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Single Valued Neutrosophic Sets for Assessment Quality of Suppliers under Uncertainty Environment

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Abstract

Quality evaluation is crucial to guaranteeing the dependability and uniformity of suppliers' products, components, and services. An overview of important topics concerning the evaluation of supplier quality is presented in this study. The evaluation includes everything from product quality and regulatory compliance to production methods, delivery times, customer service, financial stability, and the supplier's general reputation. Businesses may build a robust supply chain, ensure customer happiness, and make educated choices regarding supplier agreements by carefully considering these factors. Considering a supplier's dedication to innovation, long-term relationship possibilities, and ongoing development is also essential to evaluating their quality. Decreased defects and recalls, increased operational efficiency, better brand perception, regulatory compliance, and reduced risk are all advantages of a thorough review. Businesses can stay ahead of the competition and provide consumers with better goods and services if they prioritize supplier quality inspections. We used multi-criteria decision-making (MCDM) to deal with conflicting criteria in assessing the quality of suppliers. The neutrosophic set deals with uncertain information in the assessment process. The neutrosophic set is integrated with the MCDM method, such as the TOPSIS method. The TOPSIS method is used to rank the suppliers. We conducted this study at a drug company. We used 15 criteria and 20 suppliers. We conducted a sensitivity analysis to ensure the stability of the results.

Keywords: Single valued neutrosophic sets, Uncertainty, Assessment, MCDM, Supplier, Supply chain, TOPSIS method.

1 | Introduction

Businesses across a wide range of sectors rely heavily on supplier quality assessments. Businesses depend on suppliers to provide high-quality products, parts, and services that match their specifications. Companies may keep product quality constant, reduce risk, and maintain customer happiness by assessing supplier quality. Companies may build a robust supply chain that helps them achieve their goals by carefully evaluating their suppliers. This will allow them to make educated choices about their relationships [1–3]. To find reliable and suitable suppliers, it is necessary to evaluate their quality thoroughly. Product quality, manufacturing



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procedures, delivery performance, customer service, supplier reputation, financial stability, and regulatory compliance are all aspects that fall under this category. Suppliers' capacity to reliably satisfy quality standards, meet supply needs, and provide continuous support may be assessed by looking at these factors [4–6].

A supplier's quality management system, including their certifications, quality control methods, and compliance with applicable industry standards, is usually reviewed thoroughly at the beginning of the evaluation process [7, 8]. Production facilities, equipment, and compliance with good manufacturing standards are some aspects that businesses evaluate via on-site audits and inspections [9, 10]. Quality evaluations of suppliers also heavily rely on supplier performance indicators, including on-time delivery rates, defect rates, and customer complaints. Evaluating the current status of a supplier's operations is only the beginning of a thorough supplier quality evaluation. Thinking about their dedication to innovation, long-term collaboration possibilities, and constant progress is also part of it. Suppliers who take the initiative to improve quality, allocate resources to R&D, and align with the long-term objectives of the customer are more likely to help the buyer succeed and create a win-win partnership [11, 12].

Robust supplier quality evaluation has several advantages. Improved operational efficiency, fewer product defects and recalls, compliance with regulations, and risk mitigation in the supply chain are all benefits that businesses get from this tool. Companies may keep their competitive advantage, improve their brand image, and provide consumers with better goods and services by choosing high-quality suppliers [13, 14]. Ultimately, evaluating suppliers' quality is an essential step for companies looking to build a solid and effective supply chain. Businesses may make sure their suppliers are up to snuff in terms of quality, strategic fit, and long-term performance by using a variety of evaluation metrics. Supply chain management relies on thorough supplier quality assessments to remain competitive, produce high-quality goods, reduce risks, and keep customers happy [15, 16].

A supplier quality assessment system must include efficient and frequent evaluations of supplier quality. When just one supplier or component has to be evaluated, multi-criteria decision-making (MCDM) approaches are the way to go [17-19]. We used the neutrosophic set to overcome uncertainty in the assessment process. Many MCDM researchers have been captivated by the ambiguity and time-periodic nature of the data [20-22]. Various periods are required to depict periodic occurrences in real life, a common source of decision-making challenges. None of the classic fuzzy set theory models using actual membership or non-membership grades can adequately characterize such issues [23-25]. To solve these MCDM challenges, criteria and alternatives might be given complicated membership grades [26-28].

