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Introducing a Novel multi-criteria Ranking of Alternatives with Weights of Criterion (RAWEC) model

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REVIEW HIGHLIGHTS

- A novel methodology for selecting distribution centers, incorporating the LMAW and RAWEC methods, is established.
- The combination of specific steps in the MCDM method is proposed to enhance and streamline the decision-making process.

ARTICLE INFO

Method name:
RAWEC

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ABSTRACT

Optimal selection of agricultural distribution center location significantly impact the agricultural industry's growth and regional development, as they enhance product accessibility for customers and streamline delivery for suppliers. Research presented in this paper focuses on the selection of locations for the needs of an agricultural distribution center using a new method of multi-criteria decision making (MCDM), referred as the Ranking Alternatives with Weights of Criterion (RAWEC) method. On a real-world example, the Brčko District of Bosnia and Herzegovina was evaluated for potential sites for the formation of an agricultural distribution center. The Logarithm Methodology of Additive Weights (LMAW) method was employed to calculate criterion weights, while potential locations were ranked using the novel RAWEC method. Additional analyses, including result validation, dynamic decision matrix and sensitivity analysis validated the use of the RAWEC method in the problem of ranking alternatives by demonstrating that the ranking order obtained by this method is consistent and constant. Furthermore, the simplicity and small number of steps of RAWEC method distinguished it from other MCDM methods.

Specifications table

Subject area:	Economics and Finance
More specific subject area:	*Selection of locations for the needs of agricultural distribution*
Name of the reviewed methodology:	*Ranking Alternatives with Weights of Criterion (RAWEC) method*
Keywords:	*Expert; MCDM; Ranking Alternatives with Weights of Criterion, RAWEC, Selection of distribution centers.*
Resource availability:	*Not applicable.*
Review question:	*- Whether the novel MCDM method can be used in the site selection for agricultural distribution centers;* *- Whether there is a difference in the selection of these locations when compared to the application of other MCDM methods; and* *- Whether the novel RAWEC method can be used in this and similar decision-making problems.*

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Method details

Previous literature context

The process of location selection is an essential part of the decision-making process for organisations in different sectors, including agriculture. The literature review presented in this paper aims to provide an overview of the literature on location selection for agricultural distribution centres. The selection of a suitable location for a distribution centre can have a significant impact on a company's competitiveness, profitability, and sustainability [1–5]. Therefore, location selection for agricultural distribution centres has become a crucial research area. The selection process involves multiple criteria and objectives that often conflict with each other [6,7] and these criteria include transportation cost [8–10], proximity to markets [11–13], and the availability of resources [14–16], a workforce, and infrastructure, among others. The traditional methods, such as cost-benefit analysis, factor rating, and weighted score, have limitations in considering the complex interactions between criteria and objectives. Hence, researchers have proposed various MCDM methods to support many different MCDM problems, including location selection for agricultural distribution centres.

In the available literature, numerous studies have focused on location selection for agricultural distribution centres using MCDM methods. Selecting the ideal location for a distribution centre, according to Agrebi and Abed [17], is a critical strategic decision for logistics managers. However, human decision-making is frequently prone to uncertainty and inaccuracy, making informed predictions about the future behaviour of markets and companies difficult. To address this issue, their research proposes an improved fuzzy multi-attribute and multi-actor decision-making (FMAADM) method that incorporates group preferences, takes into account uncertain information about alternatives and criteria weights, and verifies the obtained solution [17]. A decision support system was developed to validate the FMAADM method, and various experiments were carried out to demonstrate its efficiency and superiority over existing methods. According to the authors [17], this proposed method can assist logistics managers in making more informed decisions in uncertain environments, resulting in better distribution centre location selection outcomes.

According to Kieu et al. [1], logistics are critical to increasing an economy's competitiveness. Authors argue that to achieve this, it is necessary to adopt effective business models and increase the connectivity of infrastructure systems. They also emphasise the growing significance of distribution centres in ensuring a smooth supply chain. To that end, a hybrid MCDM model based on spherical fuzzy AHP (SF-AHP) and the Combined Compromise Solution (CoCoSo) methodology is proposed to assist in the selection of distribution centre locations for perishable agricultural products. The authors conclude that the proposed model can improve agricultural supply chain efficiency by ensuring accurate and effective distribution centre location selection [18].

Nong [19] aimed to propose an MCDM model for selecting the optimal distribution centre location. The integrated approach used ANP and TOPSIS methods to define selection criteria weights and rank alternatives, respectively. Nong [19] applied the proposed model to Dong Nai province in Vietnam, and found Long Khanh to be the most appropriate location for the distribution centre. The model presented in this paper provides more powerful methods to decision makers than traditional methods and could be applied to distribution centre location selection in all industries.

Another study [20] proposes an integrated method for evaluating potential oilseed warehouse locations in Turkey. The method combines Delphi, AHP, TOPSIS, P-Median, and panel data analysis. The findings indicate that the most important criteria are oilseed production potential and area. The authors believe that the proposed model is robust and appropriate for warehouse location selection studies, and that the study could serve as a guide for policymakers [20]. It is worth noting that this was the first study to use an integrated approach in a real world setting for location selection.

The study presented by Puška et al. [21] sought green suppliers to assist agricultural producers in implementing green agriculture production in an uncertain decision-making environment. To avoid uncertainty in expert decision-making, the study combines Z-numbers with fuzzy Logarithm Methodology of Additive Weights (LMAW) and fuzzy Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) methods. Weighting coefficients for criteria are determined using the fuzzy LMAW method, and the best alternative is chosen using the CRADIS method modified with Z-numbers and fuzzy numbers. The study [21] demonstrates how Z-numbers could be used to reduce uncertainty and how they could be combined with other fuzzy methods for selecting green suppliers.

Table 1 compiles studies utilizing MCDM methods for the selection of distribution centres, which were not previously listed in the text.

Previous literature demonstrate the utilization of various criteria in the selection of distribution centres to identify the location that best aligns with these criteria. Various approaches have evolved over time, transitioning from fuzzy set methods to modified forms such as Pythagorean and Cubic Fermatean, spherical set, and others (Table 1). This evolution reflects the dynamic nature of addressing the distribution center or location selection as a MCDM problem. In this light, the research presented in this paper propose the use of the RAWEC method to rank potential locations for a new agricultural distribution centre in Brčko District of Bosnia and Herzegovina (BiH).

Method introduction

According to the development strategy, the development of the Brčko District of BiH is based on the development of entrepreneurship, agriculture, and tourism. Therefore, the focus of this research is on the site selection for agricultural distribution centres, since this is considered necessary for agricultural development. Agricultural distribution centers do not pertain to centers for agricultural production; rather, they serve as hubs for the distribution of necessary materials and raw products for agricultural activities. Hence,

Table 1
Overview of MCDM methods in distribution center selection.

Author, year	Approach	Methodology	Country
He et al. [22]	Fuzzy set	EW-AHP, Entropy and TOPSIS	China
Ocampo et al. [23]	Fuzzy set	DEMATEL, ANP and AHP	Philippines
Yılmaz and Kabak [24]	interval type-2 fuzzy sets	AHP and TOPSIS	Turkey
Liao et al. [25]	Pythagorean fuzzy set	CoCoSo	China
Keshavarz-Ghorabaee [26]	Fuzzy set	SWARA II, MEREC and WASPAS	Iran
Alidrisi [27]	Crips numbers	DEA and PROMETHEE II	MENAT region
Rong et al. [28]	Cubic Fermatean fuzzy set	MARCOS	China
Bennani et al. [29]	Fuzzy set	SWARA, ENTROPY and VIKOR	Morocco
Puška et al. [30]	Fuzzy set	IMF SWARA and CRADIS	BiH
Erden et al. [31]	Crips numbers	BWM and ARAS	Turkey
Moslem and Pilla [32]	Spherical Fuzzy	AHP	Ireland
Stević et al. [33]	Fuzzy set	*FUCOM and MARCOS*	BiH

Table 2
Research criteria.

