developed in 1982 by Jean-Pierre Brans. Its implementation in the Visual PROMETHEE Academic software environment involves three steps (Visual PROMETHEE Academic, 2025):

- First, a fuzzy preference relation is constructed for each individual criterion, which entails quantifying the intensity of preference of one alternative over another.
- Next, a global preference is formed at the level of the entire set of alternatives, aggregating all individual preferences.

- The third step is the construction of the ranking, i.e., ordering the alternatives based on their overall preferential values.

Within the analysis, the decision-maker defines a preference function R_i for each criterion, thereby forming a fuzzy preference relation denoted S_i (a, b), which reflects the extent to which alternative a is preferred to alternative b for the given criterion. This approach enables precise ranking of options depending on the weights and preferences defined by the analyst or decision-maker (Rađenović & Rajić, 2025):

$$S_i: AxA \rightarrow [0,1];\ S_i(a,b) = P_i\big(f_i(a) - f_i(b)\big) = P_i(d) \tag{1}$$

For each alternative from the set A, inflows and outflows are calculated based on the Phi (+, −) coefficient, which ranges from −1 to +1. The values of this coefficient reflect the degree to which one alternative dominates others in the overall set. Functionally, Phi (+, −) is analogous to the Pearson correlation coefficient, the higher its value, the greater the degree of dominance of the alternative. Parameters defined in this way enable the decision-maker to make a structured, transparent, and objective decision in a multi-criteria environment on the basis of quantitative and qualitative preferences (Brans et al., 1986):

$$\Phi^+(a) = \frac{1}{n-1}\sum_{x\in A} S(a,x) \tag{2}$$

$$\Phi^-(a) = \frac{1}{n-1}\sum_{x\in A} S(x,a) \tag{3}$$

In addition to PROMETHEE, the analysis also applied the ARAS method (Additive Ratio Assessment System), developed by Zavadskas and Turskis. Unlike other multi-criteria decision-making methods, ARAS is based on a utility function, through which the performance of each alternative is calculated and compared (Zavadskas & Turskis, 2010). In the aggregation process, the values of the weighted normalized matrix for each alternative A_i and the reference point A_0 are summed (Marjanović et al., 2019). In this way, the overall performance index S_i is obtained, as well as the index of the optimal alternative S_0. After normalization and optimization of the data, the utility index U_i is also derived, which enables the final ranking (Jovčić et al., 2020):

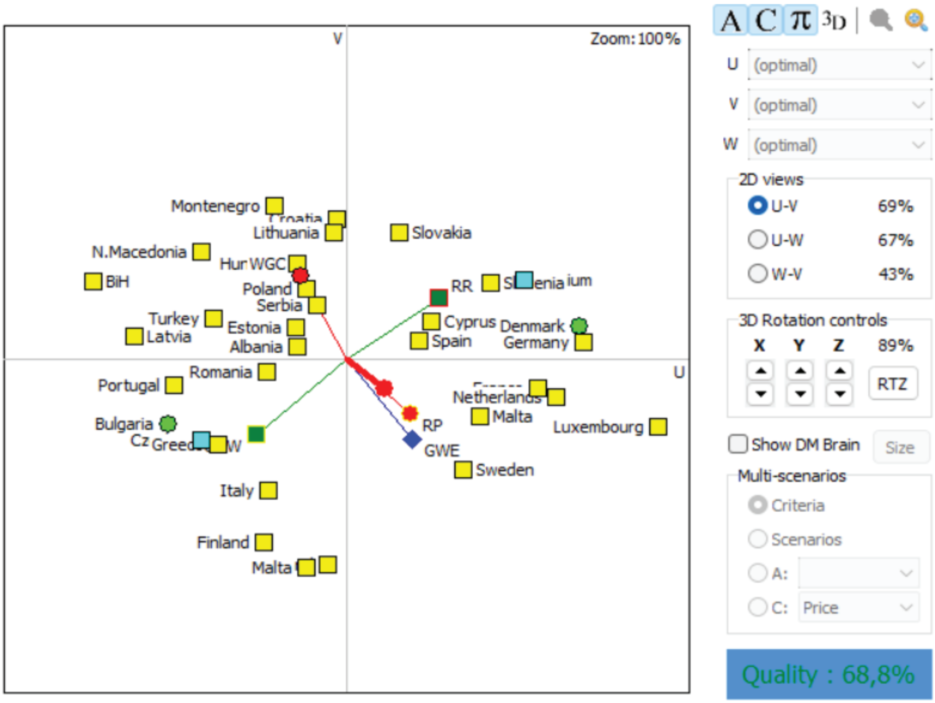
$$S_i = \sum_{j=1}^{n} y_{ij},\ \ U_i = \frac{S_i}{S_{i\,max}} \times 100\% \tag{4}$$