2 | Materials and Methods

In this section, the single valued neutrosophic TOPSIS method is introduced to assess the quality of supplier and rank the suppliers to select best one [29-30]. The steps of the TOPSIS method are introduce in Figure. 1.

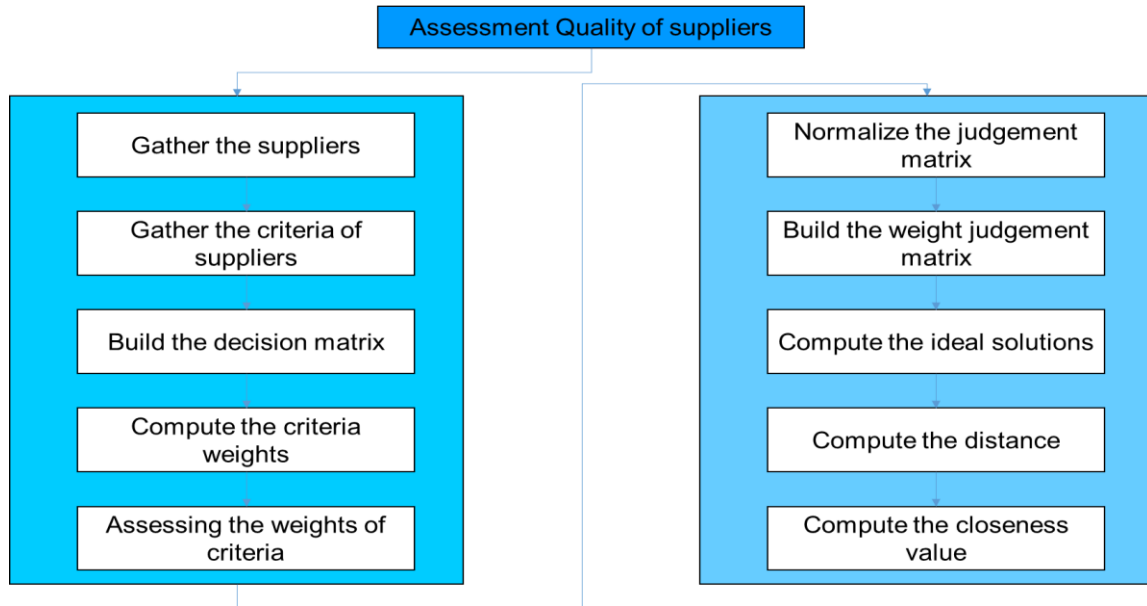


Figure 1. The steps of the proposed method.

In this section, the single valued neutrosophic TOPSIS method is introduced to assess the quality of supplier and rank the suppliers to select best one [29-30]. The steps of the TOPSIS method are introduce in Figure 1.

Step 1. Build the judgment matrix.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

Where a_{11} refers to the value in decision matrix, m refers to the number of alternatives and n refers to the number of criteria. $i = 1, 2, \dots, m; j = 1, 2, \dots, n$.

Step 2. Normalize the judgment matrix.

$$Y_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}}; \text{Positive criteria.} \quad (2)$$

$$Y_{ij} = \frac{\min a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}}; \text{Negative criteria.} \quad (3)$$

$$Y = \begin{bmatrix} Y_{11} & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{mn} \end{bmatrix} \quad (4)$$

Step 3. Compute the weights of criteria.

Step 4. Build the weight judgment matrix.

$$d_{ij} = w_j * y_{ij} \quad (5)$$

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mn} \end{bmatrix} \quad (6)$$

Step 5. Compute the ideal solutions.

The ideal solutions are computed for positive and negative criteria:

$$E^+ = (E_1^+, E_2^+, \dots, E_n^+) \quad (7)$$

$$E^- = (\max\{e_{11}, e_{21}, \dots, e_{m1}\}, \max\{e_{12}, e_{22}, \dots, e_{n1}\}, \dots, \max\{e_{1n}, e_{2n}, \dots, e_{mn}\}) \quad (8)$$

$$E^- = (E_1^-, E_2^-, \dots, E_n^-) \quad (9)$$

$$E^- = (\min\{e_{11}, e_{21}, \dots, e_{m1}\}, \min\{e_{12}, e_{22}, \dots, e_{n1}\}, \dots, \min\{e_{1n}, e_{2n}, \dots, e_{mn}\}) \quad (10)$$

Step 6. Compute the distance from each suppliers and the ideal solutions for positive and negative criteria.

$$T_i^+ = \sqrt{\sum_{j=1}^n (E_i^+ - E_{ij})^2} \quad (11)$$

$$T_i^- = \sqrt{\sum_{j=1}^n (E_i^- - E_{ij})^2} \quad (12)$$

Step 7. Compute the closeness value.

$$O_i = \frac{T_i^-}{T_i^+ + T_i^-} \quad (13)$$

3 | Results

In this section, we provide a case study for evaluating the quality of suppliers in a drug company to select the best one from 20 suppliers. We collected 15 criteria, as shown in Figure 2.

