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Ranking Performance of MARCOS Method for Location Selection Problem in the Presence of Conflicting Criteria

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ABSTRACT

The selection of the best location for a facility is generally a complex process especially when considering multiple criteria in the selection process. The costs associated with purchasing the land and related constructions makes the location selection problem a long-term investment decision. Hence, the problem should be analysed carefully with a reliable approach to avoid the consequences that follows awkward decisions. Many multiple criteria decision-making (MCDM) methods are developed recently which made the selection of a suitable MCDM method has become a confusing decision. In this study, measurement alternatives and ranking according to compromise solution (MARCOS) method is used to solve a location selection problem with conflicting criteria. The ranking produced by MARCOS method is analysed by a comparison with other common MCDM methods and a sensitivity analysis. The aim of the comparison to show that the method agreed the choice of the best alternative while the sensitivity analysis is employed to check the robustness and efficiency of this method. The sensitivity analysis includes the sensitivity of weight test and rank reversal (RR) test. The comparison of ranking with different methods showed that MARCOS method has strong ranking correlation with other methods. Moreover, the sensitivity analysis showed the reliability and robustness of MARCOS method as it produced high consistency of ranking through the tests. Thus, this study validates the applicability of MARCOS method to handle the presence of conflicting criteria in location selection problems.

1. Introduction

Decisions are made daily in human's life, no matter how accurate are these decisions when they are not very important. The decisions that have a considerable impact on something like factories, organizations or communities must be made throughout convincing ways. Here comes the decision-making science where the study of recognizing and selecting alternatives based on the priority of the decision makers are explored. Thus, making a decision means that there are alternatives to choose between them. The decision making science hopes to select the best alternative that fits the

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objectives and desires of the decision maker [1]. The science of decision making simply can be defined as the process of making important decision in the presence of certain information, this information can refer to objectives, criteria and constraints. Many steps are taken for the decision making process including identification of problem, problem structuring, decision analysis and post analysis [2]. The identification phase where the problem to be explained and defined clearly to set up the objectives and constraints. The problem structuring phase as the evaluative criteria to be defined and the alternatives to be picked and measured relative to these criteria. In the decision analysis phase, the decision-making techniques are applied while the post analysis phase where the results are verified and checked for approval.

It is important to distinct between single criterion and multiple criteria problems. A decision problem having single criterion like cost in most cases, is interested in determining the best alternative with the best value of this criterion which is a classic form of an optimization problem [3]. The process of making decision in the presence of numerous criteria is called multiple criteria decision making (MCDM) which can be classified into two branches, multiple attribute decision making (MADM) and multiple objective decision making (MODM) [4]. The MODM is related to problems where the best alternative is determined by the various interactions between the design constraints which means the alternative is designed. In MADM, the alternatives are predetermined and the selection of the best alternative is done through the various methods of MADM [5].

In the MCDM problems, the criteria should be given a certain weight to recognize their relative importance [6]. Many methods are available to determine the weights in MCDM problems which can be either subjective or objective. The subjective methods may include analytic hierarchy process (AHP), analytical network process (ANP), best-worst method (BWM), measuring attractiveness by a categorical-based evaluation technique (MACBETH), stepwise weight assessment ratio analysis (SWARA) and full consistency method (FUCOM) while the objective methods may include method based on the removal effects of criteria (MEREC), entropy weight method (EW), criteria importance through inter-criteria correlation (CRITIC) and standard deviation (SD). The EW was used widely in various research areas including risk assessment [7,8], blockchains technology [9], transportation [10] and more applications related to engineering terms. The method depends mainly on the diversity of attribute data for measuring the criteria weights. Despite the objectivity of EW, it produces reliable weights that may match the decision maker's subjectivity.

The selection of the right location for a facility is considered to be the most important factor that achieves the future success of the facility. The location selection of a facility represents the most critical step especially for large facilities as the risks of re-locating a facility is inherent challenge that must be met when taking such decision. Moreover, the facility location problem is considered to be a multiple criteria problem as many criteria can be considered in the evaluation process. These criteria can vary dependent on the decision maker, nature of problem and type of facility being located [11]. The main challenge in MCDM is finding the optimal solution when evaluating a location problem within a large number of criteria especially in the presence of conflicting criteria. The selection of the suitable approach to deal with location problem is always an immense challenge for the researchers. The organizations are always looking forward to future growth and continuity which pushed the researchers to extend the current methods and develop new methods to overcome the limitations of classical approaches [12]. Many MCDM methods are proposed in the domain of facility location problem which use different computational procedures and have different aggregation procedures. These methods may include classical approaches such as AHP [13], technique for order of preference by similarity to ideal solution (TOPSIS) [14], grey relational analysis (GRA) [15], weighted sum method (WSM) [16], weighted product model (WPM), preference ranking organization method for enrichment evaluation (PROMETHEE) family [17] and complex proportional assessment

(COPRAS) [18] while there are newly developed approaches such as evaluation based on distance from average solution (EDAS) [19], combinative distance based assessment (CODAS) [20], combined compromise solution (CoCoSo) [21], measurement alternatives and ranking according to compromise solution (MARCOS) [22]. Thus, the selection of the best method for a certain application had become one of the most important steps. Therefore, the selection of a suitable MCDM method must be analyzed carefully to ensure that the ranking can be considered as a final result for the decision makers.

The rest of this research is organized in the following pattern. The second section reviews the past researches related to the current study, while in the third section, an algorithm of MARCOS method is presented and illustrated. In the fourth section, a benchmarked example is solved using MARCOS method and the ranking is compared to other MCDM methods. The fifth section presents a sensitivity analysis to validate the results of MARCOS method, whereas the sixth section introduces the drawn conclusions from the current research.