ID	Criteria	Description	References	Criterion type
C1	Possibility of multimodal transport	Connection between the location and the potential for using multimodal transport	[17,34–37]	Benefit
C2	Size and expandability	The possibility of expanding the distribution centre is determined by the size of the location	[19,38,39]	Benefit
C3	Distance to customers and suppliers	The location's proximity to customers and suppliers	[1,17,34,40]	Cost
C4	Land costs	The site's monetary value per square metre	[1,19,41]	Cost
C5	Logistics costs	The total value of all logistics costs on the observed location	[17,36,39,41]	Cost
C6	Proximity to airport	Distance from the airport to the location	[1,19,41]	Cost
C7	Proximity to highway	Distance from the motorway to the location	[1,19,41]	Cost
C8	Proximity to railway	Distance from the railway station to the location	[1,19,35,39]	Cost
C9	Developed infrastructure	Infrastructure development levels in specific locations	[40–42]	Benefit
C10	Environmental impact.	Distribution centres' potential environmental effects	[17,40,43]	Cost

criteria related to agricultural production, such as irrigation and production potential, are not considered in the location selection process. Instead, specific criteria are utilized for the distribution of agricultural materials and raw products to farmers.

Based on the consensus of expert opinions, the connection between the locations as well as the economic and ecological characteristics are the main aspects of this research. The criteria defined in this manner (Table 2) encompass a broader aspect that must be considered when selecting a location for agricultural distribution centres. Meanwhile, the remaining five criteria incorporated actual numerical values. This approach aimed to streamline the decision-making process. The majority of these criteria are economic in nature, with only the final criterion (C10) addressing environmental factors. This criterion, comprehensive in scope, encompasses all environmental impacts, including those on water, air, or forest resources. For subsequent analyses, labels ranging from C1 to C10 will be utilized to reference these criteria, eliminating the need to repeatedly write out their full names.

After selecting ten criteria, ten locations were also chosen for the construction of the agricultural distribution center. This complexity in the research arises from the utilization of numerous criteria and alternatives. However, this complexity is inherent to the novel RAWEC method employed in this study. Such intricacy is desirable as it allows the method to be adaptable and applicable not only in this instance but also in other decision-making scenarios where alternatives must be evaluated based on defined criteria. Following the establishment of criteria, potential industrial zones that could serve as alternative locations are determined with the assistance of experts, primarily from the Department for Economic Development, Sports and Culture. Together, ten locations are selected (Table 3). These locations are mostly in suburban and rural areas surrounding Brčko, with easy access to highways and railways. The only exception is the Luka Brčko industrial zone, which is located in the city centre. While some locations are in close proximity to one another, others are spatially distant. Most of these sites are situated near the bypass connecting the eastern and western regions of Bosnia and Herzegovina. The selected locations do not overlap; each is allocated a separate area (Fig. 2). These locations will be denoted by labels ranging from A1 to A10, avoiding the necessity of utilizing their full names.

The subsequent phase involves developing the questionnaire when the criteria and alternatives are all already decided upon. The questionnaire is divided into two sections. The first section is used to calculate the weights of the criteria. Using a 9-point Likert scale of importance, ranging from absolutely low (AL) to absolutely high (AH), values were determined based on the modification of the scale by Akram et al. [60], it was decided how important the criteria were for the chosen experts (Table 4). The value of alternatives is to be identified in the questionnaire's second section. However, for five criteria, the Department of Economic Development, Sports, and Culture has delivered quantitative values, and these values will be taken into account in the evaluation of alternatives. These criteria are as follows: Size and expandability, Land costs, Proximity to airport, Proximity to highway, and Proximity to railway, while the values of the remaining five criteria are being determined by experts. To evaluate the alternatives using these criteria, the same scale of values will be used. Through this method, both subjective expert opinions and objective values are incorporated into

Table 3
Potential locations for an agricultural distribution centre.

ID	Location	Description
A1	Brka Brdo Šterac	Situated between the rural settlements of Vitanovići and Lukavac. This zone contains a facility used by the companies ZiCaffe, Oglavnina, and AluGlas, as well as Pramat, Prometal, and others.
A2	Pirometal - Interplet	Situated in the suburban settlement of Brezik. This zone is located on the territory of the former Interplet company.
A3	Boderište	Situated in the rural settlement of Bodarište. This zone currently has no facilities.
A4	Gredice – Kobilić	Situated in the suburban settlement of Gredice. This zone currently has no facilities.
A5	Brčko Distrikt Jug I	Situated between the rural settlements of Vitanovići and Donji Bukvik. The Yavuz company facility is located in this zone.
A6	Donji Rahić – Ulović	Situated between the rural settlements of Donji Rahić and Ulović. This zone currently has no facilities.
A7	Baza Mc Gowern	Situated between the suburban settlement of Brod and the rural settlement of Brka. In this zone, a pair of Malagić and Liberty factory buildings were built, two buildings that house a business incubator and facilities used by JP Komunalno Brčko.
A8	Luka Brčko	Situated in a smaller urban area. The JP Luka Brčko complex has been established within this zone.
A9	Brka Gajine	Situated in the rural settlement of Brka. The Obala company facility is located in this zone.
A10	Gredice – Gaj	Situated in the suburban settlement of Gredice. This zone currently has no facilities.

Table 4
Value scale for evaluation of criteria and alternatives.

Scale	Value
Absolutely low (AL)	1
Very low (VL)	2
Low (L)	3
Medium low (ML)	4
Equal (E)	5
Medium high (MH)	6
High (H)	7
Very high (VH)	8
Absolutely high (AH)	9

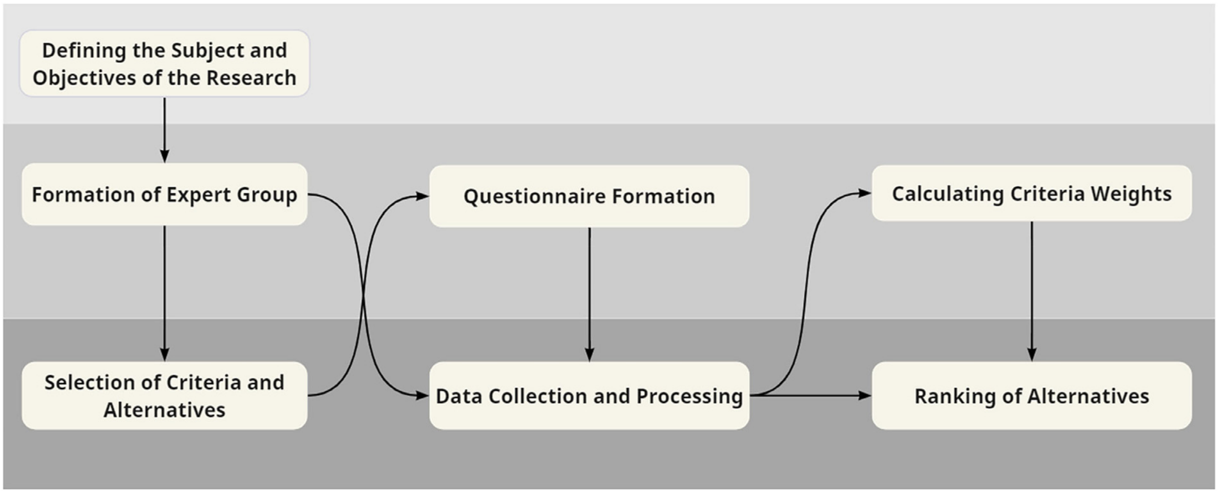

Fig. 1. Research phases.

the assessment of these locations. By employing these dual approaches, a comprehensive evaluation of all facets is undertaken in selecting locations for new distribution centers.

Since the weight of the criteria is required to rank the locations, Logarithm methodology of additive weights (LMAW) method developed by Pamučar et al. [44] is used first. Unlike similar MCDM methods, this method can determine weights and at the same time rank alternatives [45]. This research will only use the weighting component, so the weighting procedure is described. In this method, it is unnecessary to directly compare criteria; instead, criteria are evaluated using linguistic values.

The criteria weights are determined using the following LMAW method steps.

Step 1. Prioritization of criteria. In this step, each of the experts prioritizes the criteria $C = \{C_1, C_2, \ldots, C_n\}$ using a defined value scale (Table 3).

Step 2. Defining the absolute anti-ideal point ($\tilde{\gamma}_{AIP}$). The value represents the smaller of the smallest value from the set of all priority vectors.

