A TOPSIS Framework for Supplier Selection Problem

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Abstract - This paper presents a TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) framework designed to address the challenges of the Supplier Selection Problem (SSP). Recognizing the pivotal role of supplier selection in effective supply chain management, the primary objective is to establish a systematic and robust approach for the thorough evaluation and selection of suppliers. The framework incorporates multifaceted criteria such as *quality, price, warranties, services,* and *delivery* to ensure a thorough and well-rounded assessment of potential suppliers. Through the application of the TOPSIS methodology, the framework systematically evaluates each supplier's relative closeness to the ideal solution, resulting in a systematic ranking. The research findings affirm the effectiveness of the TOPSIS framework in the context of supplier selection, underscoring its practical applicability. The systematic evaluation and ranking provided by the framework contribute to informed decision-making in supply chain management, addressing the complexities inherent in the Supplier Selection Problem.

Keywords – decision making, supplier selection, TOPSIS

I. INTRODUCTION

In the dynamic landscape of modern business, effective supplier selection has emerged as a critical factor influencing the overall success and competitiveness of organizations. The ever-growing complexity of supply chains and the globalization of markets have intensified the importance of making informed decisions when it comes to choosing suppliers [1]. The importance of supplier selection cannot be overstated, as it directly impacts various facets of business operations, such as cost efficiency, product quality, and overall supply chain performance. The recent global supplier upheavals, notably the challenges posed by the COVID-19 outbreak. This unprecedented event has tested the limits of global supply chains, shedding light on the pivotal role of robust supplier selection in ensuring organizational adaptability and continuity [2]. In response to these challenges, organizations must prioritize strategic supplier selection practices to enhance their resilience and adaptability. This entails not only considering immediate needs but also anticipating future disruptions and market shifts. To navigate this complexity, a robust analytical approach is essential [3].

Selecting a supplier entails a complex decision-making process influenced by uncertainty and indecision among decision-makers [4]. In tackling this challenge, scholars have actively created and employed various methodologies and approaches for decision-making in adapting to the changing business landscape. Numerous methods have demonstrated effectiveness as solutions for an array of decision-making obstacles, including AHP, SAW, ELECTREE, VIKOR, and TOPSIS. While each method has its own strengths and weaknesses, TOPSIS stands out in several ways. Firstly, TOPSIS takes into account the relative importance of criteria and the performance of alternatives, providing a comprehensive analysis of the decision-making process [5]. Secondly, TOPSIS is known for its simplicity and ease of computation, making it a practical choice for many real-world applications [6]. Additionally, research has shown that the rankings generated by TOPSIS are relatively stable and less affected by the choice of method compared to other MCDM methods [7]. This stability and consistency make TOPSIS a reliable method for decision-making. Furthermore, TOPSIS has been found to perform well in comparative analyses under various conditions, demonstrating its robustness and effectiveness in different scenarios. These advantages make TOPSIS a preferred choice for MCDM in many practical applications. Renowned for its systematic approach, TOPSIS serves as a valuable tool for decision-makers, facilitating a meticulous evaluation and ranking of potential suppliers while considering a diverse set of criteria [8]**.**

The TOPSIS method has attracted considerable interest and broad acknowledgment. TOPSIS method is a widely utilized decision-making approach that provides a systematic and effective means of evaluating and ranking alternative solutions in diverse fields such as management, engineering, and finance. Introduced by Hwang and Yoon in 1981 [9], TOPSIS is grounded in the principles of multi-criteria decision analysis, aiming to assist decision-makers in selecting the most appropriate option from a set of alternatives based on predefined criteria. In its application, TOPSIS framework offers advantages such as simplicity, rationality, a straightforward mathematical structure, and the ability to handle infinite inputs [10]. This holistic approach ensures a thorough analysis, empowering decision-makers to make well-rounded and informed choices. The adaptability of TOPSIS is a noteworthy advantage, making it suitable for diverse decision-making challenges. This flexibility is particularly valuable in complex scenarios, such as supplier selection, where various criteria influence the overall evaluation.

This paper aims to provide practical assistance to companies in the process of selecting the most suitable suppliers. By offering insights into the implementation of the TOPSIS framework in decision support system application, the goal is to equip businesses with a robust decision-making framework for optimizing their supplier selection process. Additionally, the paper seeks to contribute to the academic field by enhancing the scholarly understanding of the practical application of TOPSIS in decision-making contexts. Through this dual focus, the paper strives to bridge the gap between theoretical knowledge and its real-world application, offering tangible benefits to both industry practitioners and researchers in the realm of supplier selection.