2. Literature Review

The absence of optimal solutions in MCDM methods had a considerable impact in the researchers' interests. Thus, current methods were extended and new methods were developed to overcome this issue. The search for the optimal solutions was not required anymore but the solution that satisfies the decision makers. The decision makers tend to carry on comparative studies to verify the results of MCDM methods while other studies integrated the fuzzy approach to overcome the uncertainty in the decision-making problems. Hence, this section reviews the past studies that include comparative analysis, fuzzy MCDM approaches and newly developed methods which were used to solve the location selection problems.

The comparison between AHP and fuzzy-AHP that was held by Suman *et al.,* [23] had worthy results that there is a variation in the priority weights between the two methods and the authors preferred the fuzzy-AHP as the method deals with linguistic terms. Moreover, Ortega *et al.,* [24] criticized fuzzy-AHP method as it requires surveying and a large amount of time for collecting the data relating to their problem. Parhizgarsharif *et al.,* [25] compared GRA and VIKOR method for the location selection of construction site. They employed best-worst method (BWM) for assigning the weights of criteria. They concluded that GRA method has higher stability and more simplicity compared to the VIKOR method. Alkafaas *et al.,* [26] proved that the best alternative will be the same regardless the MCDM method being used. They compared intuitionistic fuzzy-VIKOR approach to seven past researches that solved the same problem.

Wang *et al.,* [27] wanted to select the location for solar power plant in Vietnam. They used data envelopment analysis (DEA) method for the selection of locations between several candidate locations, fuzzy-AHP methodology for the determination of weights for criteria and TOPSIS method for the final ranking of locations. They proposed the use of TOPSIS method instead of fuzzy-AHP for the ranking of alternatives as the input data is expressed in linguistic terms and based on the previous experiences, TOPSIS method proved to be effective in dealing with subjectivity. Hossein *et al.,* [28] used the fuzzy-TOPSIS approach for selecting the location of a company that seeks for expansion to satisfy the market demand. The results showed that the integration of fuzzy approach helped to deal with the vagueness in the estimated data. Thus, the data could be effectively presented and progressed to make a more effective decision.

Chauhan and Singh [29] wanted to select a sustainable location for the disposal of healthcare waste. They used fuzzy-AHP methodology for assigning weights to criteria and fuzzy-TOPSIS for the final ranking of alternatives. Miç and Antmen [30] employed fuzzy-TOPSIS approach to select a suitable location for a healthcare facility in Adana city in Turkey. The results showed that TOPSIS method is one of the most reliable methods that can be used for such critical cases.

Ghorui *et al.,* [31] wanted to select a suitable location for the construction of shopping mall taking into consideration the accessibility as one of the major factors within their problem. They used fuzzy-AHP for the weights of criteria and fuzzy-TOPSIS for the final ranking of alternatives. They concluded that the used MCDM methods can be considered as a practical technique for ranking the locations and thus selecting the best location. Ulutaş *et al.,* [32] aimed to select a location for a logistics center at Sivas city in Turkey. They applied fuzzy-SWARA method for assigning the criteria weights and CoCoSo method for the ranking of alternatives. Hashemkhani Zolfani *et al.,* [33] determined the optimal lithium battery plant location using Bayesian BWM-MARCOS approach. The Bayesian BWM was used to determine the criteria weights and MARCOS method for the ranking of locations.

3. MARCOS Method

The MARCOS method, proposed by Stević *et al.,* [22], had much interest by researchers. The method was used widely to solve decision-making problems in different applications [12,34,35]. The evaluation process in MARCOS method depends on the relation between the alternative's score and the reference values (ideal and anti-ideal solution). On basis of this relation, the utility function is computed and the final ranking is obtained. The following are the steps of the MARCOS method:

Step 1: Formulation of the decision-making matrix,

$$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ij} & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mj} & x_{mn} \end{bmatrix}_{m \times n}$$

Step 2: Normalization of the decision-making matrix through the formula,

$$r_{ij} = \frac{x_{ij}}{x_{ai}} \tag{1}$$

$$r_{ij} = \frac{x_{ai}}{x_{ij}} \tag{2}$$

Where $x_{ai} = \{\max_j x_{ij}\ ;\ j \in Benfit\ Criteria$ or $\min_j x_{ij}\ ;\ j \in Cost\ Criteria\}$

Step 3: Determination of the weighted normalized matrix using,

$$v_{ij} = w_j r_{ij} \tag{3}$$

Step 4: The utility degree of the alternatives,

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{4}$$

$$K_i^- = \frac{S_i}{S_{aai}} \tag{5}$$

Where S_i is the sum of row elements in the weighted normalized matrix ($S_i = \sum_{j=1}^{n} v_{ij}$), S_{ai} is the sum of the ideal solution values in the weighted normalized matrix and S_{aai} is the sum of the anti-ideal solution values in the weighted normalized matrix.

Step 5: Calculation of the utility function in relation to the ideal solution $f(K_i^+)$ and the utility function in relation to the anti-ideal solution $f(K_i^-)$.

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{6}$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{7}$$

Step 6: Determination of the utility function of the alternatives using,

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \tag{8}$$

Step 7: Ranking of the alternatives based on the utility function values. The higher the utility function the more preferred the alternative.

4. Benchmarked Example

In this study, the location problem presented by Żak and Węgliński [36] is adopted. The problem addresses the selection of the most suitable region for logistics center (LC) in Poland. The problem requires to rank ten nominated locations in the presence of nine different criteria which are considered to measure the performance of the nominated locations. The nine criteria are transportation infrastructure (C1), economic development (C2), investment costs (C3), level of transportation and logistics competitiveness (C4), investment attraction (C5), transportation and logistics attraction (C6), social attraction (C7), environmental affability (C8) and safety (C9). Among the nine criteria, investment costs (C3) and level of transportation and logistics competitiveness (C4) are non-beneficial criteria where the lower values are preferred. The decision tree with evaluative criteria is shown within Figure 1 and the performance of the locations relative to the set of decision criteria is shown in Table 1. Two conflicting criteria are present within the case study, the investment cost (C3) and investment attraction (C5) as both criteria depend mainly on the land area. The larger the land area, the more money required for the land and the more attractive becomes the land.