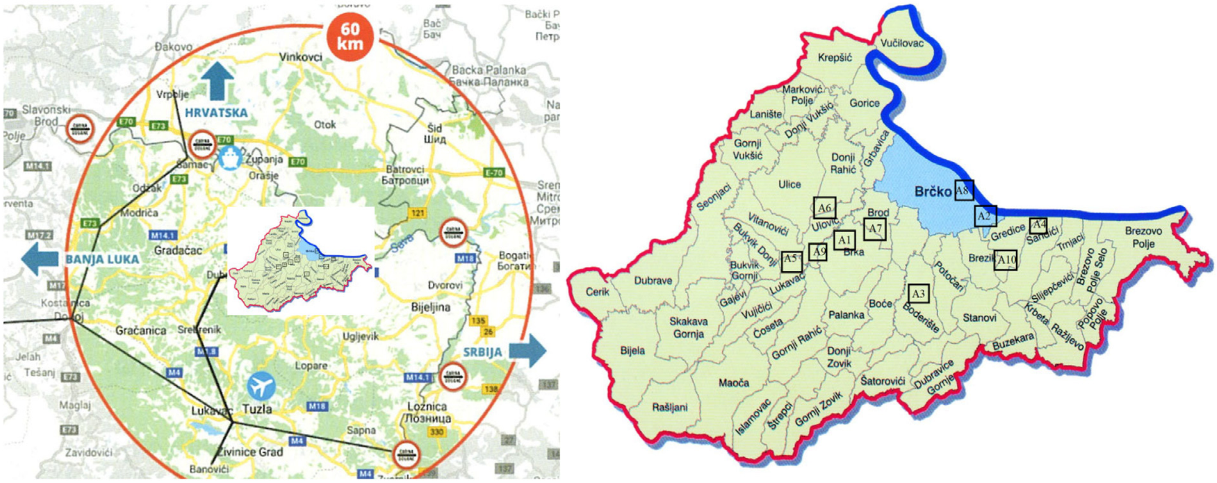

Fig. 2. Location of Brčko District and potential sites for agricultural distribution centers.

Step 3. Defining relationship vectors. In this step, each element is divided by the absolute anti-ideal point ($\tilde{\gamma}_{AIP}$). This is done to reduce the value of the criteria scores, and it is formed using the following expression:

$$\tilde{\mu}^{e}_{Cn} = \left(\frac{\tilde{\gamma}^{e}_{Cn}}{\tilde{\gamma}_{AIP}} \right) \tag{1}$$

Step 4. Determining the weight coefficients vector for each expert separately. Initially, calculating the natural logarithm (ln(x)) for the divisor is imperative. Subsequently, the product of the relationship vectors' values for all alternatives is computed, followed by the calculation of the natural logarithm for the divisor based on this value.

$$\tilde{\omega}^{e}_{j} = \left(\frac{ln\left(\tilde{\mu}^{e}_{Cn}\right)}{ln\left(\prod_{j=1}^{n} \tilde{\mu}^{e}_{Cn}\right)} \right) \tag{2}$$

Step 5. Calculation of weight coefficient aggregated vectors. The Bonferroni aggregator is used to compute these weight coefficients.

$$\tilde{\omega}_{j} = \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \tilde{\omega}_{i}^{(e)p} \tilde{\omega}_{i}^{(e)q} \right)^{\frac{1}{p+q}} \tag{3}$$

Step 6. Calculation of the final values of the weighting coefficients.

The next phase of this research is the ranking of locations and the site selection for agricultural distribution centres. In order to obtain which location has the best indicators, the novel RAWEC method for ranking of alternatives is used. The selection of this method over other is motivated by the aim to streamline decision-making processes. Emerging methods often add complexity to decision-making by introducing additional steps that complicate calculations. To address this issue, the RAWEC method was developed to simplify the process by reducing the number of steps and avoid complex calculations. It involves just four steps, with the first two being common across all methods. The uniqueness of this method is that it combines two steps that are typically found in other methods, namely the creation of the weighted normalised decision matrix and the calculation of deviation from ideal and anti-ideal values. This method consists of the following steps:

Step 1. Formation of the decision matrix. This step represents the first step in all other MCDM methods. In this step, the alternatives are evaluated using the set criteria, and an initial decision matrix is formed.

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} C_1 & C_2 & . & C_n \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{11} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{4}$$

Step 2. Normalization of the decision matrix. When normalizing the initial decision matrix, double normalization is used, following expressions:

$$n_{ij} = \frac{x_{ij}}{x_{j\ max}},\ and\ n'_{ij} = \frac{x_{j\ min}}{x_{ij}},\ for\ benefit\ criteria,\ and \tag{5}$$

$$n_{ij} = \frac{x_{j\ min}}{x_{ij}},\ and\ n'_{ij} = \frac{x_{ij}}{x_{j\ max}},\ for\ cost\ criteria. \tag{6}$$

Where $x_{j\ min}$ represents he minimum value of alternatives according to certain criteria, and $x_{j\ max}$ - the maximum value of alternatives according to certain criteria.

By using double normalization, the initial decision matrix is normalized in two ways. By applying the first normalization (n_{ij}) all criteria are transformed into benefit criteria, where the highest values for individual criteria receive the maximum value, which is the value one (1). By applying the second normalization (n'_{ij}) all criteria are converted into cost criteria. With this normalization, the lowest values of alternatives for certain criteria take on the maximum value, i.e. the value of one (1).

Step 3. Calculating the deviation from the criterion weight. The weighting of the normalised decision matrix and the calculation of the deviation from the weight of the criteria are combined in this step. This is accomplished by employing the following expressions:

$$v_{ij} = \sum_{i=1}^{n} w_j \cdot \left(1 - n_{ij}\right) \tag{7}$$

$$v'_{ij} = \sum_{i=1}^{n} w_j \cdot \left(1 - n'_{ij}\right) \tag{8}$$

Where w_j represents criteria weight.

This step begins by calculating the normalised data's deviations from the maximum values, which are represented by the number 1. Next, calculation of the total deviation from the weight of the criteria by multiplying the deviation by the weight of the criteria is performed. The deviation for the first value (v_{ij}) is desirable to be as small as possible, while the deviation for the second value (v'_{ij}) as large as possible. Based on these deviations, the final value of the alternatives is calculated.

Step 4. Calculating the value of the RAWEC method. This is calculated based on the following expression:

$$Q_i = \frac{v'_{ij} - v_{ij}}{v'_{ij} + v_{ij}} \tag{9}$$

The RAWEC method returns a value that can range between −1 and 1. The superiority of an alternative is determined by how high the method's value of that alternative is. The alternative with the highest value represents the ideal selection.

Test

When evaluating locations for the establishment of an agricultural distribution centre, the weights of the selected criteria must first be determined. Therefore, the experts first ranked the criteria according to their importance. The linguistic values were used to evaluate the criteria which were then converted to numerical values and further, the LMAW steps were followed. The next step was to determine the absolute anti-ideal point that was produced, taking into account that the value produced must be less than the minimum value of the criterion evaluation. Relationship vectors were then established for the observed criteria. The vector of weight coefficients was then determined, and finally, the Bonferroni aggregator was used to calculate the weight of the criteria.

The results of the LMAW method implementation demonstrate that criterion C1 - Possibility of multimodal transport ($w = 0.1122$) received the most weight. Criteria C3 - Distance to customers and suppliers and C10 - Environmental Impact were slightly less weighted, with the weights differing only after the fourth decimal place. Criterion C6 - Proximity to airport ($w = 0.042$) received the least weight. The fact that this mode of transportation is least utilised for agricultural products should be considered as the cause for this weight of C6 criterion. This criterion's inclusion is due to its consideration in certain development plans for the Brčko District of BiH, which include the expansion of the airport. It is important to note that these weights represent the current state of these criteria and may evolve over time. For instance, the construction of a highway through the Brčko District would likely increase the importance of transportation-related criteria compared to the current situation where all locations have similar distances from highways and the airport. The expert ratings were first transformed into numerical values, and the average values of these expert ratings for individual alternatives to the observed criteria were calculated. In this manner, the preliminary decision-making matrix for this research (Table 5) was formed. This decision matrix serves as the foundation for calculating the RAWEC method's value.