3. Results and Discussion

The following graphic presents the GAIA (Geometrical Analysis for Interactive Aid) matrix, which is used for multi-criteria decision analysis (Figure 2). This space enables the visualization of trade-offs between alternatives (countries) and criteria (indicators), grouping alternatives into “mini-clusters” by quadrants (Rađenović & Rajić, 2024). The vectors in the plot represent the direction and importance of each indicator, while the projections of countries relative to the vectors indicate their position in the circular economy. Germany, Denmark, and Spain show strong alignment with the indicators Recycling Rate (RR) and Resource Productivity (RP), whereas Serbia, Estonia, and Albania lie closer to the negative sides of the vectors, suggesting a need for interventions and policy improvements. In this context, multi-criteria methods such as PROMETHEE, combined with the GAIA tool, provide powerful visual insights into relationships between different indicators and alternatives (countries). The GAIA matrix offers a clearer understanding of how individual countries perform across multiple criteria, knowledge that is essential for strategy-making in the circular economy. In the GAIA chart shown, alternatives (countries) are depicted as yellow squares, while criteria are represented as vectors. The GAIA vector (red arrow) symbolizes the direction of the optimal compromise among all criteria, and the best alternative is located near that vector. GAIA analysis provides insight into: (a) Countries that are leaders in advancing the circular economy; (b) Criteria that exert the greatest influence on overall performance; (c) Clustering of countries by similarity, which can support the creation of regional strategies; (d) Linkages among indicators that help target measures with the highest impact.

The quality of the GAIA model is 68.8%, meaning that the two dimensions (U and V) explain almost 70% of the total variance in the data. This represents a sufficient level of reliability for drawing practical conclusions. GAIA analysis is a powerful decision-support tool in the domain of the circular economy. Based on the results, it is possible to formulate targeted policy measures and waste-management strategies. Countries with lower performance can use insights into the strengths of other countries as guidance for improvement. The GAIA method enables a visual understanding of complex interrelationships in a multi-criteria environment, crucial for making sustainable decisions in environmental planning. France, the Netherlands, Germany, and Malta are positioned closer to the GAIA vector and to the criteria RP and GWE. This indicates that these countries display balanced performance in terms of resource productivity and waste generation efficiency per unit of GDP. Serbia, Albania, Romania, and Estonia are located in the second quadrant, closer to the negative direction of the GAIA vector and indicators such as WGC, pointing to lower performance and higher waste generation per capita. Slovenia, Slovakia, and Sweden show an association with the Recycling Rate (RR), suggesting relatively high recycling rates. Italy and Finland are situated isolated from the main group, which may indicate a specific performance pattern not aligned with most other countries.

Figure 2: GAIA matrix



Source: Authors' calculations

The Western Balkan and Eastern European countries must improve resource productivity and expand recycling capacities in order to approach the optimal performance values of the circular economy. The "red stick" clearly indicates that countries such as the Netherlands, Luxembourg, and Sweden are leaders in the circular economy, and that development strategies should move in that direction. The most important priorities for improving performance are reducing waste per capita, increasing the recycling rate, and optimizing resources in production. The "red stick" (Decision stick) is a key element of the analysis:

- The direction and length of the stick indicate the preferred direction for optimizing the decision based on all criteria considered.
- It is oriented toward countries with better circular-economy performance, such as the Netherlands, Luxembourg, and Sweden.
- This means that the optimal strategy for improving circular-economy performance follows the path of countries with high resource productivity and effective waste-management systems.
- Countries that are farther from the stick's direction (Serbia, Bosnia and Herzegovina, Albania, North Macedonia) deviate significantly and have weaker circular-economy performance.

Applying the ARAS method and analyzing the values in the resulting table, it was determined that Sweden is the top-ranked country in terms of the selected circular-economy indicators. This position is the result of high values in both the overall performance index and utility, which sets Sweden apart as the most successful example of good practice within this research framework (Table 1).