The criteria weights are assigned using entropy weight method (EW) which produced satisfying weights for the proposed problem [37]. However, the interested reader can refer to Żak and Węgliński [36] for further information about the adapted problem.

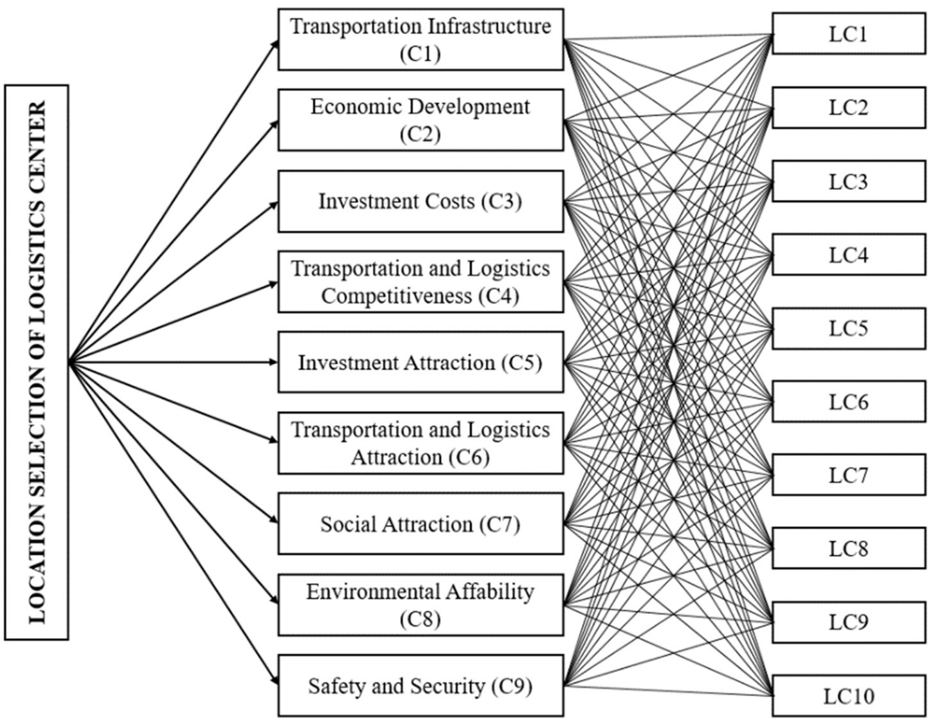


Fig. 1. The decision tree with evaluative criteria

Table 1
The decision-making matrix with the nominated locations, set of criteria and criteria weights

Locations	Criteria								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
LC1	90.3	11350	392	9	1110	9709	4.5	7.5	7.5
LC2	132.2	11558	421	12	1019	13379	7.17	6.5	4.5
LC3	98	9416	395	6	1176	6991	4.33	6.5	8
LC4	101.3	13275	443	9	312	11904	4.17	6.5	6
LC5	138.5	11939	402	6	606	7958	7	8	7.5
LC6	146.8	20049	424	18	284	15669	4	6.5	3.75
LC7	133.1	9396	393	7	900	10425	7	6	7.5
LC8	121.7	12989	395	10	2789	13275	8	7.5	5.25
LC9	222.7	13822	406	12	1733	14382	4.17	4	3.75
LC10	146.9	10131	397	13	2355	11653	7	4.5	4.75
E_j	0.851	0.799	0.934	0.935	0.833	0.903	0.794	0.918	0.841
w_j	0.125	0.168	0.055	0.054	0.141	0.081	0.173	0.069	0.133

4.1 Computations and Results

Since the decision-making matrix is determined and criteria weights are assigned using entropy weights, MARCOS method is employed to rank the alternatives on basis of their utility scores. By applying Eq. (1-8), the utility degrees and functions can be computed and the final ranking of the locations can be determined on basis of utility function score as shown in Table 2. The location (LC8) appears to have the highest score and hence is first ranked while the location (LC4) has the lowest score and hence is last ranked.

Table 2
The results of applying MARCOS method for ranking the nominated locations

Locations	K_i^+	K_i^-	$f(K_i^+)$	$f(K_i^-)$	$f(K_i)$	Rank
LC1	0.6303	1.4642	0.6991	0.3009	0.5580	7
LC2	0.6566	1.5254	0.6991	0.3009	0.5813	6
LC3	0.6213	1.4433	0.6991	0.3009	0.5501	8
LC4	0.5767	1.3397	0.6991	0.3009	0.5106	10
LC5	0.7031	1.6334	0.6991	0.3009	0.6225	2
LC6	0.6204	1.4411	0.6991	0.3009	0.5492	9
LC7	0.6826	1.5857	0.6991	0.3009	0.6043	4
LC8	0.7993	1.8567	0.6991	0.3009	0.7076	1
LC9	0.6707	1.5581	0.6991	0.3009	0.5938	5
LC10	0.6956	1.6160	0.6991	0.3009	0.6159	3

4.2 Comparative Analysis

In this section, The ranking produced by MARCOS method is discussed by comparing it with TOPSIS, GRA, EDAS and CoCoSo methods that were previously used to solve the same problem [37]. The deviations in the ranking produced by the methods are measured using spearman's relational correlation coefficient which will indicate the degree of association between MARCOS method and the other methods. Figure 2 shows the ranking of MARCOS method in comparison with TOPSIS, GRA, EDAS and CoCoSo methods. The final results show that alternative A8 was always picked as the best alternative regardless the method being used. Alternative (A4) has been ranked as the worst alternative except for CoCoSo method.