II. STUDY SIGNIFIANCE

A. Literature Study

The TOPSIS method, introduced in 1981 by Yoon and Hwang, has become a widely utilized decision-making approach for tackling multi-criteria decision problems. Operating on the principle of approximating the ideal positive solution while distancing from the ideal negative solution, TOPSIS has demonstrated effectiveness across various domains. For instance, to address the complexities of sustainable supplier selection, a combined AHP-TOPSIS approach was employed [11]. This approach takes into account uncertainties and assesses both quantitative and qualitative data. The study introduces ethics as the fourth dimension of sustainability, alongside the Triple Bottom Line, recognizing its pivotal role in supplier selection. When applied to an actual electronics company, the research reveals that economic factors still play a significant role in the choice of sustainable suppliers. The study underscores the prioritization of human rights, safety, pollution control, resource reduction, code of conduct, and transparency in the supplier selection process. The TOPSIS method effectively combines tangible and intangible sustainability criteria, delivering a ranking of suppliers based on their closeness to the positive ideal solution.

The research presents an innovative approach to analyzing interval-valued q-rung orthopair fuzzy soft sets (IVq-ROFSS) using correlation coefficients, a method not commonly applied in this context [12]. The study enhances the multi-attribute decision-making TOPSIS by incorporating expanded measures and mathematical formulations of correlation constraints. The results highlight the proposed methodology as a robust MADM tool for intricate data interpretation and prioritization. The method's practical application is demonstrated through the selection of Cloud Service Providers (CSPs) in managing cloud services. The formulated algorithm outperforms conventional models, guaranteeing meticulous data organization and producing outcomes that are more dependable and consistent. This highlights the importance of the suggested TOPSIS approach and emphasizes the ongoing advancement in decision-making methodologies to attain outcomes in data analysis and decision-making processes that are more reliable and accurate.

Expanding on TOPSIS's versatility, its capabilities were harnessed to evaluate green suppliers [13]. The study highlights the importance of the TOPSIS method in prioritizing "green development" for businesses committed to "carbon compliance" and "carbon neutrality." After identifying 45 potential metrics and refining them with expert input, a dedicated evaluation system for green suppliers was developed, tailored for high-energy-consuming enterprises. Successful case studies demonstrated the practicality and stability of the TOPSIS model, proving its effectiveness in sustainable supplier selection.

In addressing challenges within ultra-dense deployment for the Internet of Things (IoT) and Industry 5.0, the I-MEREC-TOPSIS method was proposed [14]. This approach focuses on achieving optimal network selection during vertical handovers, ensuring reliable, low-latency, and seamless connectivity. By intelligently integrating the I-MEREC weight method with the TOPSIS decision-making technique, the study highlights the efficacy of TOPSIS in enhancing service quality and user experience within ultra-dense heterogeneous networks.

Furthermore, in a study, a novel TOPSIS approach is introduced to predict and explain instances of Information Disorder [15]. This research reveals two noteworthy discoveries: the utilization of opposition structures to elucidate relationships among instances and the creation of an interpretable prediction approach by combining Fuzzy Rough Sets and TOPSIS with these frameworks. These insights could prove invaluable for analysts and decision-makers in comprehending Information Disorder, with promising applications for future research.

In essence, these studies collectively underscore the enduring value of the TOPSIS method in diverse decision-making scenarios. Emphasizing its practicality, stability, and versatility, TOPSIS continues to prove its efficacy across various domains, showcasing its adaptability to address complex challenges.

B. Methodology

1. System Design

Choosing a supplier requires evaluating various aspects to assess their suitability for a company [16]. The aim is to identify the most fitting and reliable suppliers for procuring materials, guaranteeing superior product quality, competitive pricing, punctual deliveries, outstanding services, and warranties. The significance of each criterion varies based on the specific needs and objectives of the company. Table 1 outlines the criteria for the selection process, while Table II delineates the available alternatives.

