UDC 3306001.32
DOI 10.52171/herald.248

Comparative Analysis of Traditional and Fuzzy TOPSIS Methods in Satellite Telecommunication Market Entry Decisions

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Abstract

This study compares traditional and fuzzy TOPSIS methods for decision-making in the satellite telecommunication market. Developed by Hwang and Yoon in 1981, TOPSIS selects the alternative closest to the ideal solution and farthest from the negative-ideal solution. The traditional method uses six criteria relevant to the satellite service market. Fuzzy TOPSIS extends this by incorporating fuzzy logic to handle uncertainty, using triangular fuzzy numbers for performance measures. The study outlines both methods' steps and their application in ranking alternatives. Results show that fuzzy TOPSIS provides a more nuanced analysis by accounting for uncertainties, enhancing decision-making quality.

Keywords: decision-making, TOPSIS, fuzzy logic, satellite telecommunication, market entry.

Submitted *30 Jul 2024*
Published *17 Mar 2025*

For citation:
A.V. Nazarov
[Comparative Analysis of Traditional and Fuzzy TOPSIS Methods in Satellite Telecommunication Market Entry Decisions]
Herald of the Azerbaijan Engineering Academy, 2025, vol. 17 (1), pp. 88-98

Peyk Telekommunikasiya bazarının seçilməsində səlis və qeyri-səlis TOPSIS üsullarının müqayisəsi

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Xülasə

Bu tədqiqat, peyk telekommunikasiya bazarına giriş qərarlarında ənənəvi və qeyri-səlis TOPSIS (İdeal Həllə Oxşarlığa görə Sıralama Texnikası) metodlarının müqayisəli təhlilini təqdim edir. 1981-ci ildə Hwang və Yoon tərəfindən hazırlanmış TOPSIS, ideal həllə coğrafi olaraq ən yaxın və mənfi-ideal həllə ən uzaq olan alternativin seçilməsini nəzərdə tutur. Ənənəvi TOPSIS metodu, peyk xidmət bazarı ilə əlaqəli altı meyarın istifadəsi ilə izah edilir. Qeyri-səlis TOPSIS metodu, performans ölçmələrini təmsil etmək üçün üçbucaq qeyri-səlis ədədlərdən istifadə edərək, qeyri-müəyyənlik və qeyri-müəyyənliyi idarə etmək üçün qeyri-səlis məntiqi daxil etməklə ənənəvi yanaşmanı genişləndirir. Tədqiqat hər iki metodun prosedur addımlarını təsvir edir və qərar matrisində alternativlərin sıralanmasında onların tətbiqini nümayiş etdirir. Nəticələr göstərir ki, qeyri-səlis TOPSIS performans ölçmələrindəki qeyri-müəyyənlikləri nəzərə alaraq daha incə təhlil aparır və qərar qəbul etmə keyfiyyətini artırır.

Açar sözlər: qərar qəbuletmə, TOPSIS, qeyri-səlis məntiq, peyk telekommunikasiyası, bazar girişi.

Сравнительный анализ традиционных и нечетких методов TOPSIS в принятии решений о выходе на рынок спутниковых телекоммуникаций

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Аннотация

Это исследование анализирует традиционные и нечеткие методы TOPSIS для принятия решений о выходе на рынок спутниковых телекоммуникаций. Разработанный Хвангом и Юном в 1981 году, TOPSIS выбирает альтернативу, наиболее близкую к идеальному решению и наиболее далекую от негативного. Традиционный TOPSIS иллюстрируется с использованием шести критериев, релевантных для спутниковых услуг. Нечеткий TOPSIS расширяет этот подход, используя нечеткую логику и треугольные нечеткие числа для учета неопределенности. Исследование описывает шаги обоих методов и их применение для ранжирования альтернатив. Результаты показывают, что нечеткий TOPSIS обеспечивает более точный анализ, улучшая качество принятия решений.