As can be seen from the initial decision matrix (Table 5), certain criteria are benefit criteria (max) and their values should be as high as possible, while others are cost criteria (min) and their values should be as low as possible. As the RAWEC method begins with this initial decision matrix, the first distinguishing feature of this method is the use of double normalisation. In this instance, a particular kind of normalisation is used, in which all criteria are first converted into benefit criteria, and then into cost criteria. This is the distinction between this method and the DNMA (Double Normalization-based Multi-Aggregation) method, which employs two different normalisations [46].

Table 5
Initial decision matrix.

	C1 max	C2 max	C3 min	C4 min	C5 min	C6 min	C7 min	C8 min	C9 max	C10 min
A1	5.80	35.9	2.60	10	3.20	75	35	8	6.60	3.40
A2	6.60	36.0	2.60	25	3.00	70	25	5	6.40	4.20
A3	3.60	20.8	4.80	5	4.80	70	35	10	3.40	4.60
A4	5.40	37.0	4.60	6	4.00	90	35	10	3.20	4.20
A5	5.80	105.0	4.40	6	3.60	70	40	15	5.80	3.80
A6	4.60	88.0	4.20	6	3.80	70	30	15	4.40	4.60
A7	7.20	170.0	2.60	15	2.60	80	40	5	7.00	4.20
A8	7.40	21.0	1.60	120	2.40	80	20	3	7.40	4.80
A9	6.00	36.0	3.60	6	3.40	70	40	15	6.00	4.40
A10	5.00	44.0	4.60	6	4.00	70	25	11	3.40	4.20
Max	7.40	170.0	4.80	120	4.80	90	40	15	7.40	4.80
Min	3.60	20.8	1.60	5	2.40	70	20	3	3.20	3.40

Benefit normalisation transforms all criteria into benefit criteria, and the best alternative values take on the value of one (1). In contrast, cost normalisation transforms all criteria into cost criteria, and the worst values of the alternative are assigned a value of one (1). The RAWEC method states that in order to be superior to other alternatives, the alternative must have values closer to value one (1) in benefit normalisation. With cost normalisation, the values of the alternatives must be as small as possible, or as far away from the maximum values, which are one (1) in this normalisation.

The normalization calculation procedure is illustrated using alternative A1 as an illustration for criteria C1 and C4. Initially, the decision-making matrix identifies maximum and minimum values for alternatives across specific criteria. This initial step is pivotal due to the distinct expressions employed during normalization. Criterion C1 signifies the maximum criterion, whereas C4 denotes the minimum, necessitating the use of different formulas.

$$n_{11} = \frac{5.80}{7.40} = 0.784; n'_{11} = \frac{3.60}{5.80} = 0.621.$$

$$n_{14} = \frac{5}{10} = 0.500; n'_{14} = \frac{10}{120} = 0.083.$$

Normalization calculations exhibit divergence based on whether the criterion is maximized or minimized. For a minimized criterion at n_{ij} the alternative's value is divided by the maximum value for that criterion. Conversely, when the criterion is minimized from the alternative's minimum value, a different calculation ensues. Subsequently, computing n'_{ij} involves a reverse procedure. This process extends to compute values for other alternatives, culminating in a normalized decision-making matrix where all criteria are perceived as benefit and cost criteria (Table 6).

Based on this, the deviation from the criterion weight is calculated as the Step 3 of the RAWEC method. Both normalisations have a maximum value of one (1). These values are multiplied by the weight values to reveal that the maximum values are actually the weight values $(1 \cdot w_j = w_j)$. Therefore, the RAWEC method determines the weighted values' deviations from the weight value $(w_j - n_{ij} \cdot w_j)$, and the expressions $w_j \cdot (1 - n_{ij})$, and $w_j \cdot (1 - n'_{ij})$ are obtained by extracting the common multiple as the expressions from the RAWEC method's Step 3. In this manner, the calculation of criteria weights and the calculation of deviations from the maximum values from normalisations were combined. In the specific example provided, this process unfolds as follows:

$$v_{11} = 0.112 \cdot (1 - 0.784) = 0.024; v'_{11} = 0.112 \cdot (1 - 0.621) = 0,043.$$

$$v_{14} = 0.105 \cdot (1 - 0.500) = 0.052; v'_{14} = 0.105 \cdot (1 - 0.083) = 0.096.$$

Similar computations for values v_{ij} *and* v'_{ij} collectively contribute to the summation of these deviations.

Calculating the RAWEC method's value is the final step (expression 9). For alternative A1, this calculation stands as follows $Q_1 = \frac{0.4211-0.3429}{0.4211+0.3429} = 0.1023$. Similar computations are applied to ascertain values for other alternatives. The best alternative, determined through the RAWEC method, is the one yielding the highest value, while the least favourable option corresponds to the lowest RAWEC value.

In this case, a ranking of alternatives for potential sites for an agricultural distribution centre is obtained using four steps (Table 7). The results revealed that the Baza Mc Gowern (A7) has the best indicators, while the Bodarište (A3) has the worst.

During the validation process, the RAWEC method's results is compared to the results of other methods. It should be noted that the data utilized can influence the effectiveness of results across all methods, including RAWEC. However, this research did not address the availability and quality of information; rather, it focused on introducing a new method capable of accommodating both subjective and objective assessments.

Validation

The first step in analysing the results is to validate them using other MCDM methods. This analysis contrasts the results obtained by the RAWEC method with those of other MCDM methodologies [47]. Each MCDM method employed shares common steps such as

Table 6
Normalized initial decision matrix.

Benefit normalisation (n_{ij})										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.784	0.211	0.615	0.500	0.750	0.933	0.571	0.375	0.892	1.000
A2	0.892	0.212	0.615	0.200	0.800	1.000	0.800	0.600	0.865	0.810
A3	0.486	0.122	0.333	1.000	0.500	1.000	0.571	0.300	0.459	0.739
A4	0.730	0.218	0.348	0.833	0.600	0.778	0.571	0.300	0.432	0.810
A5	0.784	0.618	0.364	0.833	0.667	1.000	0.500	0.200	0.784	0.895
A6	0.622	0.518	0.381	0.833	0.632	1.000	0.667	0.200	0.595	0.739
A7	0.973	1.000	0.615	0.333	0.923	0.875	0.500	0.600	0.946	0.810
A8	1.000	0.124	1.000	0.042	1.000	0.875	1.000	1.000	1.000	0.708
A9	0.811	0.212	0.444	0.833	0.706	1.000	0.500	0.200	0.811	0.773
A10	0.676	0.259	0.348	0.833	0.600	1.000	0.800	0.273	0.459	0.810
Cost normalisation (n'_{ij})										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.621	0.579	0.542	0.083	0.667	0.833	0.875	0.533	0.485	0.708
A2	0.545	0.578	0.542	0.208	0.625	0.778	0.625	0.333	0.500	0.875
A3	1.000	1.000	1.000	0.042	1.000	0.778	0.875	0.667	0.941	0.958
A4	0.667	0.562	0.958	0.050	0.833	1.000	0.875	0.667	1.000	0.875
A5	0.621	0.198	0.917	0.050	0.750	0.778	1.000	1.000	0.552	0.792
A6	0.783	0.236	0.875	0.050	0.792	0.778	0.750	1.000	0.727	0.958
A7	0.500	0.122	0.542	0.125	0.542	0.889	1.000	0.333	0.457	0.875
A8	0.486	0.990	0.333	1.000	0.500	0.889	0.500	0.200	0.432	1.000
A9	0.600	0.578	0.750	0.050	0.708	0.778	1.000	1.000	0.533	0.917
A10	0.720	0.473	0.958	0.050	0.833	0.778	0.625	0.733	0.941	0.875

Table 7
Final ranking order using the RAWEC method.

