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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.

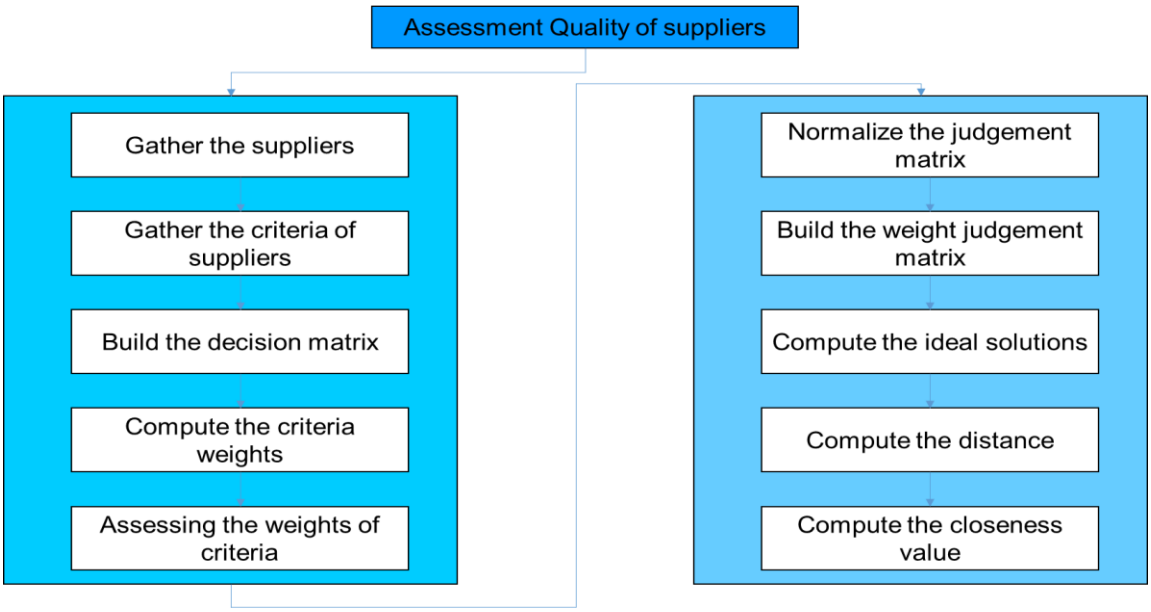

Figure 1. The steps of the proposed method.

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.

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

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

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.