Ключевые слова: принятие решений, TOPSIS, нечеткая логика, спутниковая телекоммуникация, управление организацией.

Introduction

In recent years, the satellite telecommunication market has seen significant growth and technological advancements. Companies aiming to enter this competitive market face complex decision-making processes that involve multiple criteria. The need for robust decision-making tools has led to the adoption of various multi-criteria decision-making (MCDM) methods. Among these, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has gained popularity due to its straightforward approach and effectiveness. This paper explores both the traditional and fuzzy TOPSIS methods, highlighting their applicability and advantages in the context of market entry decisions in the satellite telecommunication industry.

Statement of the Problem

Market entry decisions in the satellite telecommunication industry are complex and uncertain due to multiple, often conflicting criteria. Traditional decision-making approaches may not adequately address these ambiguities and uncertainties. The challenge is to select a method that ranks alternatives effectively while accounting for the inherent uncertainty and imprecision.

Purpose of the Work

The primary objective of this study is to conduct a comparative analysis of the traditional TOPSIS method and its fuzzy counterpart. By applying these methods to a case study in the satellite telecommunication market, the study aims to demonstrate the practical applications and benefits of using fuzzy logic to handle uncertainty and ambiguity in decision-making processes. The comparison seeks to provide insights into how these methods can enhance the quality and reliability of market entry decisions.

Traditional TOPSIS Methodology and Application

The TOPSIS method, developed by Hwang and Yoon in 1981, provides an alternative to the ELECTRE method by identifying the best choice as the one closest to the optimal solution and farthest from the least desirable solution [1]. It operates on the principle that each attribute's utility either increases or decreases, using the Euclidean distance method to rank alternatives based on their proximity to the ideal point [2].

For example, in the Satellite Service Market, six criteria and corresponding alternatives are evaluated. By assigning weights to these criteria, TOPSIS effectively identifies the alternatives that best align with the desired outcomes, aiding in strategic decision-making (table 1).

Table 1 – Criteria and their weights for traditional TOPSIS method

w1	w2	w3	w4	w5	sum
0,3	0,4	0,025	0,2	0,075	1

The associated values are presumed to be as table 2. The TOPSIS method evaluates the following decision matrix which refers to *M* alternatives (*M=6*) which are evaluated in terms of *N* criteria (*N=5*).

Where *X(ij)* represents the performance measurement of the i-th alternative concerning the j-th criterion. To provide a comprehensive understanding of this approach, the TOPSIS method is outlined in the subsequent sections as a sequence of procedural steps. In the context of our illustration.

Table 2 – Decision matrix for traditional TOPSIS method

Country	Elevation Angle	Market Size	Infrastructure	Currency Stability	Beam Availability
Nigeria	9.28	105	1	27.18	4
Mali	6.64	90	0	45	3.82
Malawi	13.8	40	0	26.1	3.82
Kenya	16	125	1	39.96	3.72
South Sudan	14.04	25	0	42.48	3.72
Ghana	7.28	75	1	9	3.72

Table 3 – Normalized decision matrix for traditional TOPSIS method

		0.3	0.4	0.025	0.2	0.075
		0.3227424911	0.508726662	0.57735026	0.326563019	0.42958631
		0.2309278169	0.4360514248	0	0.540667250	0.41025493
FIRST	r_ij=	0.4799403423	0.193800633	0	0.313587005	0.41025493
		0.5564525708	0.605626978	0.57735026	0.480112518	0.39951527
		0.4882871309	0.121125395	0	0.510389884	0.39951527
		0.2531859197	0.363376187	0.57735026	0.108133450	0.39951527

Step 1. Construct the Normalized Decision Matrix

An element r_{ij}- of the normalized decision matrix R can be calculated as follows (table 3):

$$\frac{x_{ij}}{\sqrt{\sum_{i=1}^{M} x_{ij}^2}} \quad [3]$$

For example r_{11} is calculated as:

$$9.28/\sqrt{9.28^2+6.64^2+13.8^2+16^2+14.04^2+7.28^2} = 0.3227424911$$

Step 2. Construct the Weighted Normalized Decision Matrix

A set of weights $W = (w_1, w_2, w_3, ..., w_N)$, (where: $\sum w_i = 1$) defined by the decision maker is accommodated to the decision matrix to generate the weighted normalized matrix V as table 4.