ID	Alternatives	v_{ij}	v'_{ij}	Q_i	Rank
A1	Brka Brdo Šterac	0.3429	0.4211	0.1023	4
A2	Pirometal - Interplet	0.3346	0.4467	0.1435	3
A3	Boderište	0.4730	0.1636	−0.4861	10
A4	Gredice – Kobilić	0.4453	0.2616	−0.2599	9
A5	Brčko Distrikt Jug I	0.3475	0.3436	−0.0056	5
A6	Donji Rahić – Ulović	0.3991	0.3092	−0.1269	7
A7	Baza Mc Gowern	0.2441	0.4780	0.3238	1
A8	Luka Brčko	0.2284	0.3786	0.2474	2
A9	Brka Gajine	0.3835	0.3183	−0.0929	6
A10	Gredice – Gaj	0.4137	0.3004	−0.1587	8

normalization and weighting. However, certain steps are unique to individual methods. Normalization of the initial decision matrix entails standardizing all values to a uniform scale ranging from zero to one. Nevertheless, there exist various normalization procedures, depending on the method utilized in its original form. Therefore, the validation assessment examines how these normalization procedures influence the ranking. The subsequent step typically involves weighting the normalized decision matrix by multiplying it with the respective weights. In this research, the results of eight methods will be used, namely: Simple Additive Weighting (SAW), Additive Ratio Assessment (ARAS), MABAC, TOPSIS, VIKOR, CRADIS, and Weighted Aggregated Sum Product Assessment (WASPAS). Well-established methods such as SAW, TOPSIS, ARAS, and VIKOR are employed to validate the results and procedures against these widely accepted methods in practice. Conversely, the application of newer methods like MABAC, WASPAS, and CRADIS aims to promote their adoption in practical applications, considering their distinct steps and methodologies. The initial decision matrix and weights used by the aforementioned methods are the same [48] as those used by the RAWEC method. The MABAC method uses the geometric mean, and so on. The SAW method, adds up the weighted normalised values of the alternatives, the ARAS method uses the function degree of usefulness (optimal alternatives), the MABAC method uses the geometric mean, and so forth. Furthermore, these methods employ various normalisations, which could affect the ranking of alternatives.

Carrying out the steps of the aforementioned methods reveals that there are more or less significant differences in the ranking of alternatives when compared to the RAWEC method (Fig. 2). The implementation of the VIKOR method displays the greatest deviation from other methods (Table 7). The VIKOR method's steps are a contributing factor to this occurrence [49]. The normalisation and weighting of normalised decision matrices are combined in this method [50]; however, since the MABAC method also employs the same normalisation, this is not the cause. Instead, the cause should be found in determining the maximum individual deviation and compromise of those solutions [51]. The TOPSIS method is the next method that differs significantly from the others. This is due

Table 8
Correlation of the ranking orders.

	RAWEC	SAW	ARAS	MABAC	MARCOS	TOPSIS	VIKOR	CRADIS	WASPAS
RAWEC	1.000	.988	.976	.976	.988	.830	.758	.988	.988
SAW	.988	1.000	.964	.952	1.000	.818	.782	1.000	.976
ARAS	.976	.964	1.000	.939	.964	.903	.709	.964	.952
MABAC	.976	.952	.939	1.000	.952	.745	.685	.952	.952
MARCOS	.988	1.000	.964	.952	1.000	.818	.782	1.000	.976
TOPSIS	.830	.818	.903	.745	.818	1.000	.661	.818	.806
VIKOR	.758	.782	.709	.685	.782	.661	1.000	.782	.830
CRADIS	.988	1.000	.964	.952	1.000	.818	.782	1.000	.976
WASPAS	.988	.976	.952	.952	.976	.806	.830	.976	1.000
Average	.937	.935	.921	.894	.935	.800	.749	.935	.932

to the fact that this method employs a different normalisation (vector normalisation) [52], and when calculating the deviation, a different result is obtained when compared to other methods.

When all of the results of the methods are analysed and contrasted with the RAWEC method, it is determined that the RAWEC method's results do not significantly differ from the results of other methods, and the ranking it produced is regarded as valid. Notably, alternatives A7 and A8 consistently secure the first and second positions across the majority of methods, suggesting these locations as optimal choices for establishing an agricultural distribution centre. However, due to the inherent nature of MCDM methods, aiming for an unequivocally optimal location is unattainable. These methods necessitate a compromise between defined criteria, resulting in compromise rather than definitive optimal outcomes [53].

The rankings produced by these methods are then analysed in more detail using Spearman's correlation coefficient. The findings of this analysis (Table 8) show that the RAWEC method correlates well with other methods, apart from the TOPSIS and VIKOR methods, with which the RAWEC method has the smallest correlation. Further, the RAWEC method is related to the SAW, MARCOS, CRADIS, and WASPAS methods in that the ranking orders differ only for two alternatives, whereas the ARAS and MABAC methods differ for four. What should be noted is that the three methods, namely SAW, MARCOS, and CRADIS, have the same ranking order. It has been demonstrated in this way that the method does not significantly differ from other methods, allowing it to be used when ranking alternatives. When comparing these methods, the advantage of the RAWEC method is as follows: compared to the SAW method, the RAWEC method ranks based on deviations, whereas the SAW method solely ranks alternatives based on their weighted values. The MARCOS method ranks based on ideal and anti-ideal values that require calculation. Unlike the RAWEC method, which calculates the distance from these values during evaluation, the MARCOS method necessitates the computation of these values. Similarly, the CRADIS method involves determining the deviation from the ideal and anti-ideal values, which must be calculated separately. This process entails multiple steps, whereas the RAWEC method accomplishes this in a single step. Contrary to the WASPAS method, which essentially compromises between the results of the WAS and WPM methods, the RAWEC method's compromise pertains to deviations rather than different methodologies. The connectivity between methods is demonstrated through the average correlation, computed by determining the average correlation value of a specific method with others, excluding its correlation with itself from consideration. Observing these average correlation results reveals that the RAWEC method's outcomes exhibit the strongest correlation with those of all other methods. This robust correlation underscores the representative nature of the RAWEC method's results compared to the broader spectrum of outcomes. Consequently, it can be inferred that the RAWEC method's outcomes possess superior connectivity with results from other methods, establishing their reliability. This substantiates the applicability of these findings for future research endeavours.

The effects of the dynamic decision matrix will be calculated as the next step in evaluating the validity of the RAWEC method. This calculation is carried out in such a way that after the initial ranking order is established, the alternative with the worst ranking is excluded from the analysis and the ranking is then carried out again [54]. The process is repeated until only two alternatives are left. The purpose of such an analysis is to determine whether the method produces consistent results. The results of this analysis (Fig. 3) demonstrate that the rankings do not change when the number of alternatives is reduced, indicating that the results of the RAWEC method are reliable and consistent, supporting its application to different MCDM problems.

Moreover, a standard sensitivity analysis is conducted, typically employed in MCDM applications [55]. In this analysis, the weights of individual criteria are altered, and it will be determined how these changes affect the ranking order of alternatives [56,57]. The weights of each criterion are decreasing by 30, 60, and 90% in this analysis, reducing the impact of specific criteria on the final ranking order. In this process, if one of the alternatives receives a lower ranking, it implies that it outperformed the other alternative with that specific criterion, i.e. that the advantage of the alternative for that specific criterion decreases as the weights are decreased.

The sensitivity analysis (Fig. 4) revealed that the ranking order remained unaltered solely for two alternatives, namely A3 and A4. For all other alternatives, the ranking order underwent changes. In the analysis, A7 emerged as the most favourable alternative, while A8 exhibited superior indicators in five scenarios. The findings demonstrated that A7 outperformed A8 in terms of location size and land price, thus earning higher rankings across various scenarios. A8′s disadvantage stemmed from its location in a more restricted part of the city, which hindered expansion prospects, and the inflated price of the land relative to other sites evaluated. The ranking of A1 and A2 followed a similar trend, where A1 prevailed over A2 in two scenarios due to the latter's better access to the highway and railway. Only one scenario showed A5 as inferior to A9, but the latter proved sensitive to infrastructure development, leading to

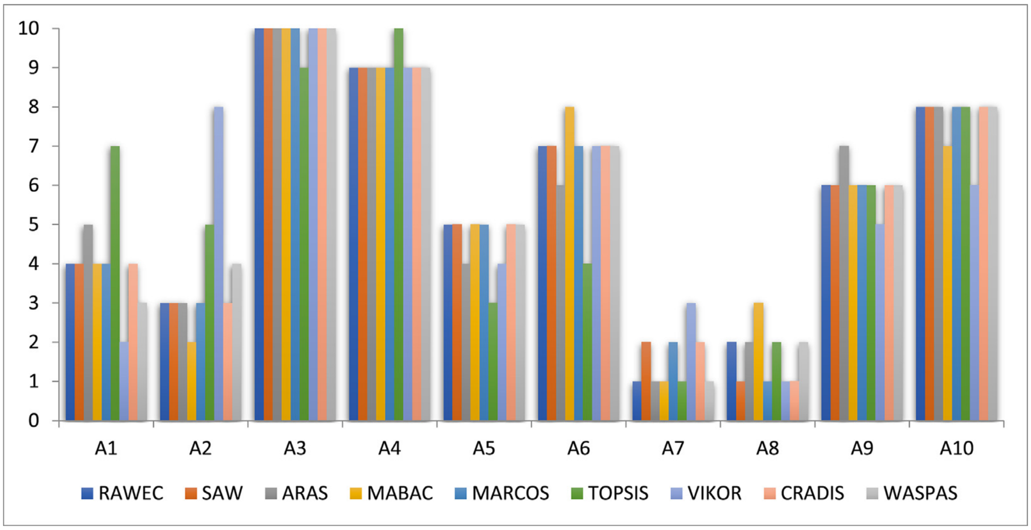

Fig. 3. Ranking order of alternatives obtained by applying different MCDM methods.