Step 1. Build the judgment matrix using Eq. (1).

Step 2. Normalize the judgment matrix for positive and negative criteria by Eqs. (2-4) as shown in Table 1.

Step 3. Compute the weights of criteria as shown in Figure 3. We show the Regulatory Compliance is the best criterion and Corporate Social Responsibility is the worst criterion.



Figure 2. The 15 criteria of suppliers in Drug Company.

Table 1. Normalization judgment matrix.

ASA	ASA ₁₉	ASA ₁₈	ASA ₁₇	ASA ₁₆	ASA ₁₅	ASA ₁₄	ASA ₁₃	ASA ₁₂	ASA ₁₁	ASA ₁₀	ASA ₉	ASA ₈	ASA ₇	ASA ₆	ASA ₅	ASA ₄	ASA ₃	ASA ₂	ASA ₁	
0.10	0.21	0.39	0.09	0.21	0.25	0.10	0.13	0.21	0.38	0.14	0.21	0.27	0.21	0.25	0.25	0.26	0.14	0.21	0.09	ASQ ₁
2502	061	4394	4494	061	5855	2502	053	061	6386	7747	061	7477	061	3053	025	1061	7747	061	4494	
0.36	0.20	0.35	0.14	0.14	0.20	0.14	0.20	0.29	0.20	0.14	0.20	0.14	0.14	0.20	0.29	0.37	0.20	0.20	0.14	ASQ ₂
5057	4409	0377	1813	3419	4409	1813	4409	1879	4409	1813	4409	2311	1813	4409	138	9459	4409	4409	0705	
0.20	0.20	0.20	0.10	0.14	0.10	0.39	0.33	0.29	0.33	0.18	0.20	0.27	0.20	0.10	0.16	0.20	0.20	0.10	0.23	ASQ ₃
771	771	771	1446	6029	1091	0147	3678	8534	8022	0068	771	3656	8065	1446	3878	771	771	3855	2983	
0.12	0.22	0.22	0.22	0.28	0.28	0.12	0.17	0.28	0.30	0.19	0.12	0.17	0.31	0.29	0.14	0.22	0.17	0.08	0.28	ASQ ₄
148	7158	8146	8804	1808	1808	148	3167	1808	8211	3908	148	3167	7034	4977	8805	8146	3167	4279	1808	
0.18	0.18	0.23	0.18	0.30	0.24	0.30	0.18	0.16	0.23	0.18	0.18	0.22	0.18	0.22	0.34	0.18	0.22	0.13	0.26	ASQ ₅
6529	6848	3693	6848	2844	6459	3553	6529	1706	1566	6529	5465	6601	6529	6601	1497	7593	4119	0854	88	
0.04	0.16	0.20	0.16	0.27	0.27	0.30	0.29	0.16	0.30	0.16	0.29	0.16	0.30	0.19	0.18	0.30	0.16	0.07	0.10	ASQ ₆
6188	7838	1317	7838	2669	2669	6753	7197	7551	6753	7551	6878	7551	6753	0805	9849	6753	7838	5175	3844	
0.07	0.07	0.30	0.19	0.29	0.30	0.26	0.26	0.19	0.17	0.29	0.16	0.29	0.16	0.19	0.19	0.16	0.30	0.12	0.15	ASQ ₇
3447	3727	6611	8868	9391	0324	6402	6402	8868	3037	9702	398	9702	37	6689	6689	4634	0324	1997	9965	
0.18	0.18	0.33	0.09	0.18	0.26	0.33	0.33	0.24	0.18	0.22	0.18	0.24	0.24	0.16	0.20	0.14	0.18	0.12	0.22	ASQ ₈
519	5507	975	0131	5507	2505	9046	9046	469	519	4974	519	3986	3986	0545	9835	5054	519	9915	4974	
0.13	0.35	0.19	0.26	0.08	0.23	0.17	0.18	0.22	0.25	0.19	0.35	0.17	0.19	0.23	0.23	0.35	0.17	0.09	0.05	ASQ ₉
5	9129	616	0304	8347	6809	0055	087	2265	8439	616	9129	0055	616	569	569	9875	013	547	4447	
0.30	0.16	0.19	0.16	0.30	0.27	0.16	0.30	0.27	0.19	0.16	0.20	0.16	0.30	0.21	0.17	0.27	0.16	0.11	0.19	ASQ ₁₀
4416	5931	9369	6214	4479	0978	5931	3785	0032	8738	5931	1577	5931	3785	7666	224	0032	4984	5142	7161	
0.28	0.21	0.04	0.18	0.28	0.17	0.32	0.17	0.32	0.21	0.13	0.17	0.21	0.08	0.32	0.23	0.24	0.21	0.17	0.23	ASQ ₁₁
676	3318	1061	9949	5759	5895	1479	5595	1479	0981	7538	5595	3318	5461	2146	1344	8904	0981	5595	3014	
0.27	0.19	0.35	0.31	0.16	0.22	0.19	0.19	0.13	0.13	0.19	0.35	0.22	0.19	0.09	0.19	0.23	0.19	0.28	0.19	ASQ ₁₂
048	0816	0071	0856	5422	7057	0816	1143	4152	3861	1904	0071	9596	0816	3195	0816	1809	0816	6224	0816	
0.23	0.43	0.28	0.23	0.26	0.16	0.11	0.16	0.11	0.16	0.23	0.31	0.23	0.16	0.10	0.10	0.16	0.28	0.23	0.16	ASQ ₁₃
8091	7164	6071	8091	6608	7388	5877	7026	5877	7252	8091	5946	8091	7026	7254	6643	7026	6071	8996	7026	
0.28	0.28	0.11	0.26	0.42	0.20	0.23	0.26	0.23	0.20	0.18	0.11	0.11	0.23	0.18	0.11	0.11	0.23	0.23	0.23	ASQ ₁₄
125	4365	3924	2114	944	2927	4078	2114	4078	4529	4682	4325	4325	4479	4949	3924	4325	5413	5413	5413	
0.30	0.11	0.16	0.23	0.27	0.20	0.15	0.23	0.16	0.42	0.37	0.30	0.18	0.23	0.16	0.11	0.16	0.11	0.09	0.16	ASQ ₁₅
7537	2793	258	1754	4492	0912	9496	1754	258	3854	8473	7537	2848	3076	258	2793	258	2793	9267	258	

