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Ranking Factors Affecting Supply Chain Risk with a Combined Approach of Neutrosophic analytical hierarchy process and TOPSIS

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Abstract

Supply chain risk management involves identifying, ranking, and adopting appropriate strategies to control and deal with risks that could disrupt chain performance. These risks can be caused by different issues and descriptions and surveys about these risks are associated with uncertainty, ambiguity, qualitativeness and incomplete and sometimes contradictory information. Therefore, their ranking needs the techniques that can model the mentioned issues. neutrosophic logic makes it possible to model propositions with uncertainty, incomplete information, ambiguity, qualitativeness, and even inconsistency. Accordingly, the approach of the present study is to use a combined method of neutrosophic hierarchical analysis and TOPSIS for ranking the risk. Core of this paper is proposed a hybrid decision making method for identification and ranking of supply chain management by a Neutrosophic analytical hierarchy process and TOPSIS approach. The case study is Mobarakeh Steel Company of Isfahan and three criteria including resilience, agility and robustness are considered as major strategies to deal with risk and seventeen risk-related issues are ranked as options. The results show that government constraints, economic and environmental risks, inventory shortages, technology risk, forecast risk and financial (cash) problems are the most important risks threatening the supply chain. Therefore, we believe that the proposed framework provides managers with valuable knowledge for decision making.

Keywords: Neutrosophic Logic, Neutrosophic Hierarchical Analysis, TOPSIS, Resilience, Agility, Robustness.

1 | Introduction

Supply chain is a network of processes which its ultimate goal is to provide the goods and services needed by customers and includes suppliers, manufacturers, distributors, wholesalers, retailers and reverse logistics that work together in a coordinated and cooperative way to satisfy the customers. The purpose of supply chain management is to plan, execute and control supply chain operations in the most optimal way possible. Existence of goals, challenges and individual planning of components, their interactions with each other and with other environmental variables such as government, international trade, technology environment, natural environment (natural disasters), etc. impose risks on a supply chain. Identifying, determining the importance and evaluating the consequences of potential risks and ultimately adopting strategies to prevent, deal with or reduce them, is the ultimate goal of risk management in the supply chain. The source of risk in the supply chain of an organization can result from inside or outside, the

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probability of risk occurrence can be from low to very high, the consequences of a disruption can range from small losses to complete stoppage of manufacturing and distribution cycle and finally dealing strategies also can vary from avoidance to complete acceptance. The objective of this study is to identify and rank the risks associated with the supply chain of Mobarakeh Steel Company of Isfahan with a combined approach of neutrosophic hierarchical analysis and TOPSIS. Neutrosophic logic is a development of fuzzy theory and allows propositions to be valued in the context of incomplete, ambiguous, emotional, and inconsistent information. Considering risk, especially in the changing conditions of our country, is always associated with some uncertainty, ambiguity, incomplete information and inconsistency, and therefore decision-making in the field of supply chain risk management with neutrosophic approach is the objective of this research.

This paper organize as follows: in the section 2, presented a literature review, in the section 3, provided research methodology details, in section 4, presented a numerical results in the real case and finally, in section 5 presented a conclusion and further research for future.