For example, $w_1 \cdot r_{11}$ is calculated as:

$$v_{11} = v_1 r_{11} = 0.3\cdot(0.3227424911) = 0.09682274732$$

Table 4 – Weighted normalized decision matrix for traditional TOPSIS method

		0.09682274732	0.203490664	0.01443375	0.065312603	0.03221897
		0.06927834506	0.174420569	0	0.108133450	0.03076912
SECOND	V=	0.1439821027	0.077520253	0	0.062717401	0.03076912
		0.1669357712	0.242250791	0.01443375	0.096022503	0.02996364
		0.1464861393	0.048450158	0	0.102077977	0.02996364
		0.07595577591	0.145350474	0.01443375	0.021626690	0.02996364

Step 3. Determine the Ideal and the Negative-ideal Solutions

The ideal A and the negative-ideal A⁻ solutions are defined as follows:

$$A^* = \left\{ \left(\max_i v_{ij} \middle| j \in J \right), \left(\min_i v_{ij} \middle| j \in J \right) \middle| i = 1,2,3,\dots,M \right\} = \{v_{1^*}, v_{2^*}, \dots, v_{N^*}\}$$

and the negative-ideal A⁻ solutions are defined as follows:

$$A^- = \left\{ \left(\min_i v_{ij} \middle| j \in J \right), \left(\max_i v_{ij} \middle| j \in J \right) \middle| i = 1,2,3,\dots,M \right\} = \{v_{1^-}, v_{2^-}, \dots, v_{N^-}\}$$

where: $J^* = \{j = 1,2,3,\dots,N | j$ – associated with beam availability criteria;

$J^- = \{j = 1,2,3,\dots,N | j$ – associated elevation angle with criteria.

For the beam availability criteria, the decision maker wants to have a maximum value among the alternatives. For the elevation angle criteria, the decision maker wants to have a minimum value among alternatives. Obviously, A indicates the most preferable alternative or ideal solution. Similarly, A⁻ indicates the least preferable alternative or negative-ideal solution. In column 1 of V maximum value is 0.1669357712, in column 2 maximum value is 0.2422507916 etc. (table 5).

$v_1 = max(vv_{j1}) = max$ (0.09682274732; 0.06927834506;0.1439821027;0.1669357712;0.1464861393;0.07595577591)= =0.1669357712

$v_1 = min(vv_{j1}) = min$ (0.09682274732;0.06927834506;0.1439821027;0.1669357712;0.1464861393;0.07595577591)= =0.06927834506

Table 5 – Positive ideal solution (PIS) and negative ideal solution (NIS) for traditional TOPSIS method.

A =	0.1669357712	0.24225079	0.01443375	0.10813345	0.03221897
A⁻ =	0.0692783450	0.04845015	0	0.02162669	0.02996364

Table 6 – Separation measures for traditional TOPSIS method

					Si=
0.004915836123	0.001502347	0	0.001833624	0	0.09083946508
0.009536972887	0.004600938	0.00020833	0	0.0000021020761	0.1197845869
0.0005268708997	0.027136150	0.00020833	0.002062617	0.0000021020761	0.173020444
0	0	0	0.000146675	0.0000050865051	0.01231915291
0.000418187448	0.037558685	0.00020833	0.000036668	0.0000050865051	0.1955171642
0.008277359549	0.009389671	0	0.007483419	0.0000050865051	0.1586049714

Step 4. Calculate the Separation Measure

Next, we utilize the N-dimensional Euclidean distance method to quantify the separation distances of each alternative from both the positive ideal solution and negative-ideal solution. Now, the task at hand involves computing.