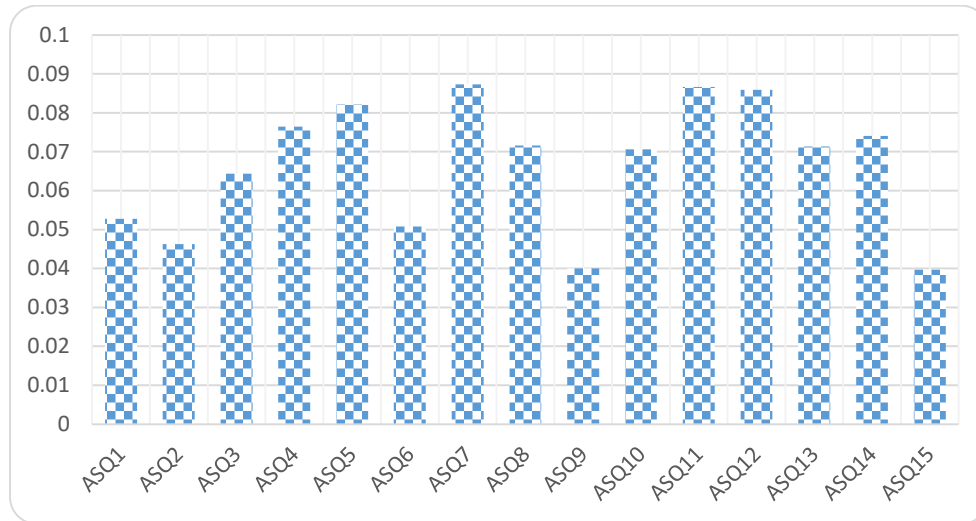


Figure 3. The weights of 15 criteria in quality assessment suppliers.

Step 4. Build the weight judgment matrix by Eqs. (5) and (6) as shown in Table 2.

Step 5. Compute the ideal solutions for positive and negative criteria using Eqs. (7–10).

