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Case Report

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Abstract

There are different multi-criteria decision-making techniques. PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), VIKOR (ViseKriterijumska Optimizacija I Kompromisno Resenje), and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and ELECTRE (Elimination and Choice Translating Reality) are part of the widely used MCDM (Multi Criteria Decision-Making) methods. PROMETHEE is focused on outranking through pairwise comparison, VIKOR is focused on compromise, TOPSIS is based on the distance from the “Positive Ideal Solution (PIS)” and “Negative Ideal Solution (NIS)”. Using a logistics centre location selection problem as a case study, this paper presented the comparative analysis of these 3 methods. The ranking of the locations considered using PROMETHEE II and VIKOR are the same except for TOPSIS. This inconsistency is attributed to the inability of TOPSIS to consider the relative importance of the distances from PIS and NIS. This indicates that the issue of selecting a location for a logistics center also highlighted inconsistencies in the results due to the difference in the foundational principles of the MCDM methods. It underscores the necessity of comparing various MCDM methods before choosing the most suitable one.

Keywords: PROMETHEE, VIKOR, TOPSIS, Comparative Analysis, Multi Criteria Decision-Making

1. INTRODUCTION

Multi-Criteria Decision Making (MCDM) is a critical process used in various fields to narrow down number of alternatives to select the most appropriate one based on multiple conflicting criteria (Zanakis et al., 1998). Among the numerous methods available, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) and VIKOR (ViseKriterijumska Optimizacija I Kompromisno Resenje) methods are widely recognized for their effectiveness in solving complex multi decision-making problems. Since (Depontin et al., 1983) has revealed that “decision studies varied so much in quantity, quality and precision of information” making it difficult to classify a method as perfect for solving a particular problem, new MCDM methods have been introduced as a result of further improving existing ones to fit specific decision-making problems. Likewise, to achieve a best option theoretically and practically, several comparative analyses of the widely used methods have been conducted in different sectors including science, business, engineering and management. (Zlaugotne et al., 2020) compared TOPSIS, VIKOR, COPRAS, MULTIMOORA, and PROMETHEE-GAIA methods to find the best renewable energy. From the comparison, TOPSIS, VIKOR and PROMETHEE-GAIA have similar priority selection and hydropower plant was chosen as the best renewable energy for Latvia, but MULTIMOORA and COPRAS outputs benefits Solar PV. To develop a hybrid model to evaluate and select the best bucket wheel excavators (BWE) (Savkovic et al., 2022) TOPSIS, VIKOR and PROMETHEE methods were compared. Evaluating the results of the methods by experts, PROMETHEE was ranked best in aligning with experts’ opinion followed by TOPSIS, then lastly VIKOR in selecting the best BWE. In the sugar industry, pipes play a vital role in the efficient operation of industry activities, making the decision to select pipe material critical. For this reason, (Anojkumar et al., 2014) compared four MCDM methods, TOPSIS, VIKOR, PROMETHEE, and ELECTRE to select the best pipe material among 5 different steel grades. The material alternative considered as the best suitable material has obtained the top rank in TOPSIS, ELECTRE and VIKOR except for PROMETHEE. For live cargo transport truck selection (De Siqueira Silva et al., 2022), compared AHP-TOPSIS-

2N, PROMETHEE-SAPEVO-M1 and SAPEVO-M methods. In this case, the truck considered best was ranked highest by PROMETHEE-SAPEVO-M1 and AHP-TOPSIS-2N but ranked second by SAPEVO-M. From the above-mentioned comparative analysis studies, it shows that often different techniques results in different ranking of options also the inconsistencies varies with the problem nature. (Zanakis et al., 1998) attributed the inconsistencies to the difference in algorithm to select preferred alternative, difference in calculations with criteria weights, attempts of algorithms to scale the objectives affecting the already chosen weights, and the additional parameters introduced by algorithms that affect selection of preferred alternative.

From literature review over the past years, no comparative analysis article was recorded for location selection multi-criteria problem. To address this existing gap in the MCDM research, this study aims to compare PROMETHEE, VIKOR and TOPSIS by comparing the results from VIKOR and TOPSIS method with that of PROMETHEE method used by (Fabry et al., 2024) to select a location for a logistics centre in Czech Republic. We chose TOPSIS and VIKOR methods to compare in addition with the PROMETHEE because of the difference in their approach to handle decision making problem. TOPSIS is distance based, VIKOR is focused on compromise. And also, VIKOR's compromise logic and PROMETHEE's preference functions allow modeling varying stakeholder weights (e.g., prioritizing "container terminal" access over "price") which is the main reason VIKOR is also considered in this comparative study.