TABLE I
SUPPLIER CRITERIA

No	Criteria	Code
1.	*Quality*	QL
2.	*Price*	PR
3.	*Warranties*	WR
4.	*Services*	SV
5.	*Delivery*	DL

TABLE II
SUPPLIER ALTERNATIVES

No	Criteria Code	Kriteria
1.	Supplier A	SA
2.	Supplier B	SB
3.	Supplier C	SC
4.	Supplier D	SD
5.	Supplier E	SE

The information was gathered from proficient respondents associated with Company X in Surakarta, Indonesia. The initial expert respondent (P1) scrutinized the criteria for evaluation and assigned weights to each. Simultaneously, the second expert respondent (P2) appraised the alternatives derived from the company's supplier data. Those responding to the questionnaire were required to possess a minimum of 5 years of experience in Supply Chain Management. The outcomes of the criteria weighting are presented in Table III.

TABLE III
CRITERIA WEIGHT

Criteria	Code	Tipe	Weight
Quality	QL	Benefit	0.30
Price	PR	Cost	0.25
Warranties	WR	Benefit	0.20
Services	SV	Benefit	0.15
Delivery	DL	Benefit	0.10

2. Information System Framework (ISF)

The ISF in this study operates through three stages: input, process, and output. Input involves criteria and alternative data, while the process stage applies the TOPSIS approach to assess them. The output offers suggestions for selecting the most suitable supplier.. The detailed ISF is illustrated in Figure 1.

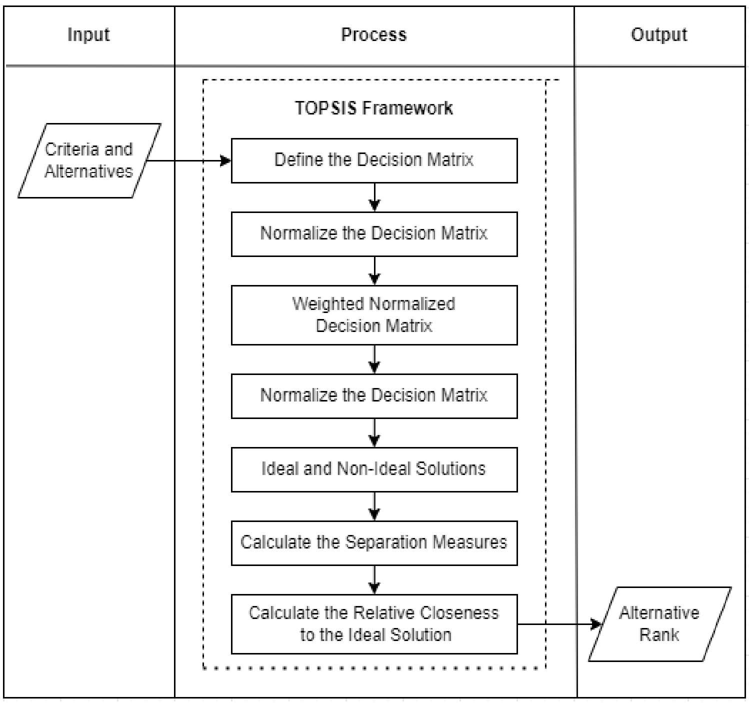

Figure 1. Information System Framework (ISF)

3. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

The TOPSIS framework relies on computing a weighted total of performance ratings for each alternative, taking into account all attributes. Initially, a normalized decision matrix is established to create a standardized scale for assessing all alternatives. This matrix facilitates the assessment of each alternative's proximity to both the ideal positive and negative ideal solution. By analyzing these distances, TOPSIS identifies the most optimal alternative. This method offers a comprehensive evaluation of alternatives by considering various attributes and their respective weights. The TOPSIS method includes the following steps in its process [9]:

Step 1. Define the Decision Matrix

The initial stage in the TOPSIS method is to formulate the decision matrix. This is the initial stage where alternatives (i) are identified as candidates for the final decision. In this step, criteria or attributes (j) are also determined as the basis for decision-making. All these alternatives and criteria are used to form suitability assessment values that constitute the decision matrix (xij). The formula for the decision matrix can be seen in equation 1.

$$\boldsymbol{x_{ij}} = \begin{bmatrix} \boldsymbol{x_{11}} & \boldsymbol{x_{12}} & \cdots & \boldsymbol{x_{1n}} \\ \boldsymbol{x_{21}} & \boldsymbol{x_{22}} & \cdots & \boldsymbol{x_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ \boldsymbol{x_{m1}} & \boldsymbol{x_{m2}} & \cdots & \boldsymbol{x_{mn}} \end{bmatrix} \quad (1)$$

The symbol xij represents the matrix of comparison of alternative j's response to criterion i, where n is the number of criteria and m is the number of alternatives.