2 | Literature review

In this section, provided an over review of neutrosophic logic that we can provide a general framework for the research model. The research model will be introduced in the next section, but in general, the risks affecting the supply chain of Mobarakeh Steel Company of Isfahan are to be ranked, which triangular neutrosophic numbers will be used to model the opinions of experts. According to the acquired knowledge, relevant studies have been conducted in this context. For example, Hesami and Savoji [1], conducted a research on the topic of risk management in supply chain management using the DEMATEL technique and identified the impact of the most important supply chain risks which, in order of priority, were: environmental, financial resources, strategy, information and communication technology, equipment and technology. Saberi et al. [2], identified disruptive risks in the supply chain of Mobarakeh Steel Company and then reduced their potential effects for the next four periods. According to the experts of the company, graphite electrode was identified as the most strategic material required by the company and the risks associated with its supply were shown as the most important risks disrupting the supply chain. The weights of these risks were obtained by analytical network process that the most important risk was the risk of supplier inflexibility. Other risks, in order of their importance, were the risk of long delivery times of orders, low quality risk and price increase risk, respectively. Fakoor Saghih and Ulfat [3], conducted a study entitled supply chain risk management with the approach of identifying and dealing with vulnerable points and used the fuzzy TOPSIS method. Talebi and Iron [4], studied supply chain risks and supplier selection in the Iranian automotive industry using analytical network process. Then, the identified risks were considered as supplier selection criteria and the suppliers of Zamyad Automotive Company were prioritized using the analytical network analysis process. Kalyan and Surapati [5], used a combination of TOPSIS and neutrosophic to rank schools based on four criteria. Mohammadi and Shojaei [6], analyzed the results and achievements of previous studies using meta-synthesis. Among 401 studies found between 2000 and 2014, only 75 studies were selected for analysis. Finally, different aspects of supply chain risk management were classified into five main dimensions, seventeen sub-dimensions and one hundred and twenty-four feature codes. Then, using Shannon entropy, the position and effect of each feature code were evaluated. The results showed that the most important supply chain risks according to the content analysis included risks of supply, demand, information, product and flexibility and the most important risk reduction strategies included employing multiple suppliers, partnership and cooperation, supply strategy and the flexible product. Abdel-Basset et al. [7], used a hybrid approach to multi-criteria decision making. This hybrid approach involved hierarchical analysis in the Delphi framework and neutrosophic logic with trapezoidal numbers. The case study was international search engines. Sadeghi et al. [8], used analytical network process to analyze supply chain risks. The results showed that risk prioritization were: customer risk, financial risk, internal process risk and growth and learning risk, respectively.

Also, the key factors for the success of new product development, in order of priority, included: commercialization factor, product development team, marketing and technology. Sedighpour et al. [9], presented a resilient supply chain model in a study for the pharmaceutical industry. Abdel-Basset et al. [10], used the combined approach of SWOT strategic design matrix, hierarchical analysis and neutrosophic theory for multi-criteria decision making. In fact, the output options of the SWOT approach were ranked by neutrosophic hierarchical analysis. Aydin et al. [11], used neutrosophic hierarchical analysis to classify the factors affecting the security of websites. There were four main criteria and 17 sub-criteria for the method. Fakhrzad and Lotfi [12], in this study the issue of green backorder vendor managed inventory in two-echelon supply has been considered. But innovation in green conditions of this article or reducing the amount of pollution is as a function intended purpose. Jun Yi et al. [13], used a neutrosophic hierarchical analysis to rank five petrochemical stocks on the Kuala Lumpur Stock Exchange based on 15 financial indicators. The results of the research using Spearman and Pearson coefficient showed that the ranking of the combined research method is better than common approaches. Ravanestan et al. [14], conducted a study and used failure mode and effects analysis technique to determine supply chain resilience strategies before the occurrence of a failure and a new failure analysis after occurrence technique to determine supply chain resilience strategies after the occurrence of a failure. Relations between resilience strategies were determined using the DEMATEL method. In the some studies emphasis has been used a neutrosophic approach in their studies. Junaid et al. [15], used a combined approach of hierarchical analysis, TOPSIS and neutrosophic logic to classify the risks affecting the automotive industry in Pakistan. In this approach, first the criteria were weighted using neutrosophic pairwise comparisons and then the risks were assigned to the above three approaches and ranked using TOPSIS method. Lin and Luo [16], used a combination of TOPSIS method and triangular neutrosophic numbers to deal with the problem of transportation in critical and emergency cases and to cover uncertainty and ambiguity in the decision environment. Finally, the validity of the solutions was examined with an example. Lotfi et al. [17], indicated resilience and sustainable supply chain network design by considering renewable energy (RE) for the first time. In this study, presented a two-stage new robust stochastic optimization. The first stage locates facility location and RE and the second stage defines flow quantity between supply chain components. Lotfi et al. [18], presented a two-stage mixed-integer linear programming model for sustainable and resilient closed-loop supply chain network design considering conditional value at risk. Also, the robust counterpart model is used to handle uncertainties. Furthermore, conditional value at risk criterion in the model is considered in order to create real-life conditions.