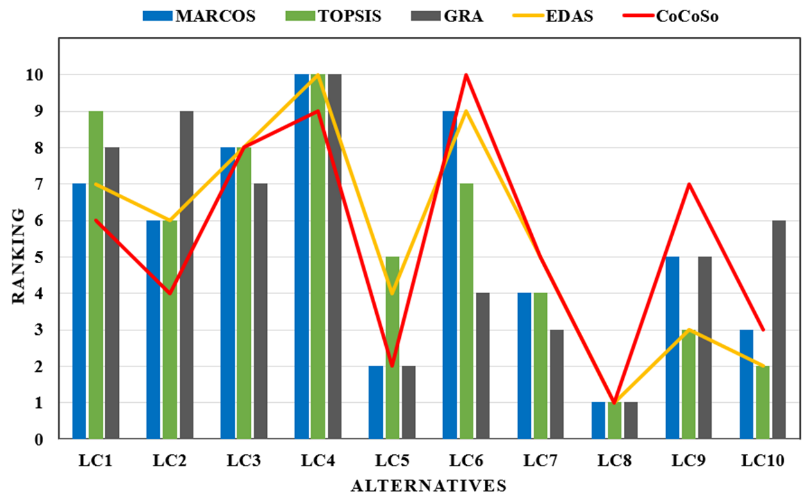


Fig. 2. The ranking of MARCOS method compared with other methods

The deviation in ranking between MARCOS method and the other methods is measured by spearman's correlation coefficient (r_s) and Wojciech Sałabun coefficient (WS). The value of r_s must fall between +1 and -1 where the value of (+1) indicates a perfect relation and the value of (-1) indicates that there is no relation between the two methods. The value of WS must fall between 0 and 1 and the ranking similarity is determined based on identified values [38]. The values of r_S and WS coefficients are determined as shown in Table 3. According to r_s coefficients, MARCOS method has a very strong relation between TOPSIS, EDAS and CoCoSo methods. While the WS coefficients indicate that MARCOS method has a high similarity with the other four methods.

Table 3
The ranking similarity between MARCOS method and the other methods

Similarity Coefficient	TOPSIS	GRA	EDAS	CoCoSo
r_s	0.867	0.721	0.939	0.927
WS	0.872	0.923	0.897	0.969

5. Sensitivity Analysis

The main aim of this analysis is to ensure the reliability, robustness and applicability of the technique for the decision-making problem. It helps to identify the critical parameters and criteria that have a direct impact on the decision-making problem. In general, if a method is found to be sensitive to weights or suffers from RRP, the results cannot be approved by the decision makers. A robust MCDM method is considered to obtain consistent ranking of at least the ranked one alternative when changing the weights of criteria within a reasonable scale. Moreover, the method must obtain consistent ranking of alternatives when subjected to rank reversal tests. Hence, two different types of analyses will be discussed, sensitivity due to change in criteria weights and a rank reversal test for each method. The criteria weights have a direct effect on the ranking of MCDM methods so it is necessary to consider some changes on the criteria weights and check the variation of ranking due to the changes made. The criteria weights will be analyzed by changing the objective weighting method and rotating the values of criteria weights.

5.1 Changing the Weighting Method

Many objective weighting methods are mentioned within the research which is available for the decision makers to select between them. The choice of the objective weighting method is based on the decision maker's preference towards the mathematical computing algorithm of the method. However, the objective weights have a direct effect on the ranking of MCDM methods. Beside entropy weighting method (EW), three different weighting methods are analyzed within this section to check the impact of changing the weighting method on the ranking of the proposed MCDM methods. The three methods are CRITIC, SD and mean weights (MW).

The new calculated weights using CRITIC, SD and MW methods are shown in Figure 3. The SD approach produced nearly equal weights similar to the weights by MW method. However, social attractiveness (C7) was given the most importance (highest value of weight) among the set of criteria by using entropy, CRITIC and SD methods.

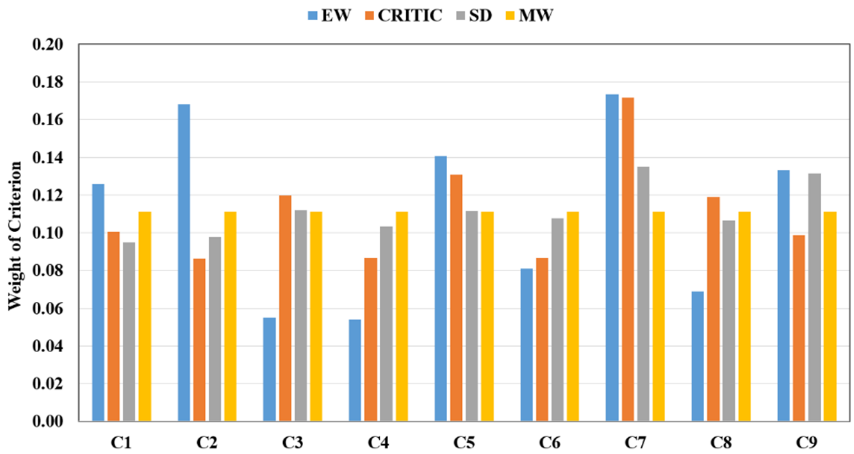
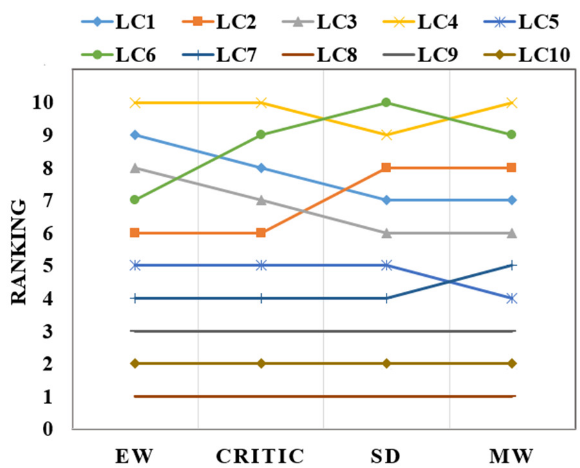
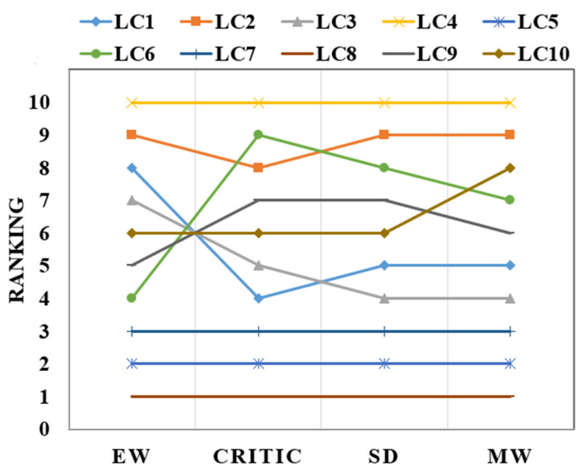