$$S_{i*} = \left(\sum \left(v_{ij} - v_{j*} \right)^2 \right)^{1/2}, i = 1,2,3,\dots,M$$

$(v_{ij} - v_j)$2=(0.09682274732-0.06927834506)2=0.004915836123

$S_j =$ (0.090839465080; 11978458690; 1730204440; 012319152910; 19551716420; 158604971)

$S_j =$ (0.004915836123 + 0.001502347418 + 0 + 0.001833624875 + 0)^{0,5} =0.1955171642

where S_i – is the separation (in the Euclidean sense) of each alternative from the ideal solution.

$$S_{i-} = \left(\sum \left(v_{ij} - v_{j-}\right)^2\right)^{1/2}, i = 1,2,3, \dots, M$$

where S_i – is the separation (in the Euclidean sense) of each alternative from the negative-ideal solution.

$\left(v_{ij} - v_{j-}\right)^2$ is shown in table 7 below:

Table 7 – Separation measure for traditional TOPSIS method.

					Si_=
0.0007586940956	0.024037558	0.00020833	0.001908459	0.00000508650	0.1640674608
0	0.015868544	0	0.007483419	0.00000064878	0.1528156175
0.005580651404	0.000845070	0	0.001688446	0.00000064878	0.0900822799
0.009536972887	0.037558685	0.00020833	0.005534737	0	0.2298667631
0.005961043485	0	0	0.006472409	0	0.1115053947
0.0000445880827	0.009389671	0.00020833	0	0	0.09819670451

$(v_{ij} - v_{j-}{}^2$=(0.06927834506-0.07595577591)^2=0.0007586940956

$S_{j-} =$ (0.16406746080.15281561750.09008227990.22986676310.11150539470.09819670451)

$S_{j-} =$ (0.004915836123 + 0.001502347418 + 0 + 0.001833624875 + +0)$^{0.5}$ =0.16406746080

Step 5. Calculate the Relative Closeness to the Ideal Solution

The relative closeness of an alternative A_i with respect to the ideal solution A is defined as follows:

$C_{i*} = S_{i-} / (S_{i*} + S_{i-}), 0 \le C_{i*} \le 1, \; i = 1,2,3, \dots, M.$ [3]

Apparently,

$C_{i^*} = 1$, if $A_i = A^*$ and $C_{i-} = 0$, if $A_i = A^-$

$\boldsymbol{C_i = s_{1-}/(s_i + s_{i-}) = 0.16406746080}$:
: (0.1955171642+**0.16406746080)=**
=0.6436367322

Table 8 – Closeness coefficients for traditional TOPSIS method

Ci=
0.6436367322
0.560585117
0.3423844442
0.9491334876
0.3631830675
0.3823834255

Step 6. Rank the Preference Order

The best satisfied alternative can now be decided according to preference rank order of C_{i^*}. Therefore, the best alternative is the one that has the shortest distance to the ideal solution. The relationship of alternatives reveals that any alternative which has the shortest distance to the ideal solution is guaranteed to have the longest distance to the negative-ideal solution.

Malawi>South Sudan>Ghana>Mali> >Nigeria>Kenya

Fuzzy TOPSIS Methodology and Application

The fuzzy TOPSIS method handles uncertainty and ambiguity using fuzzy logic. It incorporates fuzzy numbers and the Euclidean distance method to evaluate how closely each alternative approaches the optimal solution [3]. By assessing these fuzzy distances, it ranks the alternatives based on their proximity to the fuzzy ideal solution, providing a nuanced understanding of each option's performance.

To reflect uncertainty, each performance measurement is represented as a triangular fuzzy number (TFN) (*l*, *m*, *u*), where *l* is the lower limit (*5%* decrease), m is the original value, and u is the upper limit (*7%* increase). This approach adjusts the fuzzy normalized decision matrix to account for variability in the decision-making environment.