Step 2. Normalize the Decision Matrix

This stage aims to normalize the matrix xij to obtain comparable values. The formula used to find the normalized value rij is as follows:

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (2)$$

with i=1,2,3, …m; and j=1,2,3 … n

Step 3. Weighted Normalized Decision Matrix

The positive ideal solution $A^+$and the negative ideal solution A^+ can be identified through the utilization of normalized weight ratings (*Yij*) in the subsequent way:

$$y_{ij} = w_i r_{ij} \quad (3)$$

Step 4. Ideal and Non-Ideal Solutions

The determination of the positive ideal solution (A^+) is computed based on:

$$A^+ = (y1^+, y2^+, y3^+, \dots, yn^+) \quad (4)$$

The determination of the positive ideal solution (A^-) is computed based on:

$$A^- = (y1^-, y2^-, y3^-, \dots, yn^-) \quad (5)$$

Step 5. Calculate the Separation Measures

The gap between alternative A_i and the positive ideal solution is defined as:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}(y_{ij} - y_i^+)^2}\,, i = 1,2,3, \ldots .. m \quad (6)$$

The gap between alternative A_i and the negative ideal solution is defined as:

$$D_i^- = \sqrt{\sum_{j=1}^{n}(y_{ij} - y_i^-)^2}\,, i = 1,2,3, \ldots .. m \quad (7)$$

Step 6. Calculate the Relative Closeness to the Ideal Solution

The proximity of each alternative to the ideal solution is computed using the formula:

$$V = \frac{Di^-}{Di^- + Di^+}, i = 1,2,3, \ldots . m \quad (8)$$

Step 7. Rank the Alternatives

Arrange the alternatives based on their relative closeness to the ideal solution. The alternative with the highest V value is regarded as the optimal selection.

III. RESULTS AND DISCUSSION

This section gives a summary of the results of the supplier selection process utilizing the TOPSIS framework. The process of selecting suppliers involves several stages. A questionnaire is utilized to establish criteria and assess alternatives in supplier selection. The company's expert respondents complete this questionnaire, which is divided into two parts. In the initial section, the weight of each criterion is determined, while the subsequent section assesses alternative weights for each criterion using a five-point Likert scale. The Likert scale values are transformed into numerical values spanning from 1 to 5, with 5 denoting the highest score. The analysis stages of the TOPSIS method are executed through the following steps:

1. Define the Decision Matrix

The initial step involves establishing a decision matrix, incorporating various alternatives and corresponding criteria crucial for supplier selection. This matrix, as outlined by Equation 1, is presented in Table IV. It serves as the foundational basis for subsequent analyses.

TABLE IV
DECISION MATRIX

Kode	QL	PR	WR	SV	DL
SA	4	5	4	4	5
SB	3	4	5	3	4
SC	5	4	3	4	4
SD	4	4	4	3	3
SE	4	5	4	5	4

2. Normalize the Decision Matrix

The decision matrix is normalized using Equation 2, resulting in the values presented in Table V. This normalization process ensures that each criterion is on a consistent scale, facilitating fair comparisons among alternatives.

TABLE V
NORMALIZE DECISION MATRIX

Kode	QL	PR	WR	SV	DL
SA	0,44173	0,50508	0,44173	0,46188	0,55216
SB	0,33129	0,40406	0,55216	0,34641	0,44173
SC	0,55216	0,40406	0,33129	0,46188	0,44173
SD	0,44173	0,40406	0,44173	0,34641	0,33129
SE	0,44173	0,50508	0,44173	0,57735	0,44173

3. Weighted Normalized Decision Matrix

Afterward, the weighted normalized decision matrix is derived by multiplying the normalized decision matrix with the weight vector from Table 3 using Equation 3. The outcomes, presented in Table VI, reflect the relative importance of each criterion as determined by expert respondents.

TABLE VI
WEIGHTED NORMALIZED DECISION MATRIX

Code	QL	PR	SV	WC	DL
SA	0,13252	0,12627	0,08835	0,06928	0,05522
SB	0,09939	0,10102	0,11043	0,05196	0,04417
SC	0,16565	0,10102	0,06626	0,06928	0,04417
SD	0,13252	0,10102	0,08835	0,05196	0,03313
SE	0,13252	0,12627	0,08835	0,08660	0,04417

4. Ideal and Non-Ideal Solutions

Positive and negative ideal solution matrices are determined using equations 4 and 5, as shown in Table VII. These matrices represent the most and least favorable performance levels for each criterion, aiding in the evaluation of alternatives.