Fig. 3. The criteria weights by EW, CRITIC, SD and MW methods

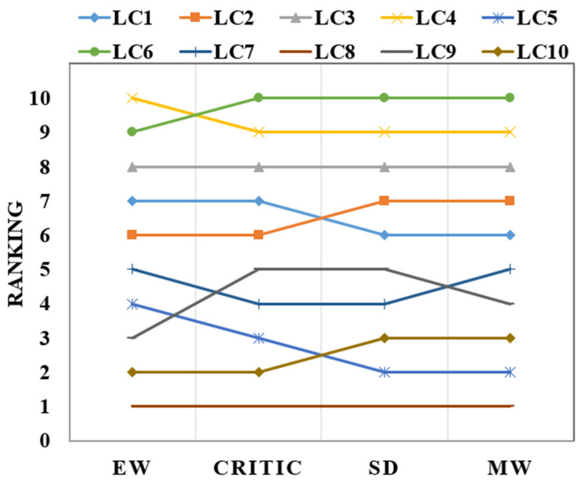
The effect of changing the weighting method on MCDM methods can be shown within Figure 4. In TOPSIS method, there is a consistency of ranking regarding the first three ranked alternatives (LC8, LC10 and LC9 respectively) regardless the used weighting method. The GRA method suffered some observable deviations especially when moving from EW to CRITIC weights with a correlation of nearly 0.69 which states that the method is sensitive to change the criteria weights. The EDAS method produced almost stable results with low deviations in ranking of alternatives. In CoCoSo method, the ranking of the first two ranked alternatives (LC8 and LC5 respectively) remained the same through the whole process. The method has perfect results regarding changing the weighting method. In MARCOS method, the ranking of LC8, LC5, LC6 and LC4 remained the same for the four weighting methods. The ranking deviation increases when moving from EW to SD weights while the least deviations occurred when moving from EW to CRITIC weights.



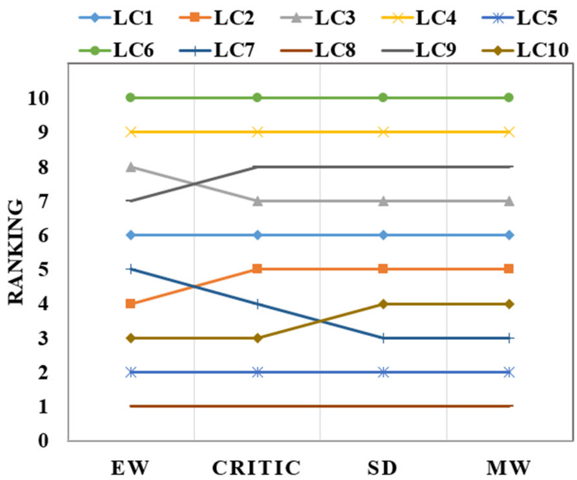
(a) TOPSIS Method



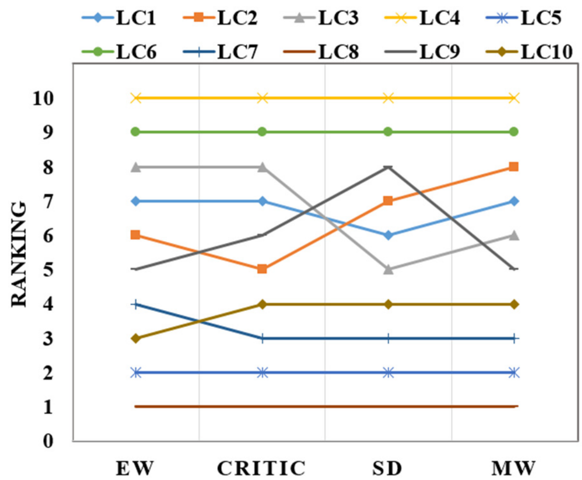
(b) GRA Method



(c) EDAS Methods



(d) CoCoSo Method



(e) MARCOS Method

Fig. 4. The effect of changing the weighting method on the MCDM methods

5.2 Rotation of Criteria Weights

The rotation of criteria weights is a popular mean to check the deviation of the ranking of alternatives due to interchanging the weights of criteria. If interchanging the weights results in a completely different ranking, the model is considered to be sensitive to those weights. Therefore, the stability of an MCDM method is confirmed if the ranking determined by the method remains the same or less unaffected by interchanging the criteria weights. Consequently, a rotation of criteria weights is performed in order to assess how the changes in criteria weights affect the ranking of the alternatives. For the nine considered criteria (C1–C9), a total of 36 (${}^{9}C_{2}$) possible interchanges are available. Here, 9 is the number of the criteria and 2 is the number of the criteria chosen at a time. Therefore, there are 36 possible interchanges in the weights.

