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A Plithogenic-Neutrosophic Perspective on Marketing Strategy: Unifying Fuzzy MCDM, TOPSIS, and DEMATEL

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ABSTRACT

This paper explores the application of fuzzy Multi-Criteria Decision-Making (MCDM) methods, specifically TOPSIS and DEMATEL, within a neutrosophic framework to address complex decision-making problems in marketing strategies. Traditional MCDM methods often face challenges when dealing with conflicting criteria and uncertain data. To overcome these limitations, fuzzy MCDM methods, leveraging the principles of fuzzy set theory, offer a more flexible and nuanced approach. This study focuses on the evaluation of 15 marketing strategy alternatives across 13 criteria, integrating fuzzy and neutrosophic methods to handle uncertainty and vagueness effectively

TOPSIS is highlighted for its effectiveness in quickly identifying the best alternatives by measuring their proximity to an ideal solution. DEMATEL, on the other hand, is recognized for its strength in modeling causal relationships among criteria, which is crucial in understanding interdependencies in decision-making contexts. By integrating neutrosophic values, which accommodate degrees of truth, falsity, and indeterminacy, both methods are adapted to handle greater levels of uncertainty. The study presents a comparative analysis of these methods, demonstrating their advantages in different scenarios.

The results provide insights into the relative strengths of TOPSIS and DEMATEL, particularly in handling indeterminacy, computational efficiency, and accuracy in ranking alternatives. The findings suggest that while TOPSIS is suitable for straightforward ranking tasks, DEMATEL offers deeper insights into the interplay between criteria. This study concludes by underscoring the potential of neutrosophic MCDM methods in enhancing decision-making across various fields, suggesting avenues for future research to further develop and refine these approaches.

Keywords:

INTRODUCTION

In decision science, Multi-Criteria Decision-Making (MCDM) methods have been developed to assist decision-makers in evaluating and ranking alternatives across multiple criteria[1]. MCDM approaches date back to the mid-20th century, with significant advancements in the late 1960s and 1970s[2]. These methods evolved to address real-world decision problems where various criteria often conflict, and exact data is not always available. Among the various types of MCDM techniques, fuzzy MCDM methods, introduced in the 1970s, have gained prominence for their ability to handle uncertainty and vagueness in decision-making. Fuzzy set theory, introduced by Lotfi Zadeh in 1965[3], [4], plays a crucial role in these methods by allowing for degrees of membership rather than binary true/false evaluations. Several fuzzy MCDM methods have been developed over the decades, including Fuzzy TOPSIS, Fuzzy DEMATEL, and other approaches like Fuzzy AHP (Analytic Hierarchy Process) and Fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje).

Among these, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and DEMATEL (Decision Making Trial and Evaluation Laboratory) have emerged as highly effective methods for handling complex decision problems that involve uncertain, imprecise, and fuzzy data[5]. TOPSIS is particularly useful for ranking alternatives by comparing their relative closeness to an ideal solution, making it a preferred method when the goal is to identify the best alternative quickly and efficiently. DEMATEL, on the other hand, excels in situations where understanding

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the interrelationship between criteria is crucial, as it identifies and analyzes the cause-and-effect relationships among the criteria. Both methods are highly suitable for neutrosophic MCDM frameworks, which extend fuzzy logic to handle even greater uncertainty by incorporating truth, falsity, and indeterminacy values. Given the complexity of decision problems that arise in fields such as marketing strategy, where multiple alternatives and criteria must be evaluated, TOPSIS and DEMATEL stand out as the most suitable methods for providing accurate and insightful rankings and analyses under conditions of uncertainty[6], [7].

This paper focuses on utilizing these two methods within a neutrosophic framework for solving MCDM problems related to marketing strategies, where 15 alternatives are evaluated across 13 criteria[8]. The structure of this paper begins with the preliminaries of the TOPSIS algorithm, where its mathematical foundation and procedural steps for solving MCDM problems using ideal solutions are discussed. The necessary modifications for integrating neutrosophic values into the decision matrix are also outlined. Following this, the preliminaries of the DEMATEL algorithm are explored, with an emphasis on its capability to model the causal relationships between criteria. The next section delves into the formation of the normal decision matrix, where linguistic terms and uncertainty values are used to create neutrosophic decision matrices. These matrices are then normalized and weighted for both TOPSIS and DEMATEL methods.