TABLE VII
POSITIVE AND NEGATIVE IDEAL SOLUTION

Matrix	QL	PR	SV	WC	DL
A^+	0,16565	0,10102	0,11043	0,08660	0,05522
A^-	0,09939	0,12627	0,06626	0,05196	0,03313

5. Calculate the Separation Measures

Distances of each alternative from the positive and negative ideal solution matrices are calculated using equations 6 and 7. The results, presented in Table VIII, quantify the relative performance of each alternative in comparison to the ideal solutions.

TABLE VIII
DISTANCE POSITIVE AND NEGATIVE IDEAL SOLUTIONS

Code	QL	PR	SV	WC	DL	D_i^+	D_i^-
SA	0,13252	0,12627	0,08835	0,06928	0,05522	0,05023	0,04872
SB	0,09939	0,10102	0,11043	0,05196	0,04417	0,07558	0,05207
SC	0,16565	0,10102	0,06626	0,06928	0,04417	0,04872	0,07382
SD	0,13252	0,10102	0,08835	0,05196	0,03313	0,05721	0,04715
SE	0,13252	0,12627	0,08835	0,08660	0,04417	0,04843	0,05392

6. Calculate the Relative Closeness to the Ideal Solution

The relative closeness values, determined using Equation 8 and presented in Table IX, provide a quantitative measure of how closely each alternative aligns with the ideal solution. This step aids in ranking the alternatives based on their desirability..

TABLE IX
RELATIVE CLOSENESS VALUE

Code	Alternatives	*V*	Rank
SA	Supplier A	0,49234	3
SB	Supplier B	0,40790	5
SC	Supplier C	0,60245	1
SD	Supplier D	0,45179	4
SE	Supplier E	0,52684	2

7. Rank the Alternatives

In the final stage of the TOPSIS framework, alternatives undergo ranking based on their relative closeness values, as depicted in Figure 2. Higher values suggest greater suitability, thereby aiding decision-makers in identifying the most appropriate supplier for selection. This critical stage ensures a comprehensive evaluation of alternatives to facilitate informed decision-making processes.

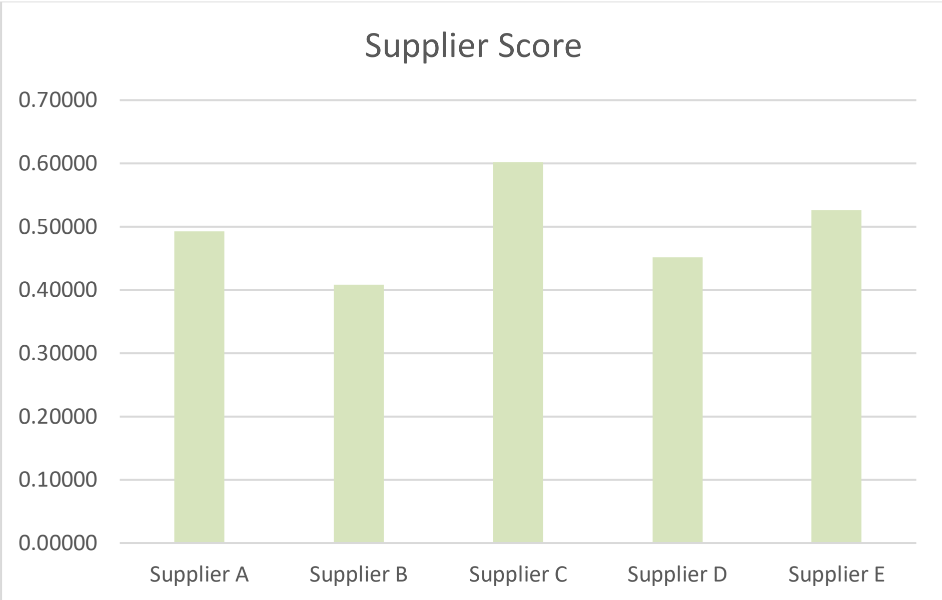

Figure 2. Supplier Rank

IV. CONCLUSION

The supplier selection analysis, employing the TOPSIS framework, has been conducted, integrating criteria derived from literature and tailored by the company's decision-maker to reflect actual circumstances. The decision-maker meticulously assigned weights to each criterion, with quality emerging as the most pivotal, closely followed by price. Subsequently, services, warranties, and delivery criteria were ranked in descending order. The TOPSIS calculations indicate that supplier C excels, securing the highest score (0,60245) and standing out as the optimal choice for the company's supplier selection.