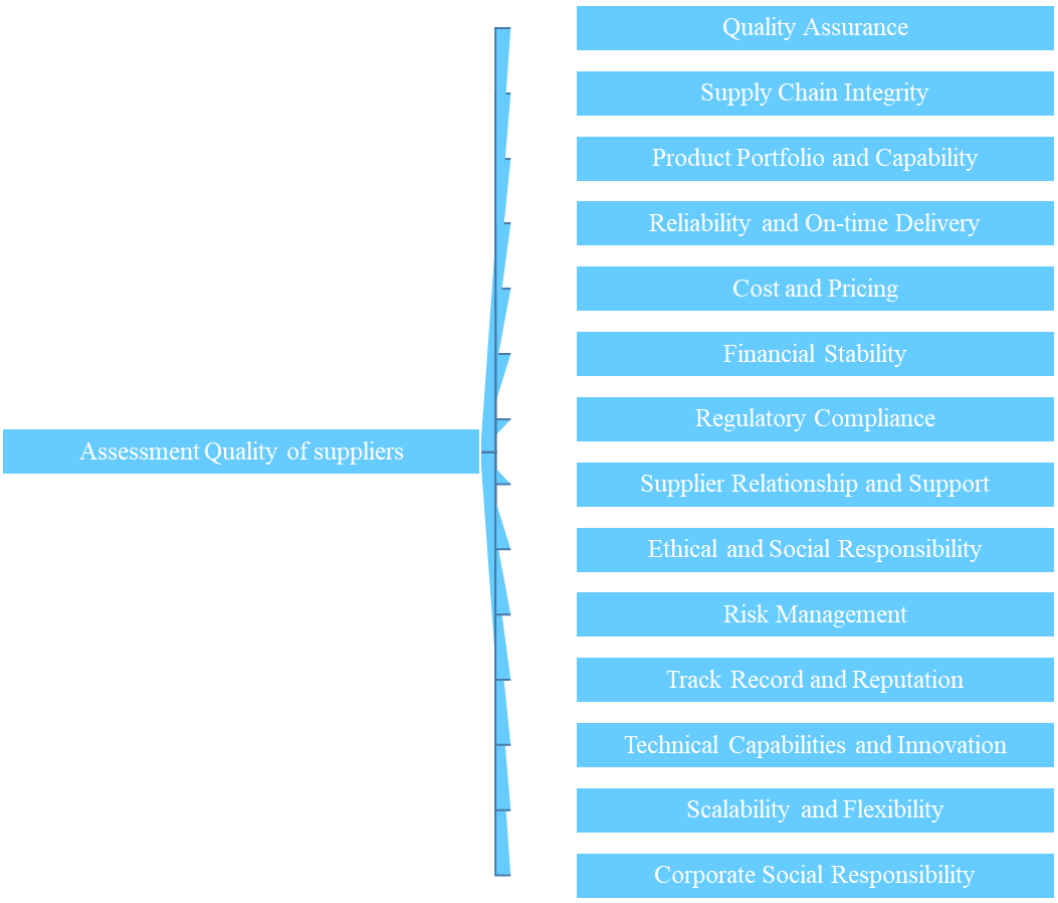

Figure 2. The 15 criteria of suppliers in Drug Company.

Table 1. Normalization judgment matrix.

	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	0.094494	0.140705	0.232983	0.281808	0.2688	0.103844	0.159965	0.224974	0.054447	0.197161	0.233014	0.190816	0.167026	0.235413	0.16258
ASA_2	0.21061	0.204409	0.103855	0.084279	0.130854	0.075175	0.121997	0.129915	0.09547	0.115142	0.175595	0.286224	0.238996	0.235413	0.099267
ASA_3	0.147747	0.204409	0.20771	0.173167	0.224119	0.167838	0.300324	0.18519	0.17013	0.164984	0.210981	0.190816	0.286071	0.235413	0.112793
ASA_4	0.261061	0.379459	0.20771	0.228146	0.187593	0.306753	0.164634	0.145054	0.359875	0.270032	0.248904	0.231809	0.167026	0.114325	0.16258
ASA_5	0.25025	0.29138	0.163878	0.148805	0.341497	0.189849	0.196689	0.209835	0.23569	0.17224	0.231344	0.190816	0.106643	0.113924	0.112793
ASA_6	0.253053	0.204409	0.101446	0.294977	0.226601	0.190805	0.196689	0.160545	0.23569	0.217666	0.322146	0.093195	0.107254	0.184949	0.16258
ASA_7	0.21061	0.141813	0.208065	0.317034	0.186529	0.306753	0.1637	0.243986	0.19616	0.303785	0.085461	0.190816	0.167026	0.234479	0.233076
ASA_8	0.277477	0.142311	0.273656	0.173167	0.226601	0.167551	0.299702	0.243986	0.170055	0.165931	0.213318	0.229596	0.238091	0.114325	0.182848
ASA_9	0.21061	0.204409	0.20771	0.12148	0.185465	0.296878	0.16398	0.18519	0.359129	0.201577	0.175595	0.350071	0.315946	0.114325	0.307537
ASA_{10}	0.147747	0.141813	0.180068	0.193908	0.186529	0.167551	0.299702	0.224974	0.19616	0.165931	0.137538	0.191904	0.238091	0.184682	0.378473
ASA_{11}	0.386386	0.204409	0.338022	0.308211	0.231566	0.306753	0.173037	0.18519	0.258439	0.198738	0.210981	0.133861	0.167252	0.204529	0.423854
ASA_{12}	0.21061	0.291879	0.298534	0.281808	0.161706	0.167551	0.198868	0.24469	0.222265	0.270032	0.321479	0.134152	0.115877	0.234078	0.16258
ASA_{13}	0.13053	0.204409	0.333678	0.173167	0.186529	0.297197	0.266402	0.339046	0.18087	0.303785	0.175595	0.191143	0.167026	0.262114	0.231754
ASA_{14}	0.102502	0.141813	0.390147	0.12148	0.303553	0.306753	0.266402	0.339046	0.170055	0.165931	0.321479	0.190816	0.115877	0.234078	0.159496
ASA_{15}	0.255855	0.204409	0.101091	0.281808	0.246459	0.272669	0.300324	0.262505	0.236809	0.270978	0.175895	0.227057	0.167388	0.202927	0.200912
ASA_{16}	0.21061	0.143419	0.146029	0.281808	0.302844	0.272669	0.299391	0.185507	0.088347	0.304479	0.285759	0.165422	0.266608	0.42944	0.274492
ASA_{17}	0.094494	0.141813	0.101446	0.228804	0.186848	0.167838	0.198868	0.090131	0.260304	0.166214	0.189949	0.310856	0.238091	0.262114	0.231754
ASA_{18}	0.394394	0.350377	0.20771	0.228146	0.233693	0.201317	0.306611	0.33975	0.19616	0.199369	0.041061	0.350071	0.286071	0.113924	0.16258
ASA_{19}	0.21061	0.204409	0.20771	0.227158	0.186848	0.167838	0.073727	0.185507	0.359129	0.165931	0.213318	0.190816	0.437164	0.284365	0.112793
ASA_{20}	0.102502	0.365057	0.20771	0.12148	0.186529	0.046188	0.073447	0.18519	0.135	0.304416	0.28676	0.27048	0.238091	0.28125	0.307537