In the comparative analysis section, a detailed comparison is made between DEMATEL and TOPSIS, examining their respective strengths in handling indeterminacy, computational efficiency, and ranking accuracy. This section includes a derivation of influence relationships in DEMATEL and the ideal distance metrics in TOPSIS[9], [10]. The subsequent section presents the rankings and results of both methods, demonstrating their performance in ranking the 15 alternatives across the 13 criteria. Finally, the paper concludes by discussing the implications of applying neutrosophic MCDM methods to marketing strategy development, highlighting the strengths and limitations of both TOPSIS and DEMATEL in different decision-making contexts. Suggestions for future research include enhancing these methods to address more complex and dynamic decision problems, further expanding the application of neutrosophic MCDM approaches.

Dematel and TOPSIS: Preliminaries, Equations, and Algorithms

DEMATEL (Decision-Making Trial and Evaluation Laboratory)

Preliminaries

DEMATEL is a method used to analyze and model complex causal relationships among factors. It is particularly helpful in identifying the key influencing and influenced factors in a system[11], [12].
Key steps involved in DEMATEL:
1. Constructing the direct-relation matrix.
2. Normalizing the direct-relation matrix.
3. Calculating the total relation matrix.
4. Determining the influence degree and the influenced degree.
5. Mapping the causal diagram.

The DEMATEL method allows for both direct and indirect influences to be captured, providing a better understanding of interrelationships in complex systems.
Equations

1. Direct-Relation Matrix (D):
D = [d_{ij}], where d_{ij} is the degree of influence that factor i has on factor j.

2. Normalized Direct-Relation Matrix (X):
X = D / max(Σd_{ij}), where max(Σd_{ij}) is the largest row sum in D.

3. Total Relation Matrix (T):
T = X (I - X)^{-1}, where I is the identity matrix.

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4. Influencing and Influenced Degrees:
a. The degree to which factor i influences other factors is $r_i = \Sigma T_{ij}$.
b. The degree to which factor i is influenced by other factors is $c_i = \Sigma T_{ji}$.
5. Causal Diagram:
Using $(r_i + c_i)$ and $(r_i - c_i)$, the causal diagram can be constructed.

Algorithm

1. Define the criteria or factors and gather expert opinions to construct the initial direct-relation matrix.
2. Normalize the direct-relation matrix.
3. Calculate the total relation matrix.
4. Determine the influence and influenced degrees (r_i and c_i).
5. Draw the causal diagram using the values of $(r_i + c_i)$ and $(r_i - c_i)$.

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

Preliminaries

TOPSIS is a multi-criteria decision-making method. It is based on the concept that the best solution should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS)[13].
Key steps involved in TOPSIS:
1. Constructing the decision matrix.
2. Normalizing the decision matrix.
3. Constructing the weighted normalized decision matrix.
4. Identifying the positive ideal solution (PIS) and negative ideal solution (NIS).
5. Calculating the separation measures for PIS and NIS.
6. Computing the relative closeness to the ideal solution.
7. Ranking the alternatives.

Equations

1. Normalized Decision Matrix:
$R = [r_{ij}]$, where $r_{ij} = x_{ij} / \sqrt{\Sigma x_{ij}^2}$ for $i=1,2,\ldots,m$ and $j=1,2,\ldots,n$.

2. Weighted Normalized Decision Matrix:
$V = [v_{ij}]$, where $v_{ij} = w_j * r_{ij}$, and w_j is the weight of the j-th criterion.

3. Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS):
PIS: $A^+ = \{v_1^+, v_2^+, \ldots, v_n^+\}$, where $v_j^+ = \max(v_{ij})$ for benefit criteria and $\min(v_{ij})$ for cost criteria.
NIS: $A^- = \{v_1^-, v_2^-, \ldots, v_n^-\}$, where $v_j^- = \min(v_{ij})$ for benefit criteria and $\max(v_{ij})$ for cost criteria.

4. Separation Measures:
$S_i^+ = \sqrt{\Sigma(v_{ij} - v_j^+)^2}$ for PIS.
$S_i^- = \sqrt{\Sigma(v_{ij} - v_j^-)^2}$ for NIS.

5. Relative Closeness to the Ideal Solution:
$C_i^* = S_i^- / (S_i^+ + S_i^-)$, where C_i^* is the closeness coefficient of alternative i.