According to the mentioned above, risks can be caused by various issues, and descriptions and surveys about these risks are generally associated with uncertainty, ambiguity, quality, and incomplete and sometimes contradictory information. Therefore, their ranking requires techniques that can model the issues mentioned. The most important contribution to this research is the use of neutrosophic logic. This modeling method is able to accept propositions with uncertainty, incomplete information, ambiguity, quality and even incompatibility. Accordingly, another innovation of this research is the presentation of a combined method of neutrophil hierarchical analysis and TOPSIS for risk rating. In Table 1, relevant studies are classified according to the research method and goal.

Table 1. Classification of the literature review.

Author(s)	Year	Method	Goal
Hesami and Savoji [1]	2012	DEMATEL	Identification the impact of the most important supply chain risk
Fakoor and Ulfat [3]	2015	Fuzzy TOPSIS	Identification the vulnerably points in the supply chain.
Kaylan and Surapati [5]	2015	TOPSIS; Neutrosophic	Ranking schools
Sadeghi et al. [8]	2017	AHP	Analysis supply chain risks
Aydin et al. [11]	2018	Neutrosophic hierarchical analysis	Classification the factors of website security
Yi et al [13]	2019	Neutrosophic hierarchical analysis	Ranking if the petro chemical stocks
Junaid et al. [15]	2020	TOPSIS; Neutrosophic	Classification the risk affecting of automotive industry
Lotfi et al. [17]	2021	Robust stochastic optimization	Definition a two stage new robust optimization
Lotfi et al. [18]	2021	MILP	Presentation a MILP model for sustainable and resilient closed loop supply chain network design
This research	2021	Neutrosophic analytical hierarchy process; TOPSIS	Ranking Factors Affecting Supply Chain Risk Mobarakeh Steel Company

3| Research methodology

Multi-criteria decision-making problems often have the same structure. In these problems, a number of options are ranked according to a number of criteria or characteristics. The objective of this study is to rank the supply chain risks of Mobarakeh Steel Company of Isfahan. As mentioned in the literature review, organizations choose strategies to deal with supply chain risks. These strategies can be in the field of promoting supply chain resilience, agility and robustness. Resilience strategies often refer to returning to normal activities at a reasonable time and after the occurrence of a risk. For example, relocating the manufacturing operations in the event of an earthquake can be a resilient measure. Agility strategies are based on speed and their goal is to adapt to the situation at the shortest possible time. The obvious difference between robustness strategies and the other two is that in this strategy, the works of the organization continue in the event of a disruption in the supply chain. For example, considering high inventory of raw materials can be a robust solution. Thus, risk management can begin by prioritizing resilience, agility, and robustness as key policies.

Assuming this introduction, in the first step of the research, these three criteria or supply chain characteristics are ranked by experts in order to deal with potential risks. So, pairwise comparisons are used in hierarchical analysis. Each expert can use one of the linguistic expressions in Table 2 for comparing the two criteria. In addition, each expert must state other three values corresponding to the degree of truth, the degree of indeterminacy, and the degree of falsity for the conducted comparison. In fact, each expert expresses a triangular neutrosophic number for pairwise comparison. Figure 1, shown research conceptual model.