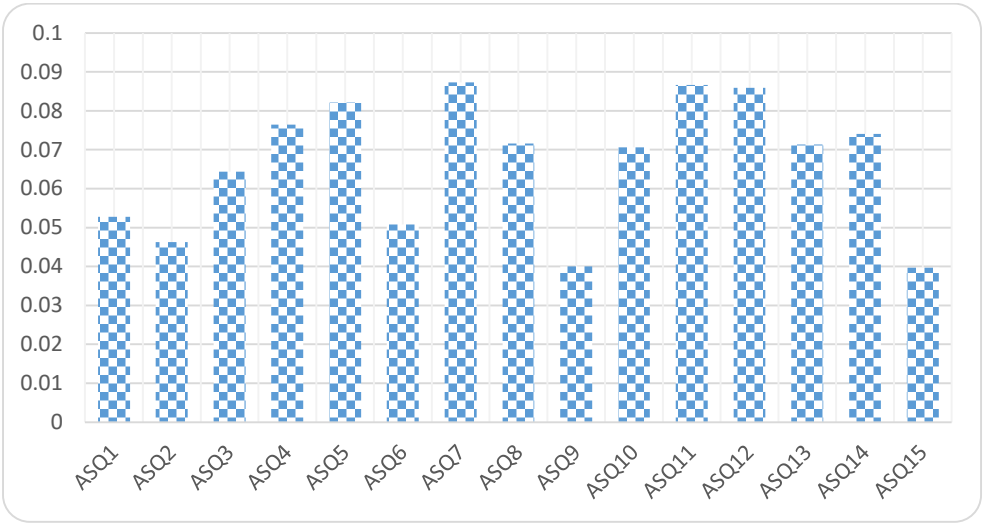

Figure 3. The weights of 15 criteria in quality assessment suppliers.