Throughout this research, our exploration delved into the fundamental principles that underpin the TOPSIS framework and its pragmatic application in the context of supplier selection. By scrutinizing TOPSIS as a tool for tackling supplier selection challenges, the investigation has unearthed valuable insights into its suitability and efficacy, particularly in navigating the complexities inherent in multicriteria decision problems within the supplier procurement domain.

The analysis, as detailed in Table X, not only highlights the merits but also carefully delineates the potential drawbacks associated with the utilization of TOPSIS. This nuanced understanding contributes to a more informed perspective, enabling decision-makers to assess the methodology's applicability in diverse supplier selection scenarios and make informed choices based on a holistic view of its advantages and limitations.

TABLE X
ADVANTAGES AND DISADVANTAGES OF THE TOPSIS

Advantages	Disadvantages
• Operates based on a fundamental ranking system;	
• The approach depends entirely on provided information;	• Significant divergence of a single indicator from the ideal solution significantly affects the outcomes;
• Independence of information is not a requirement;	• The approach is suitable when the indicators of alternatives do not exhibit significant variation.
• The method adheres to a logical and easily understandable process, presented in a simple mathematical format;	• Essentially, the method operates using Euclidean distance, and the inclusion of negative and positive values does not impact the calculations.
• The computational procedure is relatively straightforward and results are obtained quickly	

The TOPSIS framework, while robust in its systematic approach, is not immune to certain limitations that warrant careful consideration in interpreting results and applying them across various contexts. The dependence on provided information introduces sensitivity to inaccuracies or biases in the data, potentially impacting the reliability of the rankings. Moreover, the framework's sensitivity to significant deviations in a single criterion may lead to skewed outcomes, especially in volatile environments. The subjectivity in weight assignment poses a challenge, as it can introduce bias based on decision-makers' perspectives, potentially favoring certain criteria over others. The reliance on Euclidean distance calculations assumes equal importance of criteria, which may not align with the reality of varying scales or importance. Lastly, the challenges in accurately assigning weights, particularly in conflicting scenarios, underscore the need for careful consideration and potential adjustments. As such, while TOPSIS offers a systematic decision-making tool, addressing these limitations is imperative to ensure its robustness and enhance its applicability in diverse decision-making contexts.

Fundamentally, the results of the TOPSIS method highlight its practicality, effectiveness, and versatility in addressing intricate, multi-criteria decision-making situations within the organization. The systematic approach employed by TOPSIS ensures a methodical evaluation of alternatives, taking into account the relative importance of criteria and the performance of each supplier. This systematic decision-making process is not only applicable to supplier selection but can also be extrapolated to various decision-making scenarios in different domains. The logical and easily understandable process, presented in a simple mathematical format, promotes clarity and transparency in decision-making processes. Moreover, TOPSIS offers a systematic and clear framework, enabling informed decisions amid the complexities of decision-making. These analytical results serve as a valuable reference for the company in selecting the most suitable supplier based on practical circumstances. However, it is crucial to acknowledge that the efficiency of TOPSIS could be contingent upon the particular context and attributes of the decision problem under consideration. The specific industry, organizational goals, and external factors may influence the optimal application of TOPSIS. Despite being a robust method, it is essential to recognize its constraints. The effectiveness of the method relies significantly on accurately assigning weights to criteria, a task that may be subjective and challenging, particularly in the presence of conflicting objectives. This underscores the importance of thorough consideration and potential adjustment of the weighting process in real-world applications.

Furthermore, recommendations for future research may benefit from exploring specific areas for improvement. Integrating TOPSIS with other multi-criteria decision-making methods, such as BCM, BWM and AHP, could offer a more comprehensive decision-making framework. Future studies might delve into refining methodologies, adapting approaches for different industries, or addressing specific challenges that arise in supplier selection scenarios. These endeavors can contribute to enhancing the robustness and applicability of decision-making frameworks.

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