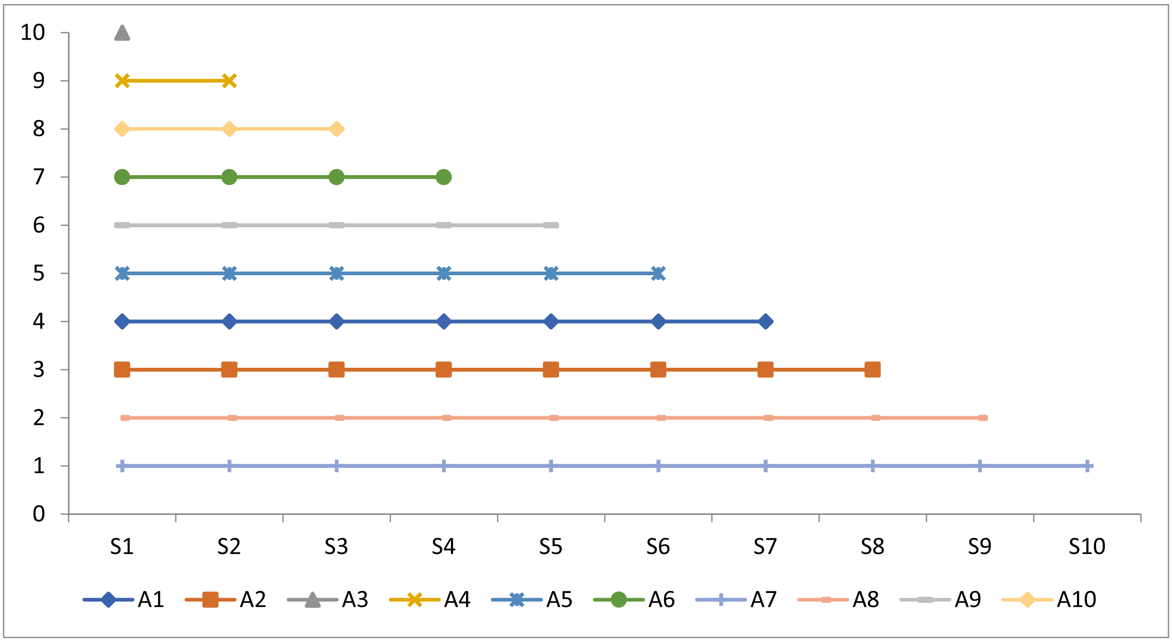

Fig. 4. The effects of the dynamic decision matrix.

A10's elevation in the rankings upon reducing the impact of this criterion. Based on the results, it is necessary to enhance the potential of these locations. The Government of the Brčko District should prioritize strengthening the transportation infrastructure to facilitate easier access to these sites. Developing multi-modal transportation systems, which enable access via various modes of transportation, is essential. Additionally, the Brčko District Government could explore introducing new modes of transportation that are currently underrepresented in the area, such as air transportation. This involves further developing the Brčko Airport and investing in the expansion of the Port of Brčko.

The sensitivity analysis provides valuable insights to the government of BiH's Brčko District, highlighting possible opportunities for improving specific industrial zones. The sensitivity analysis effectively identified the strengths and weaknesses of each location by adjusting the criteria weights and a decrease in an alternative's ranking order indicated better performance in a given criterion when compared to other alternatives. Utilizing this knowledge is essential in order to improve the setting at particular locations and increase their suitability as potential distribution centre locations. Therefore, a more in-depth analysis of these locations is necessary to provide further insights into their advantages and disadvantages. The sensitivity analysis identifies the key criteria influencing the

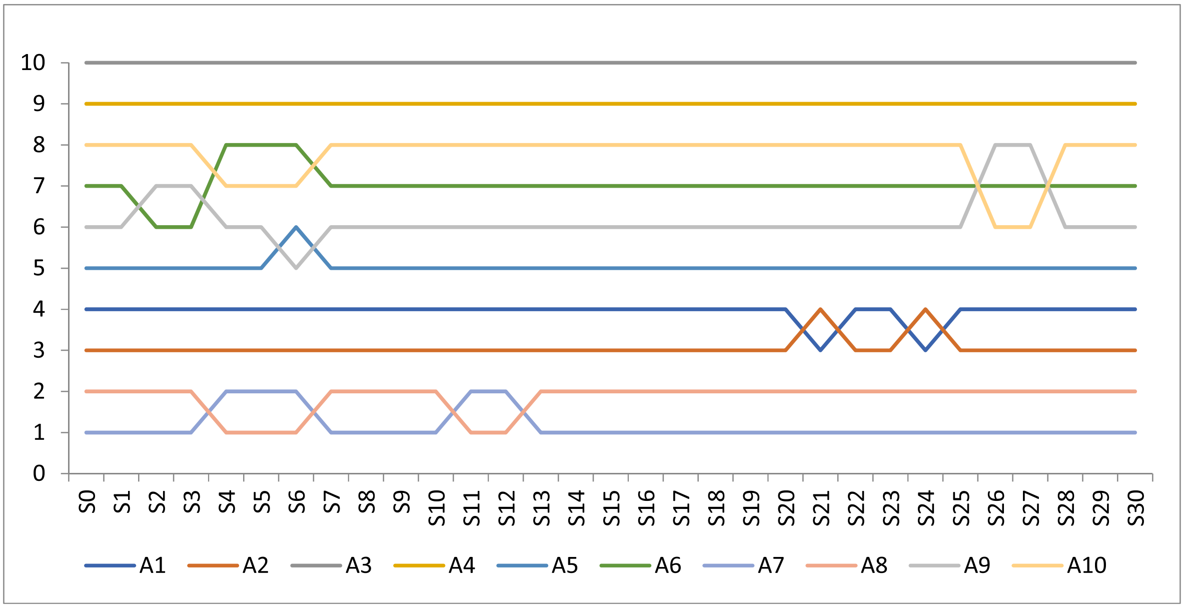

Fig. 5. Sensitivity analysis results.

change in rankings, emphasizing the need for additional sensitivity analyses in future research. This should involve the inclusion of additional experts and criteria to identify the best location not only for distribution centers but also for other infrastructure facilities such as logistics centers, warehouses, production halls, and various other facilities.

Moreover, it is essential to enhance the development of the RAWEC method through additional case studies or applications in future research endeavours. Like other MCDM methods, RAWEC comes with its own set of strengths and weaknesses. One significant limitation is its reliance on two normalizations, contrasting with methods that employ only one. Nevertheless, this aspect of the RAWEC method is rooted in the observation of deviations from the maximum value obtained through the first normalization and from the minimum value obtained via the second normalization. Subsequent research should delve into alternative normalization techniques and explore potential synergies between RAWEC and other methods.

In terms of results, the RAWEC method had a strong correlation with other methods, yet it remained distinctive. Therefore, this method can be used independently or in conjunction with another method(s) to determine the ranking order of alternatives. The RAWEC method's contribution to future research in addressing decision-making challenges lies in simplifying the decision-making process itself.

RAWEC method had a strong correlation with other methods, yet it remained distinctive. Therefore, this method can be used independently or in conjunction with another method(s) to determine the ranking order of alternatives. The RAWEC method's contribution to future research in addressing decision-making challenges lies in simplifying the decision-making process itself. This method enables decision-makers to attain reliable results through a streamlined three-step approach, as evidenced in this paper.