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	0.004988	0.006514	0.014994	0.021543	0.022066	0.005277	0.013968	0.016106	0.002181	0.013922	0.020183	0.016395	0.011919	0.017436	0.006452
ASA_2	0.011117	0.009463	0.006684	0.006443	0.010742	0.003082	0.010653	0.009301	0.003824	0.008013	0.015021	0.024592	0.017054	0.017436	0.003939
ASA_3	0.007799	0.009463	0.013368	0.013238	0.018398	0.008529	0.026224	0.013258	0.006814	0.011065	0.018275	0.016395	0.020413	0.017436	0.004476
ASA_4	0.013078	0.017567	0.013368	0.017044	0.015004	0.015589	0.014376	0.010384	0.014414	0.019067	0.021056	0.019917	0.011919	0.008467	0.006452
ASA_5	0.013209	0.013049	0.010547	0.011375	0.028034	0.009648	0.017175	0.015022	0.009044	0.012162	0.020039	0.016007	0.007061	0.008438	0.004476
ASA_6	0.013357	0.009463	0.006529	0.022549	0.018602	0.009696	0.017175	0.011494	0.009044	0.015369	0.027904	0.008007	0.007653	0.013698	0.006452
ASA_7	0.011117	0.006565	0.013039	0.024235	0.015312	0.015589	0.014294	0.017467	0.007857	0.021045	0.007402	0.016395	0.011919	0.017366	0.009249
ASA_8	0.014646	0.006588	0.017612	0.013238	0.018602	0.008515	0.026169	0.017467	0.006811	0.011716	0.018477	0.019726	0.016099	0.008467	0.007256
ASA_9	0.011117	0.009463	0.013368	0.009286	0.015225	0.015087	0.014318	0.013258	0.014384	0.014233	0.015021	0.030077	0.022545	0.008467	0.012204

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

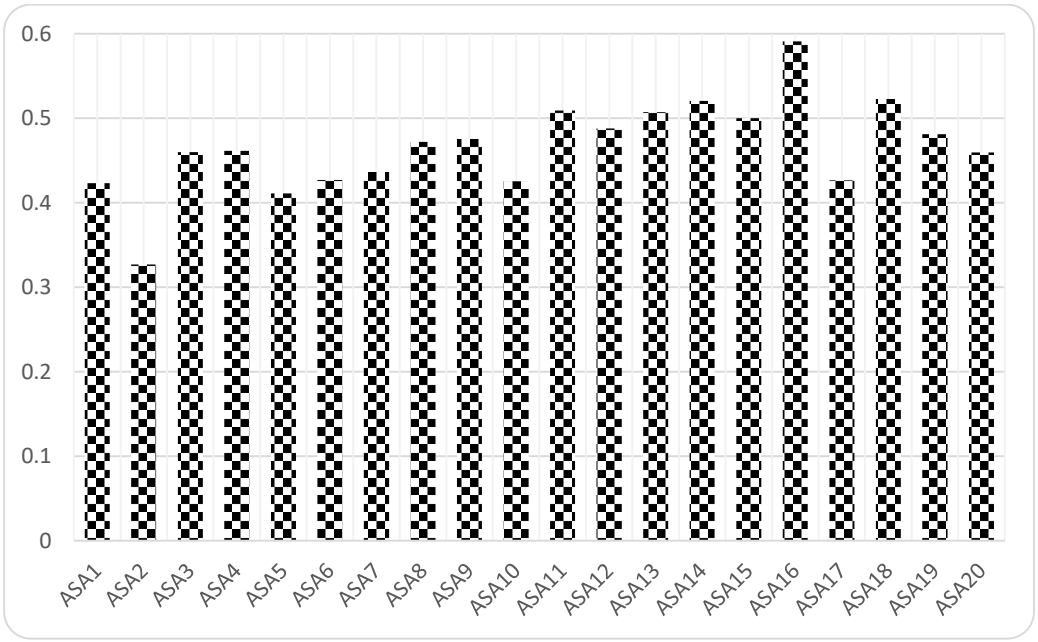

Figure 4. The rank of 20 suppliers in Drug Company.