The ranking of MCDM methods due to the interchanges in criteria weights is shown in Figure 5. The interchanges in criteria weights must have an impact on the ranking of MCDM methods. However, a method is said to be sensitive to weights when the ranking dramatically deviates so that the results cannot be trusted. In the five methods integrated with entropy weights, the TOPSIS method and GRA method are the most sensitive to weights although the ranking of the first alternative remained the same in all interchanges. The CoCoSo method and EDAS method are the least sensitive to weights as they provided a mean correlation coefficient of 0.97 and 0.95

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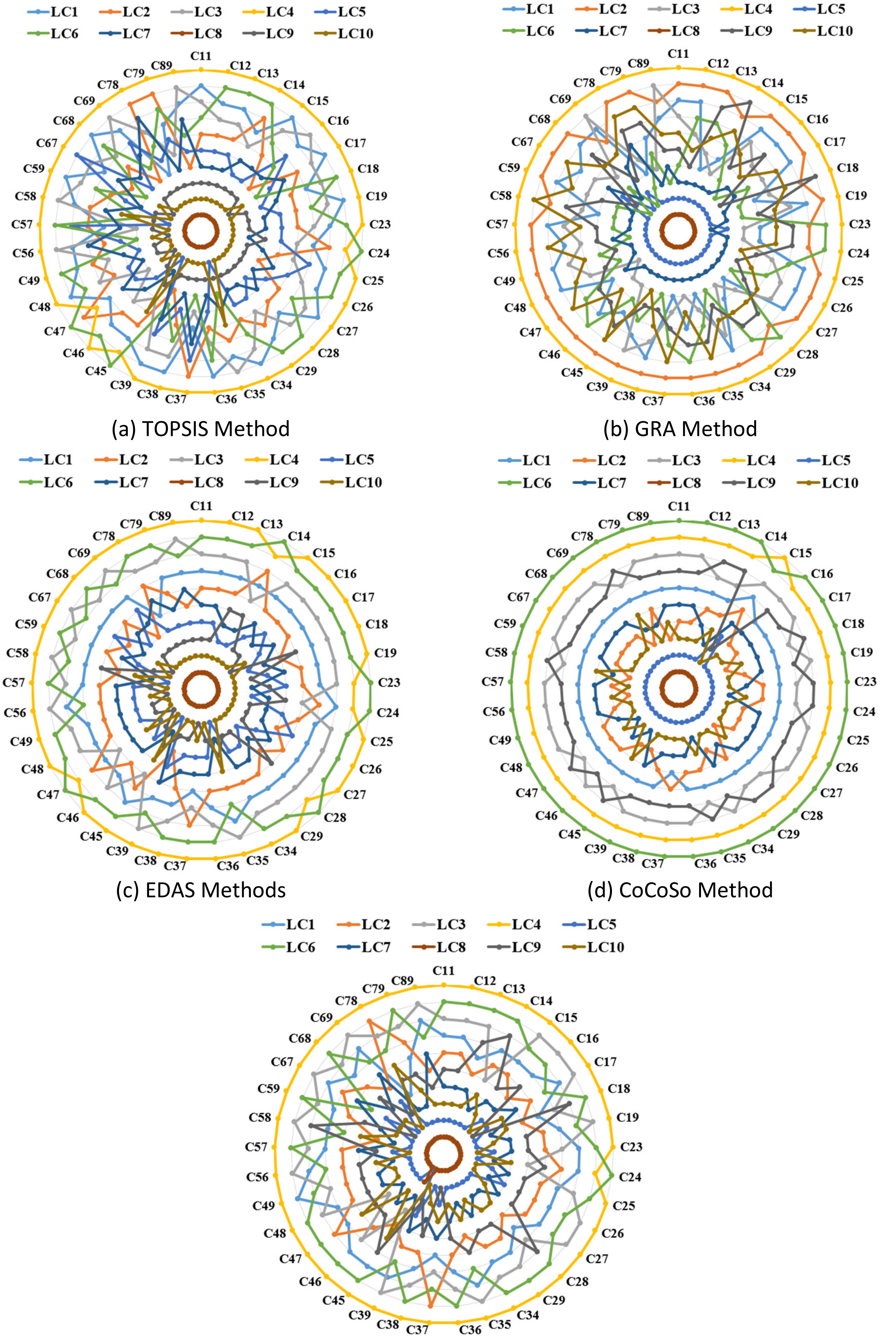
respectively. In MARCOS method, the mean value of correlation coefficient is 0.93 which indicates a minor ranking deviation occurred through the whole test.