Comparing the RAWEC method to others reveals its notable advantage in having significantly fewer steps. By consolidating two steps into one, it reduces the overall number of steps. This aligns the method's simplicity with that of the basic MCDM method SAW. However, unlike SAW, RAWEC derives results based on deviations from ideal values rather than solely ranking alternatives based on decision matrix values. RAWEC method has a small number of steps and is very simple to use, indicating that it has a good prospect in the application of MCDM methods as it does not necessitate the use of complex calculations. Furthermore, it is imperative to develop software tailored for implementing this method and similar approaches. Such software would significantly ease decision-making processes in future research endeavours (Figs. 1 and 5).

Ethics statements

Ethics approval was not required for this study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Adis Puška: Conceptualization, Methodology, Writing – original draft, Supervision. **Anđelka Štilić:** Conceptualization, Writing – original draft, Visualization. **Dragan Pamučar:** Validation, Formal analysis, Writing – review & editing. **Darko Božanić:** Validation, Formal analysis. **Miroslav Nedeljković:** Investigation, Data curation, Project administration.

Data availability

Data will be made available on request.

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References

[1] P.T. Kieu, V.T. Nguyen, V.T. Nguyen, T.P. Ho, A Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and Combined Compromise Solution (CoCoSo) algorithm in distribution center location selection: a case study in agricultural supply chain, Axioms 10 (2) (2021) 53, doi:10.3390/axioms10020053.
[2] M.B. Fakhrzad, F. Goodarzian, A Fuzzy multi-objective programming approach to develop a green closed-loop supply chain network design problem under uncertainty: modifications of imperialist competitive algorithm, RAIRO - Operat. Res. 53 (3) (2019) 963–990, doi:10.1051/ro/2019018.
[3] M.G. Ozerova, A.V. Sharopatova, J. Olentsova, Improving the competitiveness of agricultural products as a basis for solving import replacement issues, IOP Conf. Ser. (2019), doi:10.1088/1755-1315/315/2/022026.
[4] F. Taghikhah, A. Voinov, N. Shukla, Extending the supply chain to address sustainability, J. Clean. Prod. 229 (2019) 652–666, doi:10.1016/j.jclepro.2019.05.051.
[5] R.Ehtesham Rasi, M. Sohanian, A multi-objective optimization model for sustainable supply chain network with using genetic algorithm, J. Model. Manage. 16 (2) (2020) 714–727, doi:10.1108/jm2-06-2020-0150.
[6] M. Shao, Z. Han, J. Sun, C. Xiao, S. Zhang, Y. Zhao, A review of multi-criteria decision making applications for renewable energy site selection, Renew Energy 157 (2020) 377–403, doi:10.1016/j.renene.2020.04.137.
[7] Y.Ke Xu, Y. Li, H. Chu, Y. Wu, Data-driven configuration optimization of an off-grid wind/PV/hydrogen system based on modified NSGA-II and CRITIC-TOPSIS, Energy Convers. Manage. 215 (2020) 112892, doi:10.1016/j.enconman.2020.112892.
[8] X. Li, K. Zhou, Multi-objective cold chain logistic distribution center location based on carbon emission, Environ. Sci. Pollut. Res. 28 (25) (2021) 32396–32404, doi:10.1007/s11356-021-12992-w.
[9] F. Teng, W. Xinxin, B. Jiajia, W. Peng, Research on ant colony algorithm for location planning of distribution center, J. Phys. Conf. Ser. 1920 (1) (2021) 012099, doi:10.1088/1742-6596/1920/1/012099.
[10] M. Yonathan, I.N. Pujawan, Distribution network configuration of drilling material to reduce transportation cost, IPTEK J. Proc. Ser. 3 (2021) 168, doi:10.12962/j23546026.y2020i3.11198.
[11] J. Van Der Lee, S. Oosting, L. Klerkx, F. Opinya, B.O. Bebe, Effects of proximity to markets on dairy farming intensity and market participation in Kenya and Ethiopia, Agric. Syst. 184 (2020) 102891, doi:10.1016/j.agsy.2020.102891.
[12] Y. Xiong, C. Okorie, G. Ezeoke, Enhancing distribution network performance: a quantitative approach to developing a distribution strategy model, Pressacademia 7 (4) (2020) 160–182, doi:10.17261/pressacademia.2020.1331.
[13] M.N.H. Suman, N.M.D Sarfaraj, F.A. Chyon, M.R.I. Fahim, Facility location selection for the furniture industry of Bangladesh: comparative AHP and FAHP analysis, Int. J. Eng. Bus. Manage. 13 (2021) 184797902110308, doi:10.1177/18479790211030851.
[14] J. Monzón, F. Liberatore, B. Vitoriano, A mathematical pre-disaster model with uncertainty and multiple criteria for facility location and network fortification, Mathematics 8 (4) (2020) 529, doi:10.3390/math8040529.
[15] P.G. Stock, A. Wall, J. Gardner, B. Domínguez-Gil, S. Chadban, E. Muller, I. Dittmer, S.G. Tullius, Ethical issues in the COVID era: doing the right thing depends on location, resources, and disease burden, Transplantation 104 (7) (2020) 1316–1320, doi:10.1097/tp.0000000000003291.
[16] T. Baker, K. Moore, J. Lim, C. Papanastasiou, S. McCarthy, F. Schreve, M. Lawson, V. Versace, Rural emergency care facilities may be adapting to their context: a population-level study of resources and workforce, Aust. J. Rural Health 30 (3) (2022) 393–401, doi:10.1111/ajr.12846.
[17] M. Agrebi, M. Abed, M.N. Omri, ELECTRE I based relevance decision-makers feedback to the location selection of distribution centers, J. Adv. Transport. 2017 (2017) Article ID 7131094, doi:10.1155/2017/7131094.
[18] M.S. Kuo, Optimal location selection for an international distribution center by using a new hybrid method, Expert Syst. Appl. 38 (6) (2011) 7208–7221, doi:10.1016/j.eswa.2010.12.002.
[19] T.N.M. Nong, A hybrid model for distribution center location selection, Asian J. Ship. Logist. 38 (1) (2022) 40–49, doi:10.1016/j.ajsl.2021.10.003.
[20] R.E. Gergin, I. Peker, B. Baki, U.R. Tuzkaya, M. Tanyas, Oilseed warehouse location selection with an integrated approach: a case of Turkey, Kybernetes 52 (9) (2022) 3667–3705, doi:10.1108/k-10-2021-1072.
[21] A. Puška, D. Božanić, M. Nedeljković, M. Janošević, Green supplier selection in an uncertain environment in agriculture using a hybrid MCDM model: z-numbers–fuzzy LMAW–Fuzzy CRADIS model, Axioms 11 (9) (2022) 427, doi:10.3390/axioms11090427.
[22] Y. He, X. Wang, Y. Lin, F. Zhou, L. Zhou, Sustainable decision making for joint distribution center location choice, Transp. Res. D Transp. Environ. 55 (2017) 202–216, doi:10.1016/j.trd.2017.07.001.
[23] L.A. Ocampo, C.M. Himang, A. Kumar, M. Brezocnik, A novel multiple criteria decision-making approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy AHP for mapping collection and distribution centers in reverse logistics, Adv. Product. Eng. Manage. 14 (3) (2019) 297–322, doi:10.14743/apem2019.3.329.
[24] H. Yılmaz, Ö. Kabak, Prioritizing distribution centers in humanitarian logistics using type-2 fuzzy MCDM approach, J. Enterprise Info. Manage. 33 (5) (2020) 1199–1232, doi:10.1108/jeim-09-2019-0310.
[25] H. Liao, R. Qin, D. Wu, M. Yazdani, E.K. Zavadskas, Pythagorean fuzzy combined compromise solution method integrating the cumulative prospect theory and combined weights for cold chain logistics distribution center selection, Int. J. Intell. Syst. 35 (12) (2020) 2009–2031, doi:10.1002/int.22281.
[26] M. Keshavarz-Ghorabaee, Assessment of distribution center locations using a multi-expert subjective–objective decision-making approach, Sci. Rep. 11 (1) (2021) 19461, doi:10.1038/s41598-021-98698-y.
[27] H. Alidrisi, DEA-based PROMETHEE II distribution-center productivity model: evaluation and location strategies formulation, Appl. Sci. 11 (20) (2021) 9567, doi:10.3390/app11209567.
[28] Y. Rong, L. Yu, W. Niu, Y. Liu, T. Senapati, A.R. Mishra, MARCOS approach based upon cubic Fermatean fuzzy set and its application in evaluation and selecting cold chain logistics distribution center, Eng. Appl. Artif. Intell. 116 (2022) 105401, doi:10.1016/j.engappai.2022.105401.
[29] M. Bennani, F. Jawab, Y. Hani, A. ElMhamedi, D. Amegouz, A hybrid MCDM for the location of urban distribution centers under uncertainty: a case study of Casablanca, Morocco, Sustainability 14 (2022) 9544, doi:10.3390/su14159544.
[30] A. Puška, A. Štilić, Ž. Stević, A comprehensive decision framework for selecting distribution center locations: a hybrid improved fuzzy SWARA and fuzzy CRADIS approach, Computation 11 (4) (2023) 73, doi:10.3390/computation11040073.
[31] C. Erden, Ç. Ateş, S. Esen, Distribution center location selection in humanitarian logistics using hybrid BWM–ARAS: a case study in Türkiye, J. Homeland Secur. Emerg. Manage. (2023), doi:10.1515/jhsem-2022-0052.