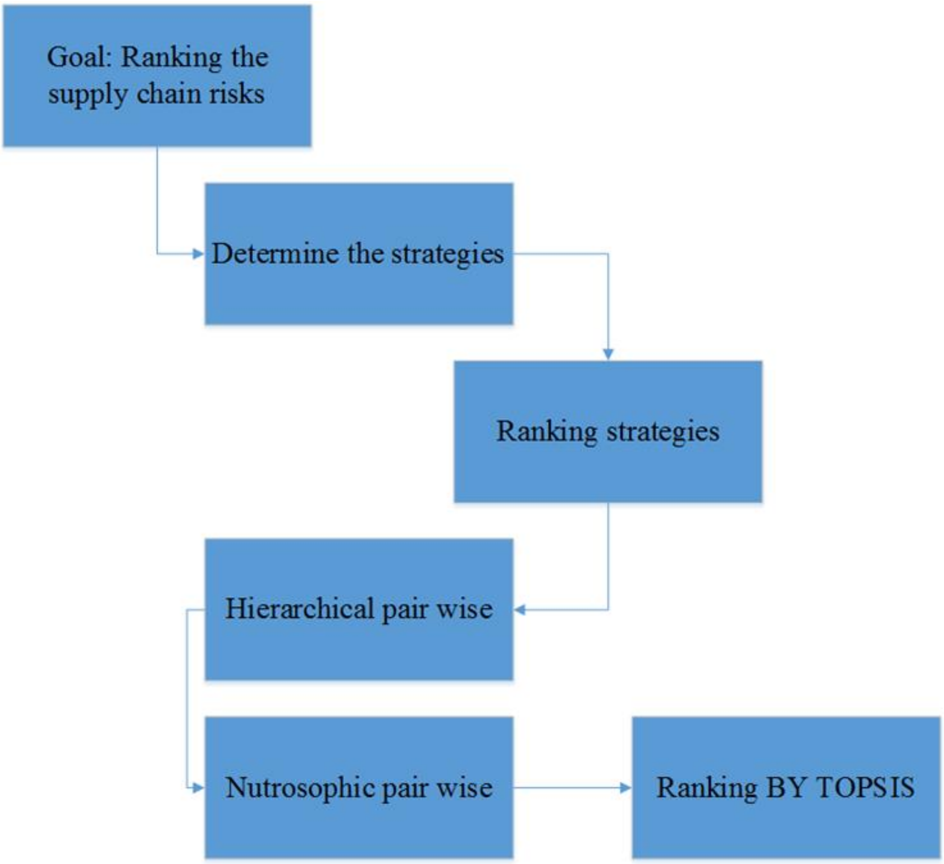

Fig. 1. Conceptual model.

Table 2. Comparative linguistic expressions and their triangular equivalents.

Number	Expressions	Triangular neutrosophic number (triangular section)
1	Equal importance	(1,1,1)
3	Relatively preferred	(2,3,4)
5	High preference	(4,5,6)
7	Very high preference	(7,8,9)
9	So high preference	(9,9,9)
2	Intermediate value	(1,2,3)
4		(3,4,5)
6		(5,6,7)
8		(7,8,9)

Therefore, a pairwise comparison table is created for each expert. Then these triangular neutrosophic numbers in Table 2 are converted to a real number by Equation (1). This method is called de-neutrosophic, and the resulting value is the score.

$$S_{(a_{ij})} = \left(\frac{L_{a_{ij}} + M_{a_{ij}} + U_{a_{ij}}}{8} \right), (2 + \alpha_{\alpha} + \theta_{\alpha} + \beta_{\alpha}) \tag{1}$$

Pairwise scores are then normalized and ranked. The consistency of pairwise comparisons is tested by inconsistency rate. After ranking the criteria, the options, the potential risks of the supply chain, are considered. Several sources of information were used to identify potential risks of the Mobarakeh Steel supply chain. So, in addition to examining the previous studies and extraction of factors, the opinions of experts and specialists, including interviews with three university professors (two in the field of industrial engineering and one in the field of industrial management), three production line experts, one production manager, two maintenance experts, one warehousing expert, one purchasing expert and one sales expert were used. The extracted risk factors are presented in Table (3).

Table 3. Risks related to the supply chain of Mobarakeh Steel Compan

Risk label	Title	Description
A1	Government restrictions	Compulsory pricing, enactment of restrictive trade laws, change of existing laws, obligation to reduce or increase exports, reduce or increase manufacturer obligations, etc.
A2	Natural disasters	Floods, earthquakes, fires, etc.
A3	Environmental and economic risks	Risks due to inflation, sanctions, taxes and environmental restrictions for waste management and gas emissions and the acquisition of standards and...
A4	Terrorist attacks	Fire, explosion and...
A5	Unresponsive IT system	Failure or inefficiency of communication system and network of the organization
A6	Risk of partner companies	Failure of partner companies such as underperformance of marketing companies
A7	Loading and transportation losses	Losses on long and risky routes
A8	Inventory shortage	Lack of raw materials and spare equipment and...
A9	Technology risk	High manufacturing cost due to not using new scientific methods in manufacturing and chain management and...
A10	Forecast error	Incorrect forecast of market supply and demand, market psychology, etc.
A11	Human error risk	Workforce errors