6. Ranking:

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The alternatives are ranked in descending order of C_i^*.
Algorithm

1. Construct the decision matrix based on the criteria and alternatives.
2. Normalize the decision matrix.
3. Multiply the normalized decision matrix by the weight of each criterion to obtain the weighted normalized decision matrix.
4. Identify the positive ideal solution (PIS) and negative ideal solution (NIS).
5. Calculate the separation measures from PIS and NIS for each alternative.
6. Compute the relative closeness to the ideal solution for each alternative.
7. Rank the alternatives based on their closeness coefficients.

Linguistic Values

Table 1:Qualitative Linguistic Value Matrix for MCDM Analysis Using TOPSIS and DEMATEL Methods Across Multiple Criteria[14]

Unnamed: 0	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13
Alt 1	High	Very High	Medium	Very High	Very High	Low	Medium	Medium	Medium	Very High	High	Medium	Very High
Alt 2	Low	High	Low	High	Very High	Very Low	High	Low	Very High	High	Very Low	Very Low	Medium
Alt 3	Medium	Low	High	High	Medium	High	High	Very Low	Medium	Very High	Medium	Very High	Very Low
Alt 4	Low	High	Very Low	High	Low	Low	Very Low	Low	Very High	Low	High	High	High
Alt 5	High	Very High	Medium	Very Low	High	Low	High	Low	Low	High	Very High	Low	Low
Alt 6	High	Low	Low	High	High	Very Low	Very High	Very High	Low	Very High	Low	Very Low	High
Alt 7	High	High	Very High	Very Low	Very High	Very High	Very Low	Very Low	Very Low	Very Low	High	Medium	Medium
Alt 8	Very Low	Medium	Medium	Very Low	Medium	Very High	Low	Low	Very Low	High	Very Low	High	Low
Alt 9	Very Low	Very High	Medium	High	Medium	Medium	Very Low	Medium	Very High	Medium	Very Low	Very High	Low
Alt 10	Medium	Very Low	Low	Low	High	Very High	Medium	Very Low	High	Very High	High	Very High	Very High
Alt 11	Medium	Very High	High	Very High	Medium	Medium	High	Low	Low	Very High	Very Low	Very High	High
Alt 12	High	High	High	High	Medium	Low	High	Very Low	Very Low	Very Low	Very Low	Medium	Very Low
Alt 13	High	Very High	Very Low	Medium	Medium	Very Low	Very High	Very Low	Medium	Low	High	Medium	Very Low

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Alt 14	High	Very Low	Very Low	Low	High	High	Low	Medium	Very Low	Very High	Very Low	Very Low	Medium
Alt 15	Very Low	Low	Low	High	Very High	Very Low	Very Low	Medium	Low	Very High	High	Low	High

The table 1 represents a linguistic value matrix implemented for multi-criteria decision-making (MCDM) methodologies, specifically the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and DEMATEL (Decision-Making Trial and Evaluation Laboratory) methods. Each alternative (Alt 1 through Alt 15) is evaluated across various criteria (Criteria 1 to Criteria 13) using linguistic descriptors, such as "Very High," "High," "Medium," "Low," and "Very Low." These linguistic terms capture subjective assessments in a structured format, which is essential for MCDM approaches like TOPSIS and DEMATEL that require qualitative values to be converted into quantitative weights or influence levels. TOPSIS utilizes these linguistic values to identify the alternative closest to the ideal solution, considering both the best and worst cases, while DEMATEL uses them to assess the causal relationships between criteria, identifying which factors are most influential in the decision-making process[10]. This table, therefore, serves as a foundational input for converting qualitative judgments into actionable data, aiding in the systematic selection and prioritization of alternatives by combining the strengths of both MCDM methods[15].

Plithogenic Values

Table 2 :Plithogenic Value Matrix for MCDM using TOPSIS and DEMATEL

Unnamed: 0	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13
Alt 1	4	5	3	5	5	2	3	3	3	5	4	3	5
Alt 2	2	4	2	4	5	1	4	2	5	4	1	1	3
Alt 3	3	2	4	4	3	4	4	1	3	5	3	5	1
Alt 4	2	4	1	4	2	2	1	2	5	2	4	4	4
Alt 5	4	5	3	1	4	2	4	2	2	4	5	2	2
Alt 6	4	2	2	4	4	1	5	5	2	5	2	1	4
Alt 7	4	4	5	1	5	5	1	1	1	1	4	3	3
Alt 8	1	3	3	1	3	5	2	2	1	4	1	4	2
Alt 9	1	5	3	4	3	3	1	3	5	3	1	5	2
Alt 10	3	1	2	2	4	5	3	1	4	5	4	5	5
Alt 11	3	5	4	5	3	3	4	2	2	5	1	5	4
Alt 12	4	4	4	4	3	2	4	1	1	1	1	3	1
Alt 13	4	5	1	3	3	1	5	1	3	2	4	3	1
Alt 14	4	1	1	2	4	4	2	3	1	5	1	1	3
Alt 15	1	2	2	4	5	1	1	3	2	5	4	2	4