Step 6. Compute the distance from each supplier and the ideal solutions for positive and negative criteria using Eqs. (11) and (12).

Step 7. Compute the closeness value using Eq. (13) as shown in Figure 4. We show that supplier 16 is the best and supplier 2 is the worst.

Table 2. The weighted normalized judgment matrix.

	ASQ ₁	ASQ ₂	ASQ ₃	ASQ ₄	ASQ ₅	ASQ ₆	ASQ ₇	ASQ ₈	ASQ ₉	ASQ ₁₀	ASQ ₁₁	ASQ ₁₂	ASQ ₁₃	ASQ ₁₄	ASQ ₁₅
ASA ₁	0.004 988	0.006 514	0.014 994	0.021 543	0.022 066	0.005 277	0.013 968	0.016 106	0.002 181	0.013 922	0.020 183	0.016 395	0.011 919	0.017 436	0.006 452
ASA ₂	0.011 117	0.009 463	0.006 684	0.006 443	0.010 742	0.003 82	0.010 653	0.009 301	0.003 824	0.008 13	0.015 21	0.024 592	0.017 054	0.017 436	0.003 939
ASA ₃	0.007 799	0.009 463	0.013 368	0.013 238	0.018 398	0.008 529	0.026 224	0.013 258	0.006 814	0.011 65	0.018 275	0.016 395	0.020 413	0.017 436	0.004 476
ASA ₄	0.013 78	0.017 567	0.013 368	0.017 44	0.015 4	0.015 589	0.014 376	0.010 384	0.014 414	0.019 067	0.021 56	0.019 917	0.011 919	0.008 467	0.006 452
ASA ₅	0.013 209	0.013 49	0.010 547	0.011 375	0.028 034	0.009 648	0.017 175	0.015 022	0.009 44	0.012 162	0.020 039	0.016 395	0.007 61	0.008 438	0.004 476
ASA ₆	0.013 357	0.009 463	0.006 529	0.022 549	0.018 602	0.009 696	0.017 175	0.011 494	0.009 44	0.015 369	0.027 904	0.008 007	0.007 653	0.013 698	0.006 452
ASA ₇	0.011 117	0.006 565	0.013 39	0.024 235	0.015 312	0.015 589	0.014 294	0.017 467	0.007 857	0.021 45	0.007 402	0.016 395	0.011 919	0.017 366	0.009 249
ASA ₈	0.014 646	0.006 588	0.017 612	0.013 238	0.018 602	0.008 515	0.026 169	0.017 467	0.006 811	0.011 716	0.018 477	0.019 726	0.016 99	0.008 467	0.007 256
ASA ₉	0.011 117	0.009 463	0.013 368	0.009 286	0.015 225	0.015 087	0.014 318	0.013 258	0.014 384	0.014 233	0.015 21	0.030 077	0.022 545	0.008 467	0.012 204

ASA ₂₀	ASA ₁₉	ASA ₁₈	ASA ₁₇	ASA ₁₆	ASA ₁₅	ASA ₁₄	ASA ₁₃	ASA ₁₂	ASA ₁₁	ASA ₁₀
0.005 41	0.011 117	0.020 817	0.004 988	0.011 117	0.013 505	0.005 41	0.006 89	0.011 117	0.020 395	0.007 799
0.016 901	0.009 463	0.016 221	0.006 565	0.006 64	0.009 463	0.006 565	0.009 463	0.013 513	0.009 463	0.006 565
0.013 368	0.013 368	0.013 368	0.006 529	0.009 398	0.006 506	0.025 109	0.021 474	0.019 213	0.021 754	0.011 589
0.009 286	0.017 365	0.017 44	0.017 491	0.021 543	0.021 543	0.009 286	0.013 238	0.021 543	0.023 561	0.014 823
0.015 312	0.015 339	0.019 184	0.015 339	0.024 861	0.020 232	0.024 919	0.015 312	0.013 275	0.019 009	0.015 312
0.002 347	0.008 529	0.010 231	0.008 529	0.013 857	0.013 857	0.015 589	0.015 103	0.008 515	0.015 589	0.008 515
0.006 413	0.006 438	0.026 773	0.017 365	0.026 142	0.026 224	0.023 262	0.023 262	0.017 365	0.015 109	0.026 169
0.013 258	0.013 281	0.024 323	0.006 452	0.013 281	0.018 793	0.024 272	0.024 272	0.017 518	0.013 258	0.016 106
0.005 407	0.014 384	0.007 857	0.010 426	0.003 538	0.009 485	0.006 811	0.007 244	0.008 902	0.010 351	0.007 857
0.021 495	0.011 716	0.014 078	0.011 736	0.021 499	0.019 134	0.011 716	0.021 45	0.019 067	0.014 033	0.011 716
0.024 839	0.018 477	0.003 557	0.016 453	0.024 752	0.015 236	0.027 846	0.015 21	0.027 846	0.018 275	0.011 913
0.023 239	0.016 395	0.030 077	0.026 708	0.014 213	0.019 508	0.016 395	0.016 423	0.011 526	0.011 501	0.016 488
0.016 99	0.031 195	0.020 413	0.016 99	0.019 024	0.011 944	0.008 269	0.011 919	0.008 269	0.011 935	0.016 99
0.020 831	0.021 061	0.008 438	0.019 413	0.031 806	0.015 03	0.017 337	0.019 413	0.017 337	0.015 148	0.013 678
0.012 204	0.004 476	0.006 452	0.009 197	0.010 893	0.007 973	0.006 329	0.009 197	0.006 452	0.016 82	0.015 019