A12	Financial (cash) problems of suppliers	Insufficient budget of suppliers
A13	Order delivery delay by Suppliers	Suppliers are delayed in delivering products and services.
A14	Machinery failure	Unpredictable equipment failure
A15	Increase in prices for raw materials	Raw material prices fluctuate in the market.
A16	Low quality of suppliers	Low quality of products received from suppliers
A17	Supplier responsiveness risk	Unresponsiveness of suppliers through previous means of communication

At this stage, a triangular neutrosophic number is assigned to each option (A1-A17) and each criterion (resilience, agility and robustness), which is the expert opinion on the classification of the role of the three strategies to deal with it. As before, the opinions of experts are gathered and de-neutrosophicated; and the TOPSIS method will be used for ranking. Therefore, the score matrix that has a real form $X_{ij_{m\times n}}$ is converted into the matrix $R = r_{ij_{m\times n}}$ by normalization $r_{ij} = x_{ij} / \sqrt{\sum_{K=1}^{m} x_{ij}^{2}}$. By multiplying the normalized matrix in the weights of importance of the criteria, according to $t_{ij} = r_{ij}, w_j$, a weighted normalized weight matrix is obtained, and the positive and negative ideals are determined according to the relations (2). Note that in all criteria, larger numbers indicate the higher importance and priority and there is no negative criterion.

$$A_b = \{\max t_{ij} \mid i = 1,\dots,m\}$$
$$A_w = \{\min t_{ij} \mid i = 1,\dots,m\} \quad (2)$$

Then the distance of each option from the positive and negative ideals is calculated according to the following relations, respectively

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2}; i = 1,\dots,m$$
$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}; i = 1,\dots,m \quad (3)$$

Finally, the criterion of proximity coefficient is calculated for all units as relation (4).

$$S_{iw} = \frac{d_{iw}}{(d_w + d_{ib})} \quad (4)$$

At the end, the options are ranked according to the smallness of the proximity criterion.

4| Examining the numerical results

First, the pairwise comparison matrix related to the three criteria of resilience, agility and robustness is examined. Each expert expresses two ternary pairs or a triangular neutrosophic number in their pairwise comparison. The first ternary is the superiority of the first criterion over the second criterion according to Table (2) and the second ternary is based on neutrosophic logic indicating the truth (certainty), indeterminacy and falsity of the comparison (expert opinion). The opinions of 12 experts were summarized and gathered in Table (4) based on the averaging of fuzzy neutrosophic numbers and according to relation in Table 2.

Table 4. Summary of expert opinions.

Comparison	Resilient	Agile	Robust
Resilient	<[1,1,1],[1,0,0]>	<[2,3,4],[0.70,0.20,0.20]>	<[4,5,6],[0.65,0.30,0.30]>
Agile	<[0.25,0.33,0.50],[0.70,0.20,0.20]>	<[1,1,1],[1,0,0]>	<[2,3,4],[0.75,0.10,0.15]>
Robust	<[0.17,0.20,0.25],[0.65,0.30,0.30]>	<[0.25,0.33,0.50],[0.75, 0.10,0.15]>	<[1,1,1],[1,0,0]>

The summarized opinions are de-neutrosophicated based on relation and the results are presented in Table (5). The resulting numbers are called scores.

Table 5. Criteria score matrix.

Criterion	Resilient	Agile	Robust
Resilient	1	2.587	3.843
Agile	0.311	1	2.812
Robust	0.158	0.338	1

The scores obtained are normalized by dividing by the sum of the column in Table (6).

Table 6. Normalized scores.

	Resilient	Agile	Robust
Resilient	0.680	0.659	0.502
Agile	0.211	0.254	0.367
Robust	0.107	0.086	0.130

Finally, the relative weight (relative importance) of each criterion (resulting from averaging the rows) is according to Table (7):

Table 7. Relative importance of criteria.