This table 2 displays a quantitative plitogenic value matrix applied in a multi-criteria decision-making (MCDM) context, specifically utilizing the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and

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DEMATEL (Decision-Making Trial and Evaluation Laboratory) methodologies. Each alternative (Alt 1 through Alt 15) is assessed across various criteria (Criteria 1 to Criteria 13) using plitogenic values, which provide a structured numerical rating for each criterion. These ratings range from 1 to 5, capturing various performance levels from low to high. Plitogenic values offer a robust way to incorporate uncertainty and complexity into the decision-making process, enhancing the assessment precision needed for MCDM techniques[16].

In the TOPSIS method, these numerical values serve as inputs to determine each alternative's proximity to an ideal solution by calculating both positive and negative ideal distances. DEMATEL uses these values to identify the causal relationships between criteria, allowing decision-makers to determine which criteria are most influential or dependent in the decision process. This quantitative matrix thus provides a clear, structured foundation for combining the strengths of both TOPSIS and DEMATEL methods, enabling systematic prioritization and selection among alternatives.

Defuzzified Values

Table 3 :Defuzzified Value Matrix for Lithogenic Neutrosophic MCDM using TOPSIS and DEMATEL

Unnamed: 0	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13
Alt 1	4	5	3	5	5	2	3	3	3	5	4	3	5
Alt 2	2	4	2	4	5	1	4	2	5	4	1	1	3
Alt 3	3	2	4	4	3	4	4	1	3	5	3	5	1
Alt 4	2	4	1	4	2	2	1	2	5	2	4	4	4
Alt 5	4	5	3	1	4	2	4	2	2	4	5	2	2
Alt 6	4	2	2	4	4	1	5	5	2	5	2	1	4
Alt 7	4	4	5	1	5	5	1	1	1	1	4	3	3
Alt 8	1	3	3	1	3	5	2	2	1	4	1	4	2
Alt 9	1	5	3	4	3	3	1	3	5	3	1	5	2
Alt 10	3	1	2	2	4	5	3	1	4	5	4	5	5
Alt 11	3	5	4	5	3	3	4	2	2	5	1	5	4
Alt 12	4	4	4	4	3	2	4	1	1	1	1	3	1
Alt 13	4	5	1	3	3	1	5	1	3	2	4	3	1
Alt 14	4	1	1	2	4	4	2	3	1	5	1	1	3
Alt 15	1	2	2	4	5	1	1	3	2	5	4	2	4

The table 3 presents a defuzzified value matrix tailored for a plithogenic neutrosophic multi-criteria decision-making (MCDM) analysis, employing the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and DEMATEL (Decision-Making Trial and Evaluation Laboratory) methods. Each alternative (Alt 1 through Alt 15) is evaluated across various criteria (Criteria 1 to Criteria 13) using defuzzified numerical scores ranging from 1 to 5, which represent consolidated evaluations derived from initial linguistic or fuzzy values. This transformation into defuzzified values is essential for processing uncertain or imprecise data inherent in MCDM.

In this context, the defuzzified values provide crisp input data that allow TOPSIS to determine each alternative's proximity to an ideal solution, capturing both optimal and least-preferred positions. DEMATEL, meanwhile,

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leverages these values to establish causal relationships among criteria, revealing influential and dependent factors in the decision framework. Together, the table's defuzzified values offer a clear foundation for systematic decision analysis, combining the strengths of both MCDM methods to prioritize and select the most suitable alternatives[17].