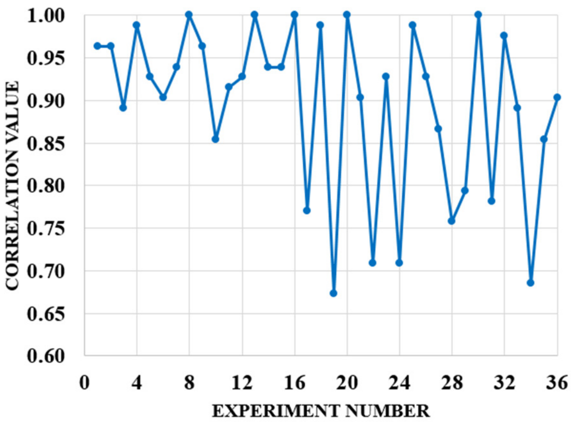
(a) TOPSIS Method (b) GRA Method

(c) EDAS Methods (d) CoCoSo Method

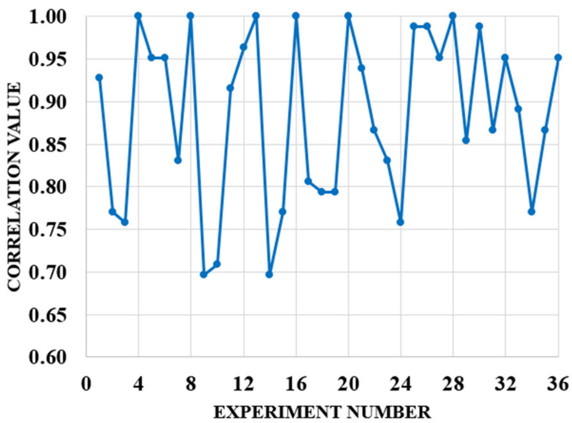
(e) MARCOS Method

Fig. 5. The effect of rotating the criteria weights on the ranking

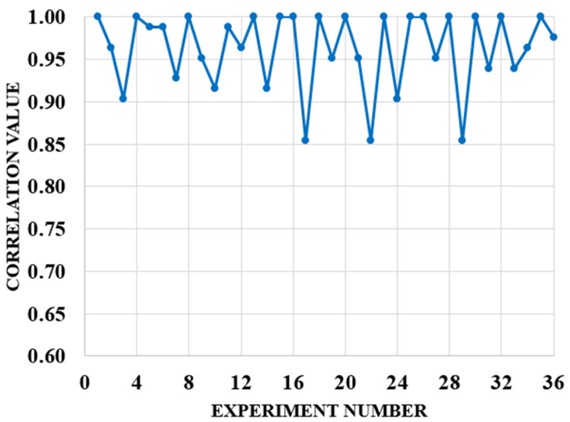
In Figure 6, a correlation chart is presented for each experiment carried in the rotation of criteria weights test. The aim of the correlation chart is to provide a clear overview of the ranking deviation for each experiment when compared to the main ranking. The CoCoSo method has the least sensitivity to weights according to the correlation chart, followed by EDAS, MARCOS, TOPSIS and GRA respectively. The valuable property of CoCoSo method is that for the most of the interchanges made, the method remained the same ranking of alternatives which makes the method authentic regarding the impact of changing criteria weights.