The remainder of the paper is structured as follows. The second section explains the steps of PROMETHEE, TOPSIS and VIKOR. In the third section TOPSIS and VIKOR methods are used on the logistic centre location selection problem. Finally, the section four discusses the results and conclusion.

2. MULTI-CRITERIA DECISION-MAKING METHODS (MCDM)

2.1 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) Method

TOPSIS is a popular MCDM method, which was proposed by (Yoon & Hwang, 1981) to determine the best alternative. The main rule of TOPSIS is that the best alternative should have shortest distance from the positive-ideal solution and the farthest distance from the negative ideal solution. This method has been widely adopted to solve MCDM problems in many different fields. The algorithm of the TOPSIS method is presented below, according to (Behzadian et al., 2012):

Step 1: Construct normalized decision matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \text{ for } i = 1, \dots, m; j = 1, \dots, n \quad (1)$$

Step 2: Construct the weighted normalized decision matrix

$$V_{ij} = w_j r_{ij} \quad (2)$$

where w_j is the weight for j criterion

Step 3: Determine the positive ideal and negative ideal solutions

$$A^* = \{V_1^*, \dots, V_n^*\}, \quad (3) \text{ Positive ideal solution}$$

where $V_i^* = \{\max(V_{ij}) \text{ if } j \in J; \min(V_{ij}) \text{ if } j \in J'\}$

$$A' = \{V_1', \dots, V_n'\}, \quad (3) \text{ Negative ideal solution}$$

where $V'_i = \{\max(V_{ij}) \text{ if } j \in J; \min(V_{ij}) \text{ if } j \in J'\}$

Step 4: Calculate the separation measures for each alternative

The separation from positive ideal alternative is:

$$S_i^* = [\sum (V_j^* - V_{ij})^2]^{\frac{1}{2}} \quad i = 1, \dots, m \quad (5)$$

Similarly, the separation from the negative ideal alternative is:

$$S'_i = [\sum (V'_j - V_{ij})^2]^{\frac{1}{2}} \quad i = 1, \dots, m \quad (6)$$

Step 5: Calculate the relative closeness to the ideal solution C_i^*

$$C_i^* = \frac{S'_i}{S_i^* + S'_i}, \quad (7) \quad 0 < C_i^* < 1$$

Finally, select the alternative with C_i^* closest to 1.

2.2 PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations)

This method was developed by (Brans et al., 1982). PROMETHEE method contains PROMETHEE I which results in partial ranking, and PROMETHEE II provides complete ranking of the alternatives as output. PROMETHEE II is based on a pairwise comparison of alternatives relative to each criterion. When applying PROMETHEE II, decision maker has to define preference function and weight of all the criteria. The weight like in the other methods shows the importance of each criterion, whereas the preference function shows the preference of an alternative to another alternative. The preference degree ranges from 0 to 1 and computed based on the difference between compared alternatives. (Vincke & Brans, 1985) introduced six preference functions: (i) linear criterion (simple comparison), (ii) U-shape criterion (preference starts after a threshold), (iii) V-shape criterion (linear increase in preference), (iv) level criterion (stepwise increase in preference), (v) V-shape with indifference criterion (linear with an indifference zone) and (vi) Gaussian criterion (uses normal distribution for preference). The PROMETHEE study being considered in this comparison study used PROMETHEE II and the linear preference function, with indifference and preference thresholds (Fabry et al., 2024). The outranking flows of the alternatives are calculated after pairwise comparison of the alternatives relative to all criteria, as follows (4),(5),(6) according to (Brans et al., 1982):

$$\phi^+(a) = \frac{1}{n-1} \sum_{x \in A} \sum_{j=1}^k P_j(a, x) W_j \quad (4)$$

$$\phi^-(a) = \frac{1}{n-1} \sum_{x \in A} \sum_{j=1}^k P_j(x, a) W_j \quad (5)$$

Where W_j is the weight assigned to criterion j , showing its importance to the other criteria. And $\phi^-(a)$ and $\phi^+(a)$ denote the negative outranking and positive outranking flows for alternative “a” respectively.

The net outranking flow is calculated as:

$$\phi(a) = \phi^+ - \phi^- \quad (6)$$

The rankings of all the alternatives are identified depending on the net outranking values. The alternative with the highest net outranking value is given the highest rank.