Decision Matrix

Table 4: Defuzzified Decision Matrix for Lithogenic Neutrosophic MCDM using TOPSIS and DEMATEL

Unnamed: 0	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13
Alt 1	0.08085332633271525	0.36965445606140045	0.2421599382774259	0.8031397563798959	0.4703006344460384	0.983423140894843	0.3988244424445531	0.8164318732193839	0.7983451249845511	0.1507175439654295	0.5081987767407187	0.6958128067908819	0.8583588048137198
Alt 2	0.3259589052018848	0.2202410475655483	0.7111495324380178	0.8095010461397154	0.3486659872917294	0.09617655109142076	0.940523264489604	0.3975720210875223	0.5177513505274801	0.837710105907328	0.6756901170392807	0.7352161192407721	0.2090716207377137
Alt 3	0.5414479738275658	0.6957843993450822	0.2285500217972997	0.1749549270959362	0.9821683433294356	0.5166358912710143	0.260829174830409	0.9962536997579243	0.9654193512887936	0.5582934536070976	0.8826363431893397	0.1887071083413794	0.2788713525921819
Alt 4	0.7003578299727713	0.8466611422383059	0.8563242918780924	0.4045081271221901	0.8877700987609598	0.8509284487675127	0.9356349942209475	0.7853406511139436	0.6689882547142286	0.5806866214364547	0.3722827665617431	0.9401334424577784	0.9736638367553173
Alt 5	0.2839209747374657	0.3053638603443934	0.4856137535862266	0.4484241429862473	0.9944574626108207	0.1759252526773454	0.01807536361552087	0.4938937151834346	0.1788227092213288	0.3664687845828599	0.7441705230565623	0.7209399242521293	0.3080607918523892
Alt 6	0.5425402305548993	0.50881407683876	0.6363326181858954	0.2504618186055841	0.5898708475605439	0.978892858275009	0.4867421529594551	0.906098787718554	0.4343943655104286	0.3500784076946757	0.6451033620305648	0.6689240596630996	0.8641675650719031
Alt 7	0.2301852682415553	0.4991933798847523	0.5720041992091831	0.768554014306309	0.04360377175443375	0.994550510797341	0.4699445139909429	0.2795603417967586	0.883494022266259	0.7477187738974139	0.9530718470239532	0.3307503046705137	0.5527649668354899
Alt 8	0.5722924	0.98033158	0.07534625600	0.3056970	0.19091103	0.26847485689	0.4852798	0.37268686709	0.39469146680	0.84421314	0.93001683481	0.07041613084	0.20891871761

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	691708383	37160457	612821	192871818	1150346	01568	742763157	40493	94722	07263114	08319	95439	53602
Alt 9	0.6711435168240506	0.35864678129616639	0.2541636490697388	0.2952905884189387	0.3225507642386005	0.8486697949246744	0.1366213314420288	0.7089109969101186	0.5528199769079077	0.2965101436477985	0.4197808564462765	0.2562069435944581	0.6115137108656805
Alt 10	0.08159418040024036	0.005184862773986776	0.6278944149486361	0.1942739535120422	0.07094091699992766	0.3967838272138884	0.05076853103939694	0.8866171489506599	0.0276167718737047	0.5788648955075587	0.438474123018087	0.6720261352951994	0.3281526674747319
Alt 11	0.1550416167277442	0.9818408883105311	0.8389335020693633	0.8604046183116753	0.2502513605158641	0.0388347344294232	0.3032655146732228	0.5370824271966554	0.3266512417960409	0.8278690037875887	0.2715429158197419	0.9652518303907698	0.4572651616137285
Alt 12	0.8420230750119814	0.194380033994873	0.4113539050566786	0.6995122107671938	0.1383530924178014	0.1327454222429698	0.969536867114159	0.7145951041799521	0.04106751676787579	0.3988209014447945	0.4335207375807421	0.7440426429991154	0.2508605273466612
Alt 13	0.18433367433137	0.08087296661719767	0.4283144749401078	0.6884999007653664	0.05819359550844361	0.9152137276264805	0.4423522297311044	0.2397873591574032	0.09387329008129175	0.1828659971073073	0.9346139973397097	0.6382705938433504	0.5166962574265667
Alt 14	0.6571113285001668	0.4356728986778911	0.7300393165618185	0.04771612769164879	0.5660372104940763	0.158646447642491	0.1201646478056422	0.3418796667164016	0.09179906581344188	0.09415698826856012	0.3114133093912942	0.9795105286215086	0.1753302698893385
Alt 15	0.01716110183175024	0.7633644230039109	0.8069129770507795	0.3463043210894008	0.4646738129396114	0.6497736826427634	0.04805892419703373	0.9491457315913859	0.8866803872980475	0.260893623341714	0.01530454029038475	0.933436308079483	0.5010398839152592