[32] S. Moslem, F. Pilla, A hybrid decision making support method for parcel lockers location selection, Res. Transport. Econ. 100 (2023) 101320, doi:10.1016/j.retrec.2023.101320.

[33] Ž. Stević, N. Mujaković, A. Goli, S. Moslem, Selection of logistics distribution channels for final product delivery: FUCOM-MARCOS model, J. Intell. Manage. Decis. 2 (4) (2023) 172–178, doi:10.56578/jimd020402.

[34] M. Agrebi, M. Abed, Decision-making from multiple uncertain experts: case of distribution center location selection, Soft. Comput. 25 (6) (2021) 4525–4544, doi:10.1007/s00500-020-05461-y.

[35] R. Elbert, J.P. Müller, J. Rentschler, Tactical network planning and design in multimodal transportation – A systematic literature review, Res. Transport. Bus. Manage. 35 (2020) 100462, doi:10.1016/j.rtbm.2020.100462.

[36] D. Dzemydienė, A. Burinskienė, A. Miliauskas, Integration of multi-criteria decision support with infrastructure of smart services for sustainable multi-modal transportation of freights, Sustainability 13 (9) (2021) 4675, doi:10.3390/su13094675.

[37] N. Koohathongsumrit, W. Chankham, Route selection in multimodal supply chains: a fuzzy risk assessment model-BWM-MARCOS framework, Appl. Soft. Comput. 137 (2023) 110167, doi:10.1016/j.asoc.2023.110167.

[38] M.P. Quynh, T.L. Thu, Q.D.Van Huong, A.P.T. Van, N. H, D.N Van, Distribution center location selection using a novel multi criteria decision-making approach under interval neutrosophic complex sets, Decis. Sci. Lett. (2020) 501–510, doi:10.5267/j.dsl.2020.2.001.

[39] B. Bairagi, A novel MCDM model for warehouse location selection in supply chain management, Decis. Mak. 5 (1) (2022) 194–207, doi:10.31181/dmame0314052022b.

[40] B.S. Okatan, İ. Peker, B. Baki, An integrated DEMATEL-ANP-VIKOR approach for food distribution center site selection: a case study of Georgia, J. Manage. Market. Logistics 6 (1) (2019) 10–20, doi:10.17261/Pressacademia.2019.1030.

[41] J. Mihajlović, P.M. Rajković, G.M. Petrović, D. Ciric, The selection of the logistics distribution fruit center location based on MCDM methodology in southern and eastern region in Serbia, Operat. Res. Eng. Sci. 2 (2) (2019) 72–85, doi:10.31181/oresta190247m.

[42] D. Pamučar, D. Božanić, Selection of a location for the development of multimodal logistics center: application of single-valued neutrosophic MABAC model, Operat. Res. Eng. Sci. 2 (2) (2019) 55–71, doi:10.31181/oresta1902039p.

[43] M. Barzehkar, N.M. Dinan, S. Mazaheri, R.M. Tayebi, G.I. Brodie, Landfill site selection using GIS-based multi-criteria evaluation (case study: saharKhiz Region located in Gilan Province in Iran), SN Appl. Sci. 1 (9) (2019) 1082, doi:10.1007/s42452-019-1109-9.

[44] D. Pamučar, M. Žižović, S. Biswas, D. Božanić, A new Logarithm Methodology of Additive Weights (LMAW) for multi-criteria decision-making: application in logistics, Facta Universitatis Series 19 (3) (2021) 361–380, doi:10.22190/fume210214031p.

[45] D. Božanić, D. Pamučar, A. Milić, D. Marinković, N. Komazec, Modification of the Logarithm Methodology of Additive Weights (LMAW) by a triangular fuzzy number and its application in multi-criteria decision making, Axioms 11 (3) (2022) 89, doi:10.3390/axioms11030089.

[46] H. Liao, X. Wu, DNMA: a double normalization-based multiple aggregation method for multi-expert multi-criteria decision making, Omega 94 (2020) 102058, doi:10.1016/j.omega.2019.04.001.

[47] M. Mijajlović, A. Puška, Ž. Stević, D. Marinković, D. Doljanica, S.V. Jovanović, I. Stojanović, J. Beširović, Determining the competitiveness of spa-centers in order to achieve sustainability using a fuzzy multi-criteria decision-making model. Sustainability, 12(20) (2020) 8584. https://doi.org/10.3390/su12208584

[48] J. Więckowski, B. Kizielewicz, A. Shekhovtsov, W. Sałabun, How do the criteria affect sustainable supplier evaluation? - A case study using multi-criteria decision analysis methods in a fuzzy environment, J. Eng. Manage. Syst. Eng. 2 (1) (2023) 37–52, doi:10.56578/jemse020102.

[49] Ş. Toptancı, Ergonomic performance evaluation in turkey's metal industry: occupational health and safety indicators through VIKOR methodology, J. Operat. Strat. Anal. 1 (3) (2023) 140–146, doi:10.56578/josa010305.

[50] M. Saqlain, Sustainable hydrogen production: a decision-making approach using VIKOR and intuitionistic hypersoft sets, J. Intell. Manage. Decis. 2 (3) (2023) 130–138, doi:10.56578/jimd020303.

[51] M. Radovanovic, A. Ranđelović, Ž. Jokić, Application of hybrid model fuzzy AHP - VIKOR in selection of the most efficient procedure for rectification of the optical sight of the long-range rifle, Decis. Mak. 3 (2) (2020) 131–148, doi:10.31181/dmame2003131.

[52] M. Baydaş, O.E. Elma, An objectıve criteria proposal for the comparison of MCDM and weighting methods in financial performance measurement: an application in Borsa Istanbul, Decis. Mak. 4 (2) (2021) 257–279, doi:10.31181/dmame210402257b.

[53] S. Moslem, A novel parsimonious best worst method for evaluating travel mode choice, in: Proc. IEEE Access, 11, 2023, pp. 16768–16773, doi:10.1109/ACCESS.2023.3242120.

[54] A. Puška, Ž. Stević, D. Pamučar, Evaluation and selection of healthcare waste incinerators using extended sustainability criteria and multi-criteria analysis methods, Environ. Develop. Sustainability 24 (9) (2022) 11195–11225, doi:10.1007/s10668-021-01902-2.

[55] G. Demir, P. Chatterjee, D. Pamucar, Sensitivity analysis in multi-criteria decision making: a state-of-the-art research perspective using bibliometric analysis, Expert Syst. Appl. 237 (2024) 121660, doi:10.1016/j.eswa.2023.121660.

[56] A.Puška Stojanović, M. Selaković, A multi-criteria approach to the comparative analysis of the global innovation index on the example of the western Balkan countries, Econ. Innov. Econ. Res. J. 10 (2) (2022) 9–26, doi:10.2478/eoik-2022-0019.

[57] N. Petrović, T. Živojinović, J. Mihajlović, Evaluating the annual operational efficiency of passenger and freight road transport in Serbia through entropy and TOPSIS methods, J. Eng. Manage. Syst. Eng. 2 (4) (2023) 204–211, doi:10.56578/jemse020402.