Criterion	Resilient	Agile	Robust
Relative weight	0.613	0.278	0.108

Accordingly, the highest priority is related to adopting policies for supply chain resilience to deal with risk, and the next priorities are agility and robustness. To measure the consistency of pairwise comparisons $\lambda_{max} = 3.12$, the incompatibility index is 0.04 and the inconsistency rate is 0.069, therefore given that the IR is less than 0.1, the pairwise observations are consistent. Then the next step begins. At this step, 17 cases of risk in Table (3) were compared using triangular neutrosophic numbers according to the characteristics required to deal with them, namely resilience, agility and robustness. The summarized opinions of the experts are presented in Table (8).

Table 8. Summary of expert opinions in assessing the attribution of risks to criteria.

Criterion / Option	Resilient	Agile	Robust
A1	[6,7,8] [0.70,0.20,0.20]	[2,3,4] [0.70,0.20,0.15]	[4,5,6] [0.65,0.20,0.30]
A2	[2,3,4] [0.75,0.20,0.20]	[4,5,6] [0.80,0.10,0.10]	[7,8,9] [0.80,0.20,0.20]
A3	[7,8,9] [0.75,0.10,0.20]	[3,4,5] [0.75,0.10,0.20]	[1,2,3] [0.80,0.20,0.50]
A4	[2,3,4] [0.90,0.20,0.20]	[4,5,6] [0.80,0.30,0.20]	[7,8,9] [0.80,0.20,0.30]
A5	[2,3,4] [0.70,020,0.20]	[4,5,6] [0.80,0.25,0.30]	[7,8,9] [0.75,0.20,0.30]
A6	[3,4,5] [0.70,0.20,0.15]	[7,8,9] [0.80,0.20,0.15]	[2,3,4] [0.75,0.10,0.20]
A7	[2,3,4] [0.85,0.25,0.25]	[7,8,9] [0.75,0.15,0.15]	[3,4,5] [0.75,0.10,0.10]
A8	[6,7,8] [0.80,0.10,0.05]	[4,5,6] [0.80,0.20,0.10]	[2,3,4] [0.80,0.20,0.10]
A9	[7,8,9] [0.90,0.10,0.10]	[6,7,8] [0.80,0.20,0.20]	[3,4,5] [0.80,0.20,0.25]
A10	[7,8,9] [0.80,0.35,0.20]	[3,4,5] [0.80,0.20,0.20]	[6,7,8] [0.80,0.25,0.20]
A11	[5,6,7] [0.80,0.15,0.15]	[7,8,9] [0.85,0.20,0.20]	[5,6,7] [0.80,0.20,0.15]
A12	[3,4,5] [0.80,0.20,0.15]	[4,5,6] [0.80,0.10,0.15]	[1,2,3] [0.80,0.20,0.10]
A13	[6,7,8] [0.80,0.10,0.30]	[9,9,9] [0.80,0.10,0.30]	[3,4,5] [0.90,0.10,0.30]
A14	[5,6,7] [0.90,0.20,0.15]	[7,8,9] [0.90,0.20,0.25]	[4,5,6] [0.90,0.20,0.20]
A15	[2,3,4] [0.90,0.25,0.10]	[6,7,8] [0.95,0.25,0.15]	[6,7,8] [0.95,0.25,0.15]
A16	[2,3,4] [0.90,0.25,0.10]	[7,8,9] [0.85,0.15,0.25]	[2,3,4] [0.85,0.15,0.25]
A17	[4,5,6] [0.85,0.15,0.25]	[6,7,8] [0.75,0.15,0.15]	[7,8,9] [0.8,0.15,0.20]

Table 9. Score and normalized score matrix.