This table 5 provides a defuzzified decision matrix specifically structured for plithogenic-based neutrosophic multi-criteria decision-making (MCDM) methods, employing the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and DEMATEL (Decision-Making Trial and Evaluation Laboratory) methodologies. Each alternative (Alt 1 to Alt 15) is evaluated across multiple criteria (Criteria 1 through Criteria 13) using defuzzified numerical values derived from initial neutrosophic and lithogenic linguistic inputs. Neutrosophic sets, which capture degrees of truth, indeterminacy, and falsity, are converted to precise, crisp values that enable quantitative comparison[18].

In this matrix, the defuzzified values provide structured input data for MCDM processes. TOPSIS uses these values to calculate the relative proximity of each alternative to an ideal solution by considering both the positive and negative ideal distances, thus allowing for the identification of the best option. DEMATEL, on the other hand, leverages these values to analyze the causal relationships between criteria, identifying influential and dependent factors within the decision-making framework. This matrix format, by capturing the advantages of both TOPSIS and DEMATEL,

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facilitates systematic prioritization of alternatives while accommodating the inherent uncertainties and complex interdependencies in real-world decision scenarios[19], [20].

TOPSIS Solution

Table 6 : Decision Matrix with Closeness Scores and Rankings for plithogenic Neutrosophic MCDM using TOPSIS

Unnamed: 0	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13	Closeness	Ranking
Alt 1	1.414213562	0.3535533906	0.9803315837	0.2202410476	0.470300634460384	0.983423140894843	0.398824442444531	0.8164318732193839	0.7983451249845511	0.1507175439654295	0.5081987767407187	0.6958128067908819	0.8583588048137198	0.5393774484000625	11
Alt 2	0.5	0.2202410475655483	0.7111495324380178	0.8095010461397154	0.3486659872917294	0.09617655109142076	0.940523264489604	0.3975720210875223	0.5177513505274801	0.837710105907328	0.6756901170392807	0.7352161192407721	0.2090716207377137	0.6839637693981411	1
Alt 3	0.5	0.6957843993450822	0.2285500217972997	0.1749549270959362	0.9821683433294356	0.5166358912710143	0.260829174830409	0.9962536997579243	0.9654193512887936	0.5582934536070976	0.8826363431893397	0.1887071083413794	0.2788713525921819	0.6158511643899138	10
Alt 4	0.5	0.8466611422383059	0.8563242918780924	0.4045081271221901	0.8877700987609598	0.8509284487675127	0.9356349942209475	0.7853406511139436	0.6689882547142286	0.5806866214364547	0.3722827665617431	0.9401334424577784	0.9736638367553173	0.9438916045607572	3
Alt 5	0.5	0.3053638603443934	0.4856137535862266	0.4484241429862473	0.9944574626108207	0.1759252526773454	0.01807536361552087	0.4938937151834346	0.1788227092213288	0.3664687845828599	0.7441705230565623	0.7209399242521293	0.3080607918523892	0.9442515971251674	14
Alt 6	0.5	0.50881407683876	0.6363326181858954	0.2504618186055841	0.5898708475605439	0.978892858275009	0.4867421529594551	0.906098787718554	0.4343943655104286	0.3500784076946757	0.6451033620305648	0.6689240596630996	0.8641675650719031	0.8671989335550038	7