Table 1: ARAS ranking results

Countries	Region	Si	Ui
Belgium	Western Europe	1754.05	8.33
Bulgaria	Eastern Europe	6737.03	32.00
Czech Republic	Central Europe	17204.34	81.71
Denmark	Scandinavia	3682.14	17.49
Germany	Central Europe	4330.49	20.57
Estonia	Baltics	5541.80	26.32
Ireland	Western Europe	12981.90	61.66
Greece	South Europe	3275.68	15.56
Spain	South Europe	2726.63	12.95
France	Western Europe	2802.12	13.31
Croatia	South Europe	5223.73	24.81
Italy	South Europe	2084.38	9.90
Cyprus	South Europe	3019.33	14.34
Letonia	Baltics	3223.11	15.31
Lithuania	Baltics	1611.93	7.66
Luxembourg	Western Europe	3015.19	14.32
Hungary	Central Europe	15423.64	73.25
Malta	South Europe	2289.79	10.88
Netherlands	Western Europe	7525.31	35.74
Austria	Central Europe	7774.15	36.92
Poland	Central Europe	7782.23	36.96
Portugal	South Europe	5047.70	23.97
Romania	Eastern Europe	1691.18	8.03
Slovenia	Central Europe	7758.45	36.85
Slovak Republic	Central Europe	4196.18	19.93
Finland	Scandinavia	2960.89	14.06
Sweden	Scandinavia	21054.94	100.00
Bosnia and Herzegovina	Western Balkan	15147.53	71.94
Montenegro	Western Balkan	716.46	3.40
North Macedonia	Western Balkan	2758.66	13.10
Albania	Western Balkan	1290.58	6.13
Serbia	Western Balkan	313.90	1.49
Türkiye	South-eastern Europe	9312.93	44.23

Source: Authors' calculations

Conclusion

The results obtained using the PROMETHEE and ARAS methods indicate a high degree of consistency in identifying the best- and worst-performing countries in terms of circular-economy performance. Sweden, as the leading country in the circular economy, emerges as a clear leader under both methods. In the PROMETHEE GAIA diagram, Sweden is positioned in the positive direction of the preference vector, confirming its dominant position. Likewise, within the ARAS methodology, it attains the maximum utility value as well as the highest overall score. At the other end of the spectrum, Western Balkan countries such as Serbia, Albania, and Montenegro show significantly lower values in both models. Low utility levels and placement in the lower-left quadrant of the GAIA space suggest the need for interventions in waste management, recycling, and efficient resource use. The results also indicate that medium-developed countries such as Hungary, the Czech Republic, and Ireland exhibit stable and balanced performance, suggesting their potential use as reference models for developing countries. The PROMETHEE method, as an advanced visual and analytical tool, enables the mapping of country performance through spatial relationships and directions of dominance. Its advantage lies in its ability to represent interactions among criteria, though it requires the subjective definition of preference functions. Conversely, the ARAS method offers transparent ranking based on established relative utilities, but tends to accentuate extreme values. Combining both methods in this study provides deeper insights and supports informed recommendations for future circular-economy policy. It is recommended to adopt hybrid analytical approaches that integrate visualization, ranking, and clustering to better capture regional and national specificities. In addition, improving institutional coordination, alignment with the EU legal framework, and the application of circular-economy indicators should be priorities in future initiatives of Western Balkan countries. The evaluation of the effectiveness of PROMETHEE and ARAS for assessing circular-economy performance is based on several parameters, including the ability to differentiate among alternatives, transparency in interpreting results, and flexibility in application to different data types.

In conclusion, multi-criteria decision-making methods provide decision-makers with valuable tools for evaluating and comparing alternatives based on multiple criteria. Decision-makers should be aware of the limitations and exercise caution when applying MCDM methods, ensuring that the chosen method aligns with the decision problem and taking into account expert judgment and sensitivity analysis to improve result robustness. MCDM methods continue to evolve with ongoing research and advances in the field. As decision-making becomes increasingly complex and multidimensional, MCDM methods provide a valuable framework for making informed decisions that account for multiple criteria and stakeholder preferences. By leveraging the strengths of MCDM methods and mitigating their limitations, decision-makers can enhance the quality and effectiveness of their decision processes. Decision-making is an essential technique, and the application of these methods has increased, offering a range of useful tactics for providing decision support. The MCDM method has the capacity to identify and more precisely resolve various conflicting interests.

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