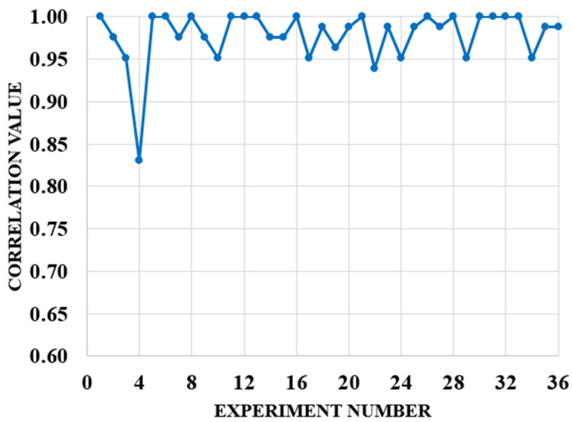
(a) TOPSIS Method



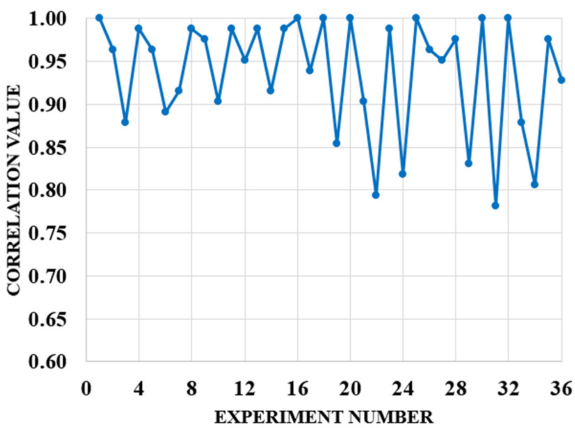
(b) GRA Method



(c) EDAS Methods



(d) CoCoSo Method



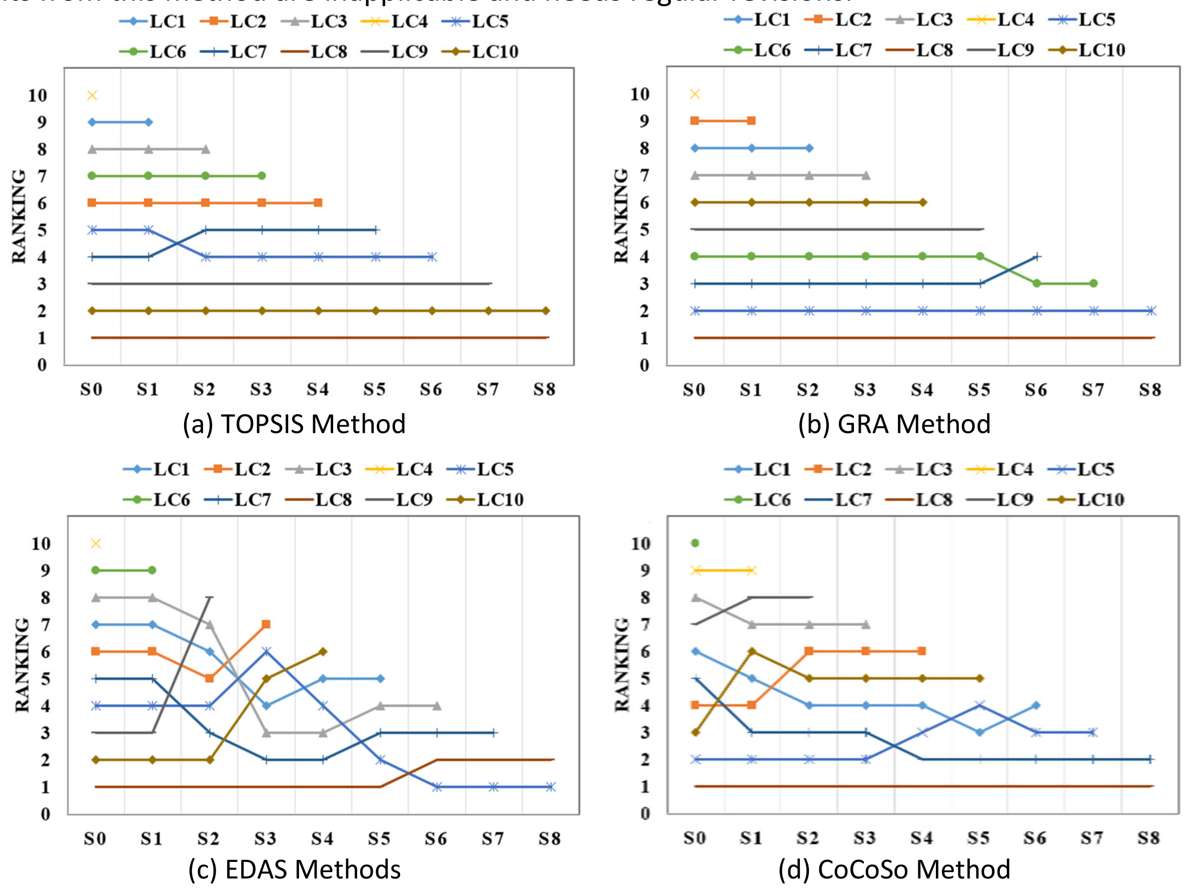
(e) MARCOS Method

Fig. 6. The correlation between each experiment and main ranking

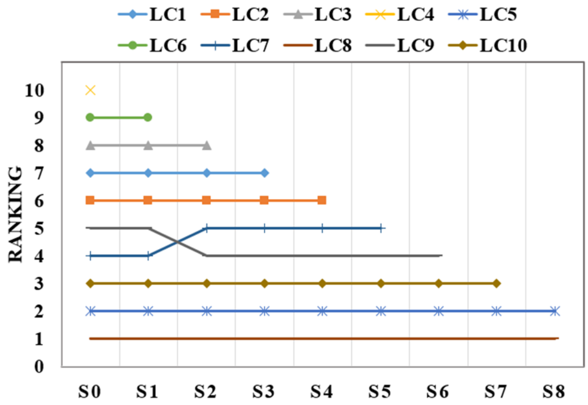
5.3 Rank Reversal Test

There are many reasons for rank reversal problem in MCDM methods, the common ones are the removal of non-discriminating criterion, replacing a non-optimal alternative by another worse one and addition or removal of irrelevant alternative. The removal of irrelevant alternatives is to be discusses within this section. The aim of this test is to check the concept of independency of alternatives in the MARCOS method and comparing it to the other four methods. The last ranked alternative within the ranking of MCDM method is removed at first and the ranking is observed. Once the last ranked alternative is removed, the ranking either change if the method suffers from RR problem or remains in the same order. The sequence continues until there is only two remaining alternatives as shown in Figure 7.

The TOPSIS, GRA and MARCOS methods provided almost the same ranking when removing the irrelevant alternatives successively. However, the concept of independency between the alternatives is still corrupted in these methods. The ranking of the best alternative (LC8) has not changed throughout the test for the three methods. The CoCoSo method changed the whole ranking of alternatives except for LC8 and LC4. The best alternative has not changed throughout the RR test. However, the method shows considerable inconsistency of ranking. The concept of independency between the alternatives in CoCoSo method is broken and invalid. In EDAS method, the ranking of alternatives has changed for almost every elimination even the ranking of the best alternative (LC8) has changed through the test. The method is incapable of handling the concept of independence between the alternatives as no alternative remained the same ranking through the whole test. The results from this method are inapplicable and needs regular revisions.



(a) TOPSIS Method
(b) GRA Method
(c) EDAS Methods
(d) CoCoSo Method



(e) MARCOS Method

Fig. 7. The rank reversal test for MCDM methods

6. Conclusions

The location selection problem has turned into a common topic which has the attentions of the organizations that are looking forward to future success. The selection of the best location in the presence of multiple criteria is still a major challenge for most of the decision makers especially when there are conflicting criteria among the evaluative criteria. In this study, MARCOS method is proposed as a reliable approach for location selection problems. The method was compared to four common MCDM methods, namely TOPSIS, GRA, EDAS and CoCoSo, in terms of final ranking, sensitivity to criteria weights and rank reversal test.

The TOPSIS method is well known to the decision makers with its applicability to handle different types of decision-making problems. Moreover, the combination of entropy-TOPSIS is widely used as a comprehensive MCDM model. By comparing TOPSIS to MARCOS method, the results proved that MARCOS method is more efficient when referring to the sensitivity to weight tests while it has the same results in the rank reversal test. Furthermore, the EDAS and CoCoSo methods have better results regarding the sensitivity to weight tests but the two methods extremely suffer from RR problem as they changed the ranking for almost every elimination.

The MARCOS method has a strong correlation coefficient with TOPSIS, EDAS and CoCoSo methods while it has a moderate correlation coefficient with GRA method. However, when checking the correlation coefficients between each pair of the methods, MARCOS method has the highest correlation value observed with GRA method. Throughout the comparisons and sensitivity tests, MARCOS method proved to be stable and reliable to use for location selection problems in the presence of conflicting criteria.

The recommendations for future research are to investigate both EDAS and CoCoSo methods to check the reasons for the rank reversals appeared within the sensitivity analysis. The two methods can be mathematically modified to overcome this issue while taking into considerations the normalization procedure as a main reason for RR.

The application of MARCOS method in a dynamic and uncertain environment is encouraged for future studies while taking into considerations that the results must be validated especially in the critical domains such as military and healthcare problems.

Data Availability

The data that support the findings of this study are openly available at https://doi.org/10.1016/j.trpro.2014.10.034.

Conflict of interest

The authors declare no conflicts of interest.

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