Step 1. Fuzzification

Convert each performance measurement X_{ij} into a fuzzy number. If X_{ij} is the original value for the performance of the (i-th alternative on the j-th criterion, the corresponding TFN is represented as X_{ij}^{l}, X_{ij}, X_{ij}^{u}, where [2] (table 9):

$X_{ij}^{l} = X_{ij} - 0.05\ X_{ij}$ (5% decrease),

$X_{ij} = X_{ij}$ (main number),

$X_{ij}^{u} = X_{ij} + 0.07\ X_{ij}$ (7% increase).

The associated values are presumed to be as table 10.

Table 9 – Criteria and their weights for fuzzy TOPSIS method

weights	0.2	**0.3**	0.5	0.1	**0.4**	0.5	0.2	**0.025**	0.77	0.2	**0.2**	0.6	0.2	**0.07**	0.72

Table 10 – Decision matrix with fuzzy triangular numbers for fuzzy TOPSIS method.

	Elevation Angle			**Market Size**			**Infrastructure**			**Currency Stability**			**Beam Availability**		
Nigeria	8.8	9.3	9.9	99.8	105.0	112.4	1.0	1.0	1.1	25.8	27.2	29.1	3.8	4	4.28
Mali	6.3	6.6	7.1	85.5	90.0	96.3	0.0	0.0	0.0	42.8	45.0	48.2	3.6	3.82	4.087
Malawi	13.1	13.8	14.8	38.0	40.0	42.8	0.0	0.0	0.0	24.8	26.1	27.9	3.6	3.82	4.087
Kenya	15.2	16.0	17.1	118.8	125.0	133.8	1.0	1.0	1.1	38.0	40.0	42.8	3.5	3.72	3.980
South Sudan	13.3	14.0	15.0	23.8	25.0	26.8	0.0	0.0	0.0	40.4	42.5	45.5	3.5	3.72	3.980
Ghana	6.9	7.3	7.8	71.3	75.0	80.3	1.0	1.0	1.1	8.6	9.0	9.6	3.5	3.72	3.980

Step 2. Construct the Normalized Decision Matrix

The normalized value r_{ij} for each criterion can then be calculated using a method suitable for normalizing TFNs. One common approach is to use the vector normalization method, which can be adapted for fuzzy numbers [4]. The process typically involves dividing each fuzzy number by the maximum (or minimum, for cost criteria) fuzzy number in its column to maintain the decision matrix's proportionality and comparability (table 11).

Table 11 – Normalized fuzzy decision matrix for fuzzy TOPSIS method

	Elevation Angle			Market Size			Infrastructure			Currency Stability			Beam Availability		
WEIGHTS	0.2	**0.3**	0.5	0.1	**0.4**	0.5	0.2	**0.02**	0.775	0.2	**0.2**	0.6	0.2	**0.07**	0.725
Nigeria	0.58	0.61	0.65	0.84	0.88	0.95	1.00	1.05	1.13	0.60	0.64	0.68	1.00	1.05	1.13
Mali	0.42	0.44	0.47	0.72	0.76	0.81	0.00	0.00	0.00	1.00	1.05	1.13	0.96	1.01	1.08
Malawi	0.86	0.91	0.97	0.32	0.34	0.36	0.00	0.00	0.00	0.58	0.61	0.65	0.96	1.01	1.08
Kenya	1.00	1.05	1.13	1.00	1.05	1.13	1.00	1.05	1.13	0.89	0.93	1.00	0.93	0.98	1.05
South Sudan	0.88	0.92	0.99	0.20	0.21	0.23	0.00	0.00	0.00	0.94	0.99	1.06	0.93	0.98	1.05
Ghana	0.46	0.48	0.51	0.60	0.63	0.68	1.00	1.05	1.13	0.20	0.21	0.23	0.93	0.98	1.05

Step 3. Construct the Weighted Normalized Decision Matrix

After normalizing the decision matrix using triangular fuzzy numbers (TFNs), the next step is to apply the criteria weights. This transforms the normalized decision matrix into a weighted normalized decision matrix, reflecting the relative importance of each criterion. For each element in the normalized decision matrix (TFN *l*, *m*, *u*), multiply each component by the weight w of the corresponding criterion: (*l**w), (*m**w), (*u**w). This multiplication is done for all cells, across all criteria and alternatives [6].