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Alt 7	0.5	0.4991933798847523	0.5720041992091831	0.768554014306309	0.04360377175443375	0.994550510797341	0.4699445139909429	0.2795603417967586	0.883494022266259	0.7477187738974139	0.9530718470239532	0.3307503046705137	0.5527649668354899	0.6364035974460113	9
Alt 8	0.5	0.9803315837160457	0.07534625600612821	0.3056970192871818	0.190911031150346	0.2684748568901568	0.4852798742763157	0.3726868670940493	0.3946914668094722	0.8442131407263114	0.9300168348108319	0.0704161308495439	0.2089187176153602	0.8009492946823997	2
Alt 9	0.5	0.3586467812961639	0.2541636490697388	0.2952905884189387	0.3225507642386005	0.8486697949246744	0.1366213314420288	0.7089109969101186	0.5528199769079077	0.2965101436477985	0.4197808564462765	0.2562069435944581	0.6115137108656805	0.6771683423829817	8
Alt 10	0.5	0.005184862773986776	0.6278944149486361	0.1942739535120422	0.07094091699992766	0.3967838272138884	0.05076853103939694	0.8866171489506599	0.0276167718737047	0.5788648955075587	0.438474123018087	0.6720261352951994	0.3281526674747319	0.5733670416719333	12
Alt 11	0.5	0.9818408883105311	0.8389335020693633	0.8604046183116753	0.2502513605158641	0.0388347344294232	0.3032655146732228	0.5370824271966554	0.3266512417960409	0.8278690037875887	0.2715429158197419	0.9652518303907698	0.4572651616137285	0.1285003532339102	15
Alt 12	0.5	0.194380033994873	0.4113539050566786	0.6995122107671938	0.1383530924178014	0.1327454222429698	0.969536867114159	0.7145951041799521	0.04106751676787579	0.3988209014447945	0.4335207375807421	0.7440426429991154	0.2508605273466612	0.811204176736003	13
Alt 13	0.5	0.08087296661719767	0.4283144749401078	0.6884999007653664	0.05819359550844361	0.9152137276264805	0.4423522297311044	0.2397873591574032	0.09387329008129175	0.1828659971073073	0.9346139973397097	0.6382705938433504	0.5166962574265667	0.8206394757439553	6
Alt 14	0.6571113285001668	0.4356728986778911	0.7300393165618185	0.04771612769164879	0.5660372104940763	0.158646447642491	0.1201646478056422	0.3418796667164016	0.09179906581344188	0.09415698826856012	0.3114133093912942	0.9795105286215086	0.1753302698893385	0.6259396701015728	4

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Alt 15	0.01716110183175024	0.763364423003910 9	0.806912977050779 5	0.3463043210894008	0.464673812939611 4	0.649773682642763 4	0.0480589241970337 3	0.949145731591385 9	0.886680387298047 5	0.260893623341714	0.01530454029038475	0.933436308079483	0.501039883915259 2	0.820426843771268 1	5

This table 6 presents a decision matrix for multi-criteria decision-making (MCDM) using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, where each alternative (Alt 1 through Alt 15) is evaluated across multiple criteria (Criteria 1 through Criteria 13) with normalized and defuzzified scores. In TOPSIS, the goal is to identify the best alternative by comparing each one's proximity to an ideal solution (the best possible values across all criteria) and an anti-ideal solution (the worst possible values). The values under each criterion are first normalized, making them dimensionless and comparable across different criteria. Using these normalized values, the distance of each alternative from the ideal and anti-ideal solutions is calculated, and a "closeness score" is then determined for each alternative. This score, which ranges from 0 to 1, reflects the relative proximity of each alternative to the ideal solution, with values closer to 1 indicating a stronger alignment with optimal performance. Based on these closeness scores, each alternative is ranked, with the highest-ranked option being the most favorable according to the criteria. This method provides a systematic, quantitative approach for decision-makers to rank and select the best alternative among multiple choices.

DEMATEL Analysis

Table 7: Criteria Prominence and Relation Matrix for DEMATEL Analysis in MCDM[21]

Criteria	Prominence	Relation
Criteria 1	0.2385968597903402	0.3549051904627206
Criteria 2	0.6798447799002458	0.9568008851264563
Criteria 3	0.7399087604473745	0.6767699044243033
Criteria 4	0.2382361524039794	0.4825209496426425
Criteria 5	0.3777288861762949	0.493025657771805
Criteria 6	0.5343274735305634	0.08328441119525964
Criteria 7	0.4965611906830777	0.09170414725848108
Criteria 8	0.3896180862192035	0.602440925901119
Criteria 9	0.2976351745093109	0.5537030523458008
Criteria 10	0.09998488716186338	0.212727895024229
Criteria 11	0.0534852967473689	0.9461945428816902
Criteria 12	0.9585414968831983	0.7812960504712025
Criteria 13	0.8471431440955898	0.113464602017448

This table 7 represents the criteria prominence and relation values calculated through the DEMATEL (Decision-Making Trial and Evaluation Laboratory) method, which is commonly applied in multi-criteria decision-making (MCDM) analyses to understand interdependencies among criteria. Each criterion (Criteria 1 to Criteria 13) is evaluated with two primary indicators: **Prominence** and **Relation**. The **Prominence** value measures the overall importance or influence of each criterion within the system, while the **Relation** value indicates whether the criterion tends to have more of a cause (positive influence) or effect (being influenced by other criteria) role within the decision-making framework[22].