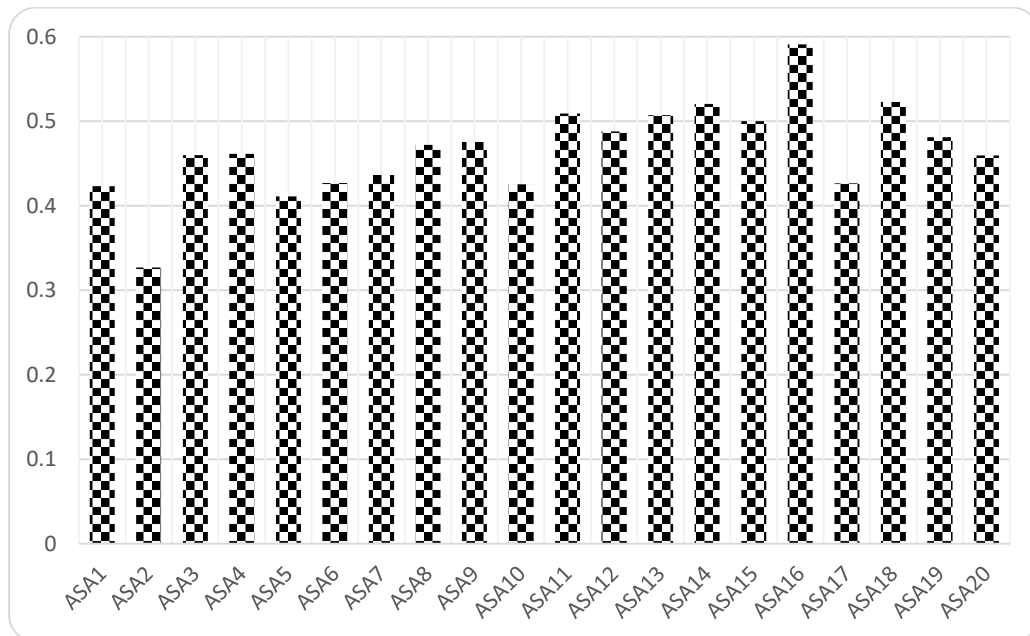


Figure 4. The rank of 20 suppliers in Drug Company.

4 | Sensitivity Analysis

In this section, we change the criteria weights and then rank the alternatives to show the stability of the results and the suggested methodology. Figure 5 shows the 15 cases of changing the weights of the criteria. We put one case with 0.06 weight and another with equal weight.

Then, we enter 15 cases as weights of criteria for the TOPSIS method and rank the suppliers as shown in Figure 6. We show the results are stable in under 15 cases in terms of criteria weights.