4 | Sensitivity Analaysis

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.

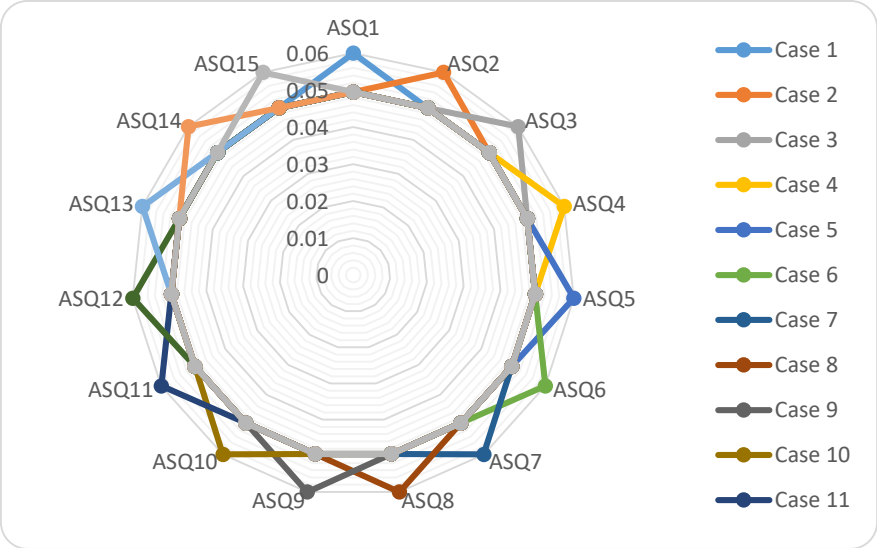

Figure 5. The fifteen cases in changing the weights of supplier's criteria.

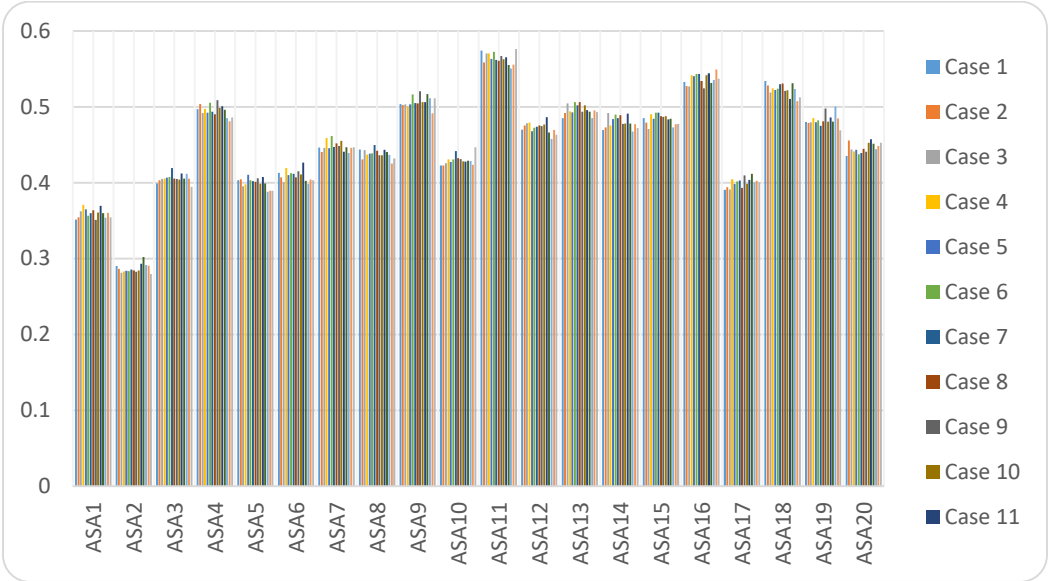

Figure 6. The rank of 20 suppliers under 15 cases.

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 Contributaion

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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