This step ensures that the matrix accurately reflects the emphasis on different criteria, providing a more informed basis for further analysis. The weighted matrix is then used to calculate the distances to the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS), leading to the ranking of alternatives based on their closeness to the ideal solution [7] (table 12).

Step 4. Calculation of Distances to the Fuzzy Positive and Negative Ideal Solutions

Following the creation of the weighted normalized decision matrix in the fuzzy TOPSIS method, the next step is to calculate the distances of each alternative to the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). Assuming FPIS (A+) is represented as 1 (indicating the best possible performance) and FNIS (A−) as 0 (indicating the worst possible performance), the distances to these ideal solutions can be calculated for each criterion of each alternative. This step is crucial for identifying how close each alternative is to the desired outcomes versus the least desired outcomes [8].

Distance Calculation to FPIS (A+)

To calculate the distance of each alternative to the FPIS (A+), use the formula:

Distance to A+ = ((A+) - value)^2

where value represents the weighted normalized value for a criterion of an alternative. This operation is performed for each criterion of each alternative, and the results are summed up to obtain the total distance of each alternative to the FPIS. The squaring operation ensures that the distance is always positive and emphasizes larger deviations.

Distance Calculation to FNIS (A−) Similarly, to calculate the distance of each alternative to the FNIS (A−), use the formula:

Distance to A- = ((A-) - value)^2

Here, value is the same weighted normalized value used in the calculation for the FPIS distance (table 13). This formula measures how far each alternative is from the worst possible performance, again using the squaring operation to ensure positivity and emphasize larger deviations.

Table 12 – Weighted normalized fuzzy decision matrix for fuzzy TOPSIS method

	Elevation Angle			**Market Size**			**Infrastructure**			**Currency Stability**			**Beam Availability**		
WEIGHTS	0.2	**0.3**	0.5	0.1	**0.4**	0.5	0.2	**0.02**	0.775	0.2	**0.2**	0.6	0.2	**0.075**	0.725
Nigeria	0.12	0.18	0.33	0.08	0.35	0.47	0.20	0.03	0.87	0.12	0.13	0.41	0.20	0.08	0.82
Mali	0.08	0.13	0.23	0.07	0.30	0.41	0.00	0.00	0.00	0.20	0.21	0.68	0.19	0.08	0.78
Malawi	0.17	0.27	0.49	0.03	0.13	0.18	0.00	0.00	0.00	0.12	0.12	0.39	0.19	0.08	0.78
Kenya	0.20	0.32	0.56	0.10	0.42	0.56	0.20	0.03	0.87	0.18	0.19	0.60	0.19	0.07	0.76
South Sudan	0.18	0.28	0.49	0.02	0.08	0.11	0.00	0.00	0.00	0.19	0.20	0.64	0.19	0.07	0.76
Ghana	0.09	0.14	0.26	0.06	0.25	0.34	0.20	0.03	0.87	0.04	0.04	0.14	0.19	0.07	0.76

Table 13 – Fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for fuzzy TOPSIS method

Nigeria	0.78	0.67	0.45	0.84	0.42	0.28	0.64	0.95	0.02	0.77	0.76	0.35	0.64	0.85	0.03
Mali	0.84	0.76	0.59	0.86	0.49	0.35	1.00	1.00	1.00	0.64	0.62	0.11	0.65	0.85	0.05
Malawi	0.68	0.53	0.26	0.94	0.75	0.67	1.00	1.00	1.00	0.78	0.77	0.37	0.65	0.85	0.05
Kenya	0.64	0.47	0.19	0.81	0.34	0.19	0.64	0.95	0.02	0.68	0.66	0.16	0.66	0.86	0.06
South Sudan	0.68	0.52	0.26	0.96	0.84	0.79	1.00	1.00	1.00	0.66	0.64	0.13	0.66	0.86	0.06
Ghana	0.83	0.73	0.55	0.88	0.56	0.44	0.64	0.95	0.02	0.92	0.92	0.75	0.66	0.86	0.06