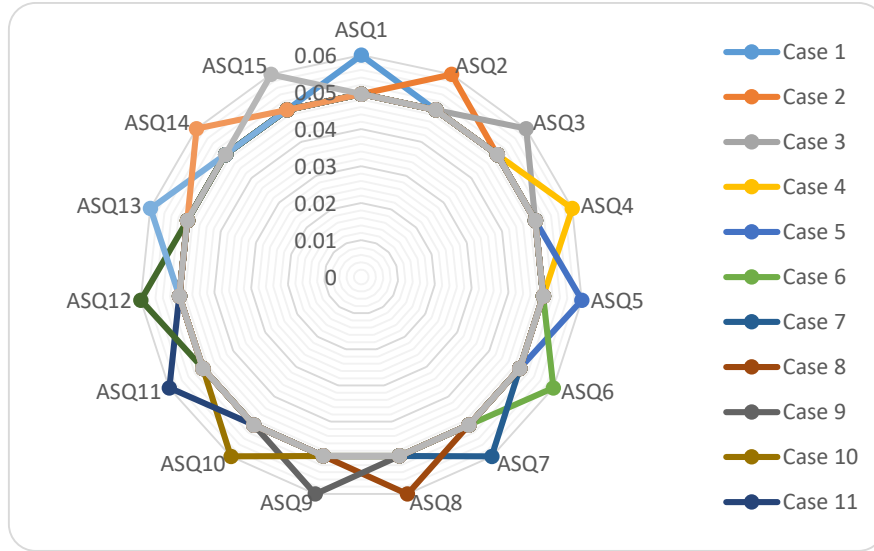


Figure 5. The fifteen cases in changing the weights of supplier's criteria.

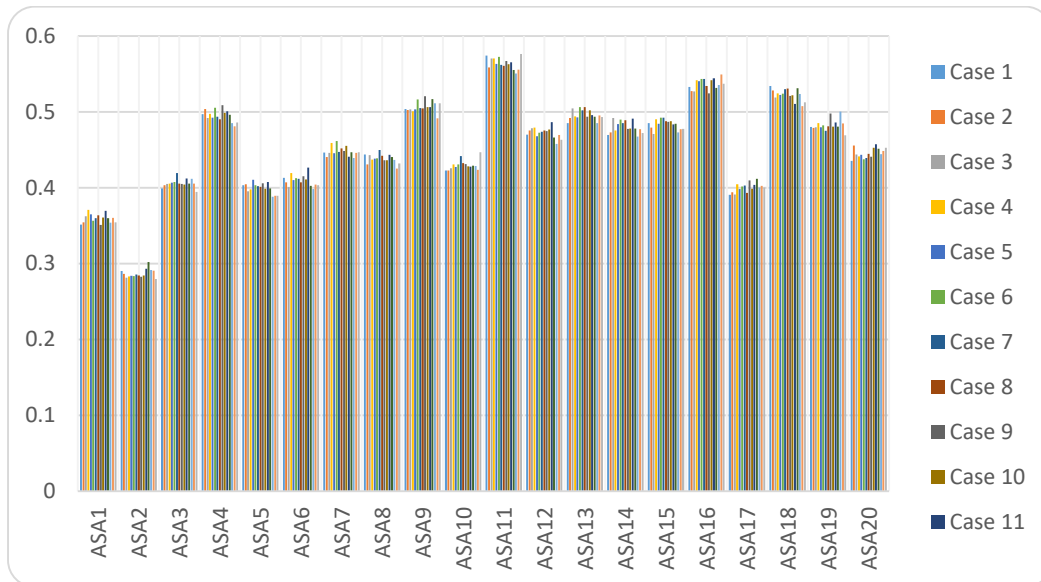


Figure 6. The rank of 20 suppliers under 15 cases.

5 | Conclusions

To build a trustworthy and effective supply chain, companies must evaluate the quality of their suppliers. Businesses may guarantee that their suppliers reliably provide high-quality goods and services that align with rules and consumer expectations by implementing a thorough review procedure. Considerations such as supplier reputation, financial stability, product quality, production methods, delivery performance, regulatory compliance, and customer service are all part of an exhaustive evaluation. Through this review process, businesses may improve operational efficiency, decrease defects and recalls, detect risks, and maintain

compliance. When looking to build solid and mutually beneficial connections with suppliers, examining their dedication to continual development, innovation, and the possibility of long-term partnerships is essential. Reduced risk, higher-quality products, adherence to regulations, more efficient operations, and a good name for the company are all advantages of supplier quality evaluation. Businesses may stay ahead of the competition, meet consumer expectations, and succeed in the long run by putting supplier quality evaluation first. We conducted this study at a drug company to select the best supplier. We used 15 criteria and 20 suppliers. We used the MCDM methods to evaluate the quality of suppliers. The TOPSIS method was used to rank the suppliers. The TOPSIS method was integrated with the neutrosophic set to overcome the uncertainty in the evaluation process.

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Author Contribution

All authors contributed equally to this work.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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