2.3 VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje)

VIKOR is the abbreviation of “Vlsekriterijumska Optimizacija I Kompromisno Resenje” which is Serbian and means “Multi Criteria Optimization and Compromise Solution” in English. This method is developed by (Opricovic, 1998). It determines the compromise ranking list and the compromise solution. It is particularly useful when a compromise solution is needed because no single alternative is perfect across all criteria. The VIKOR method has the following steps according to (Opricovic & Tzeng, 2004):

Step 1: Determine the best and the worst values of all criterion functions, $i = 1, \dots, n$. If the i th function is a beneficial criterion, then:

$$f_i^* = \max_j f_{ij}, \quad f_i^- = \min_j f_{ij}$$

If the function “ i ” is a non-beneficial criterion, then:

$$f_i^- = \max_j f_{ij}, \quad f_i^* = \min_j f_{ij}$$

Step 2: Compute the values S_j (utility measure) and R_j (regret measure), $j = 1, \dots, J$ by the relations:

$$S_j = \sum_{i=1}^n W_i (f_i^* - f_{ij}) / (f_i^* - f_i^-)$$

$$R_j = \max_i [w_i (f_i^* - f_{ij}) / (f_i^* - f_i^-)]$$

where W_i is the weight of criterion “ i ”, showing its importance to the other criteria.

Step 3: Compute the values, $j = 1, \dots, J$, by the relation:

$$Q_j = \frac{v(S_j - S^*)}{(S^- - S^*)} + \frac{(1-v)(R_j - R^*)}{(R^- - R^*)}$$

where

$$S^- = \max_j S_j, \quad S^* = \min_j S_j$$

$$R^- = \max_j R_j, \quad R^* = \min_j R_j$$

And v is introduced as weight of the strategy of the maximum group utility, whereas $(1 - v)$ is the weight of the individual regret.

Step 4: Rank the alternatives, sorting by the values S , R and Q , in decreasing order. The results are three ranking lists.

Step 5: Propose as a compromise solution the alternative (a') which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

C1: “Acceptable advantage” $Q(a'') - Q(a') \geq DQ$ where a'' is the alternative in the second position in the ranking list by Q ; $DQ = 1/(J - 1)$; J is the number of alternatives.

C2: “Acceptable stability in decision making”: alternative (a') must also be the best ranked by S or/and R .

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives a' and a'' if only condition C2 is not satisfied, or

- Alternatives a' , a'' , ..., $a^{(M)}$ if condition C1 is not satisfied; and $a^{(M)}$ is determined by the relation $Q(a^{(M)}) - Q(a') < DQ$ for maximum M (the positions of these alternatives are “in closeness”).

3. COMPARISON OF PROMETHEE, TOPSIS AND VIKOR ON THE LOGISTIC CENTRE SELECTION PROBLEM

The decision matrix data and PROMETHEE method results of the logistics centre selection problem by (Fabry et al., 2024) will be presented in this section. TOPSIS and VIKOR will then be applied on this. The results of these 3 methods will be presented for comparison purposes.

3.1 Location selection for logistics centre problem

Logistics and distribution centers play a crucial role in supply-chains of numerous manufacturing and logistics firms. Finding the most effective locations for these centers requires a comprehensive search for the best sites, emphasizing closeness to suppliers and cost reduction. The primary consideration in deciding where to establish a logistics center is the suppliers' location, as material deliveries account for a significant portion of project expenses. (Fabry et al., 2024) considered a case study, focusing on the proposal of the logistics centre location for a new international project of a major automotive company in Czech Republic where PROMETHEE method was used to decide the best suitable location to establish a new logistics center. Six locations were considered in this case, against 3 major criteria, distance, economic and infrastructure and further divided into several conflicting and different sub-criteria shown in Figure 1. Firstly, the weights of the criteria were determined using AHP method. Further information on the considered criteria can be found in the original study cited above. All the important information required to proceed with VIKOR and TOPSIS were collected from the original study and presented in Figure 1 and 2.

Main class	Distance			Economic				Infrastructure	
Local weights	0.54			0.297				0.163	
Criteria	Gravity Centre	Highway	Container Terminal	Price Offer	Unemployment	Labour Force	Wages	Traffic Intensity	Railway Quality
Label	C1	C2	C3	C4	C5	C6	C7	C8	C9
Local weights	0.648	0.122	0.23	0.599	0.104	0.078	0.22	0.8	0.2
Global weights	0.35	0.066	0.124	0.178	0.031	0.023	0.065	0.131	0.033

Figure 1. Results from AHP Method (Fabry et al., 2024)

MIN/MAX	min	min	min	max	max	max	min	min	max
weight	0.35	0.066	0.124	0.178	0.031	0.023	0.065	0.131	0.033
Criteria	Gravity Centre	Highway	Container Terminal	Price Offer	Unemployment	Labour Force	Wages	Traffic Intensity	Railway Quality
Criteria/ Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9
Hradec Králové	13	10	120	4	3.32	277717	36912	3.656	4
Kvasiny	60	40	46	7	3.32	277717	36912	3.656	2
Pardubice	22	25	153	1	3.08	265515	34823	3.176	6
Paskov	265	3	2.5	3	5.2	591399	35599	6.645	8
Nymburk	0.5	20	53	4	3.37	758515	39716	10.082	3
Mladá Boleslav	40	0.5	50	5	3.37	758515	39716	10.082	5

Figure 2. Decision Matrix and Parameters for Multi-Criteria Decision Analysis (Fabry et al., 2024)

3.2 Results of MCDM Methods

The PROMETHEE method results from (Fabry et al., 2024) and the results obtained from TOPSIS and VIKOR will be presented in this section.