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Higher prominence values suggest that a criterion holds substantial weight in the decision process, either as an influencer or as one impacted by other criteria. The **Relation** values, meanwhile, distinguish the causality within the system: criteria with high relation scores typically act as influential factors, affecting other criteria, while those with lower relation values are primarily affected by other factors. Together, these values allow decision-makers to map out the network of causal relationships among criteria, identifying which criteria are critical drivers in the decision context and which are more dependent. By visualizing these relationships, DEMATEL aids in prioritizing the most influential criteria, enhancing the precision of decision-making in complex, interdependent scenarios[23], [24].

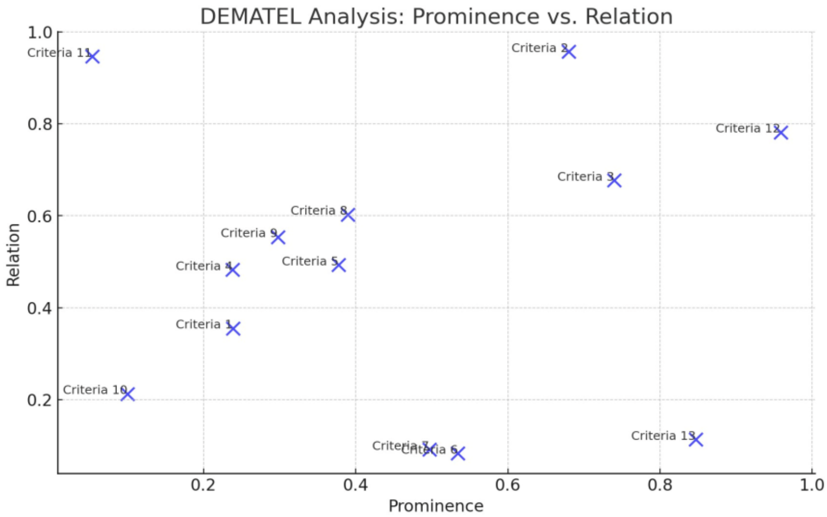

Figure 1 : prominence vs relations

Explanation of DEMATEL Analysis Graph

The graph above represents the results of a DEMATEL analysis, showing the 'Prominence' and 'Relation' values for various criteria[25]. In this context:

- **Prominence**: Indicates the overall importance or influence of a criterion. Higher prominence values suggest that the criterion plays a significant role in the overall evaluation.
- **Relation**: Reflects how strongly a criterion is interrelated with others. Higher relation values mean the criterion has more substantial connections or dependencies with other criteria.

Key Observations:

1. **Criteria with High Prominence and Relation**: Criteria such as 'Criteria 2' and 'Criteria 12' have high values for both prominence and relation, suggesting they are not only important but also have significant interdependencies with other criteria.
2. **Criteria with High Prominence but Low Relation**: Some criteria, like 'Criteria 13', have high prominence but lower relation values, indicating they are influential but less dependent on other criteria.
3. **Criteria with Low Prominence and Relation**: Criteria such as 'Criteria 11' and 'Criteria 10' have lower values for both metrics, suggesting they play a less critical role in the overall system.

This type of analysis helps decision-makers understand not just the importance of each criterion but also how they interact with each other. The graph allows for quick identification of key criteria that need to be managed carefully due to their high impact and strong interrelations.

CONCLUSION

In conclusion, this study demonstrates the effectiveness of integrating fuzzy MCDM methods, specifically TOPSIS and DEMATEL, within a neutrosophic framework to enhance decision-making in complex marketing strategy evaluations. By accommodating uncertainty, vagueness, and indeterminacy, these methods offer a more comprehensive approach to handling conflicting criteria and uncertain data. The comparative analysis highlights that

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TOPSIS excels in efficiently ranking alternatives, making it suitable for straightforward decision-making scenarios, while DEMATEL provides deeper insights by revealing causal relationships among criteria, which is valuable for understanding complex interdependencies. The findings underscore the potential of neutrosophic MCDM approaches in improving decision-making processes across various domains. Future research can explore the integration of these methods with other advanced decision-making techniques to further refine their application and expand their usefulness in different contexts.

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