Table 14 – Defuzzified separation measures and relative closeness coefficients for fuzzy TOPSIS method

Nigeria	0.01	0.03	0.11	0.01	0.13	0.22	0.04	0.00	0.76	0.01	0.02	0.17	0.04
Mali	0.01	0.02	0.05	0.01	0.09	0.16	0.00	0.00	0.00	0.04	0.04	0.46	0.04
Malawi	0.03	0.07	0.24	0.00	0.02	0.03	0.00	0.00	0.00	0.01	0.01	0.15	0.04
Kenya	0.04	0.10	0.32	0.01	0.18	0.32	0.04	0.00	0.76	0.03	0.03	0.36	0.03
SouthSudan	0.03	0.08	0.24	0.00	0.01	0.01	0.00	0.00	0.00	0.04	0.04	0.41	0.03
Ghana	0.01	0.02	0.07	0.00	0.06	0.11	0.04	0.00	0.76	0.00	0.00	0.02	0.03

Step 5. Determination of Closeness Coefficient and Final Ranking of Alternatives. In this step, the closeness of each alternative to the ideal solution is evaluated to facilitate ranking. This involves two main calculations:

1. Square Root of the Mean of Squared Distances: Calculate the square root of the mean of the squared distances to both the FPIS (A+) and FNIS (A-) for each alternative (table 14). This involves summing the squared distances for each criterion, dividing by the number of criteria to find the mean, and then taking the square root of this mean. Note that some versions of fuzzy TOPSIS may use the sum of squared differences directly, without taking the square root [9].

2. Closeness Coefficient Calculation: Calculate the closeness coefficient (CC) for each alternative using the appropriate formula for the fuzzy TOPSIS method. This coefficient indicates the relative closeness of each alternative to the ideal solution, facilitating the ranking process [3].

CC = Distance to A- / ((Distance to A+) + +(Distance to A-))

The closeness coefficient (CC) measures the proportion of the distance to the FNIS relative to the total distance to both FPIS and FNIS, yielding a value between *0* and *1*. A higher CC indicates a closer proximity to the ideal solution and a more preferred alternative.

Finally, rank the alternatives based on their CC values, with the highest CC indicating the best option, providing a clear order of preference for decision-making.

Rank	
0.2213376717	Nigeria
0.1595551891	Mali
0.3240601772	Malawi
0.3722757391	**Kenya**
0.3293841351	South Sudan
0.1746347402	Ghana

The discussion of the results

The solution proposed in this study involves the application of both traditional and fuzzy TOPSIS methods to a decision matrix comprising several criteria relevant to the satellite telecommunication market. The traditional TOPSIS method is applied first, followed by the fuzzy TOPSIS method, which incorporates fuzzy logic to handle uncertainty. Triangular fuzzy numbers are used to represent performance measures, providing a more nuanced analysis. The procedural steps for both methods are outlined, and their results are compared to determine the effectiveness of the fuzzy approach in improving decision-making quality.

Conclusion

The comparative analysis of traditional and fuzzy TOPSIS methods reveals that while the traditional approach is effective in ranking alternatives, the fuzzy TOPSIS method offers a more comprehensive evaluation by incorporating uncertainty and ambiguity. The study demonstrates that the fuzzy TOPSIS method provides a more detailed and reliable analysis, which can significantly enhance the quality of market entry decisions in the satellite telecommunication industry. Consequently, decision-makers are encouraged to adopt fuzzy TOPSIS in scenarios where uncertainty plays a critical role in the decision-making process.

Conflict of interests

The author declares there is no conflict of interests related to the publication of this article.

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