3.2.1 PROMETHEE Method Results

Using PROMETHEE II method, the locations were completely ranked according to the net outranking flow value, ϕ , which is a result of the difference between the positive and negative outranking flow as shown in Table 1. The locations were ranked in decreasing order of ϕ value as: Kvasiny (first), Hradec Králové, Mladá Boleslav, Nymburk, Pardubice, and Paskov (last). Kvasiny was ranked the best location for a logistics center.

Table 1. Complete Ranking of Locations by PROMETHEE II (Fabry et al., 2024)

Rank	Location	ϕ	ϕ^+	ϕ^-
1	Kvasiny	0.1327	0.263	0.1303
2	Hradec Králové	0.0906	0.2042	0.1136
3	Mladá Boleslav	0.0194	0.188	0.1686
4	Nymburk	-0.0186	0.1692	0.1879
5	Pardubice	-0.0375	0.1942	0.2317
6	Paskov	-0.1866	0.2127	0.3994

3.2.2 VIKOR Method Results

Compromise ranking of the locations by the compromise solution method is presented in the Table 2. The locations are ranked in an increasing order of the VIKOR index value, Q . The ranking shows the order as PROMETHEE where Kvasiny was ranked the highest and Paskov ranked the least location.

Table 2. Complete Ranking of Locations by VIKOR

Rank	Alternatives	S_j	R_j	Q_j
1	Kvasiny	0.300351	0.078733	0
2	Hradec Králové	0.327002	0.096811	0.085291
3	Mladá Boleslav	0.389997	0.131	0.271154
4	Nymburk	0.41345	0.131	0.316888
5	Pardubice	0.436387	0.178	0.448247
6	Paskov	0.556752	0.35	1

3.2.3 TOPSIS Method Results

The complete ranking of the locations by TOPSIS method is shown in the Table 3. TOPSIS method results showed an inconsistency with the previous methods. Unlike VIKOR and PROMETHEE, TOPSIS was beneficial to Nymburk and ranked Kvasiny fourth, which was ranked the highest by VIKOR and PROMETHEE.

Table 3. Complete Ranking of Locations by TOPSIS

Rank	Location	S_i^*	S_i^-	C^*
1	Nymburk	0.083895	0.345291	0.804525
2	Hradec Králové	0.088249	0.330214	0.789111
3	Mladá Boleslav	0.085826	0.303507	0.779555
4	Kvasiny	0.095982	0.289637	0.751096
5	Pardubice	0.13924	0.313756	0.692624
6	Paskov	0.343168	0.109698	0.242231

4. CONCLUSION AND DISCUSSION OF RESULTS

The results presented in Table 1, 2, and 3 revealed an inconsistency associated with methods used. PROMETHEE and VIKOR ranked the locations in the following order as Kvasiny, Hradec Králové, Mladá Boleslav, Nymburk, Pardubice, and Paskov. TOPSIS on the other hand, ranked the locations in the order: Nymburk, Hradec Králové, Mladá Boleslav, Kvasiny, Pardubice, and Paskov. PROMETHEE and VIKOR ranked Kvasiny as the highest best location for a new logistics centre the automotive company while TOPSIS ranked Nymburk as the highest best location. Aside associating the difference in the rankings to difference in the methods used, the inconsistency displayed by TOPSIS in this case can be interpreted differently. The main principle in TOPSIS is to find an alternative with the shortest distance from the “positive ideal solution” and the longest distance from the “negative ideal solution” and it does not consider the impact of these two “reference” points. Nymburk dominated in terms of the economic criteria (see Figure 1 and 2) which can be reason why TOPSIS ranked it the highest at expense of the relative importance with the other criteria. Like the other comparative analyses MCDM problems from literature, location selection of logistics center problem also revealed inconsistency in the results because of the

difference in the core principles of the methods. This shows that it is important to compare different MCDM methods before settling down on the best option.

This study only considered the logistics center selection problem to compare the results of PROMETHEE, VIKOR and TOPSIS. Therefore, further comparative analysis research can be conducted in the future to cover extensively different problem types in order to make decision makers make more confident and reliable decisions.

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Declaration of Interest

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Data Availability Declaration

The data used in this study are included within this manuscript and are available from the cited sources. Further data can be obtained from the references provided.