Criterion / Option	Resilient	Agile	Robust	Resilient	Agile	Robust
A1	6.038	2.644	4.031	0.781	0.342	0.522
A2	2.644	4.875	7.200	0.291	0.536	0.792
A3	7.350	3.675	1.575	0.878	0.439	0.188
A4	2.813	4.313	6.900	0.327	0.501	0.801
A5	2.588	4.219	6.750	0.309	0.504	0.806
A6	3.525	7.350	2.756	0.410	0.854	0.320
A7	2.644	7.350	3.825	0.304	0.845	0.440
A8	6.956	4.688	2.813	0.786	0.530	0.318
A9	8.100	6.300	3.525	0.747	0.581	0.325
A10	6.750	3.600	6.169	0.687	0.366	0.628
A11	5.625	7.350	5.513	0.522	0.682	0.512
A12	3.675	4.781	1.875	0.582	0.757	0.297
A13	6.300	8.100	3.750	0.577	0.741	0.343
A14	5.738	7.350	4.688	0.550	0.704	0.449
A15	2.869	6.694	6.694	0.290	0.677	0.677
A16	2.925	7.350	2.756	0.349	0.877	0.329
A17	4.594	6.431	7.500	0.422	0.590	0.688

Finally, by multiplying the normalized weight of each option in each criterion by the weight of each criterion, the table of weighted normalized weights is obtained, the result of which is presented in Table (10).

Table 10. Weighted normalized matrix.

Criterion / Option	Resilient	Agile	Robust
A1	0.479	0.095	0.056
A2	0.178	0.149	0.085
A3	0.539	0.122	0.020
A4	0.200	0.139	0.086
A5	0.189	0.140	0.087
A6	0.251	0.237	0.034
A7	0.186	0.234	0.047
A8	0.482	0.147	0.034
A9	0.45	0.161	A9
A10	0.421	0.101	A10
A11	0.320	0.189	A11
A12	0.357	0.210	A12
A13	0.353	0.206	A13

A14	0.337	0.195
A15	0.178	0.188
A16	0.214	0.243
A17	0.258	0.164

According to Table (10) and (8), the positive and negative ideals are presented in Table (11).

Table 11. Positive and negative ideals.

Criterion / Ideal	Resilient	Agile	Robust
Positive ideal	0.539	0.243	0.087
Negative ideal	0.178	0.095	0.020

The distance of each option to the positive and negative ideals was calculated according to relation and the relative proximity criterion was calculated according to relation and the results are presented in Table (12).

Table 12. : The distance of the options from the ideals and the criterion of proximity.

Index / Option	The distance to the positive ideal	The distance to the negative ideal	Criterion of relative proximity
A1	0.163	0.303	0.349
A2	0.372	0.084	0.814
A3	0.138	0.362	0.277
A4	0.354	0.082	0.810
A5	0.364	0.081	0.817
A6	0.292	0.160	0.645
A7	0.354	0.142	0.713
A8	0.123	0.309	0.285
A9	0.126	0.288	0.305
A10	0.185	0.248	0.427
A11	0.227	0.174	0.565

A16	0.328	0.153	0.681
A17	0.291	0.119	0.710

Since the lower the proximity criterion, the higher the option rank, the ranking of the options is described in Table (13).

Table 13. Ranking the options.

Risk	Relative proximity	Rank
Government restrictions	0.349	1
Environmental and economic risks	0.277	2
Inventory shortage	0.285	3
Technology risk	0.305	4
Forecast error	0.427	5
Financial (cash) problems of suppliers	0.474	6
Order delivery delay by Suppliers	0.483	7
Machinery failure	0.525	8
Human error risk	0.565	9
Risk of partner companies	0.645	10
Low quality of suppliers	0.681	11
Supplier responsiveness risk	0.710	12
Loading and transportation losses	0.713	13
Increase in prices for raw materials	0.773	14
Terrorist attacks	0.810	15
Natural disasters	0.814	16
Unresponsive IT system	0.817	17

To analyze the sensitivity of the ranking results with the combined approach of the research, some changes have been done to the relative weights of resilience, agility and robustness criteria. At first, 10% of the weight of the superior criterion or resilience was reduced and added to the second criterion or agility, and then, this 10% was added to the third criterion or robustness, and the proximity criterion for these two conditions was calculated in Table (14).

Table 14. Criterion of proximity by changing the relative weight coefficients of the criteria.

Sensitivity analysis approach / Option	Normal weight of the criteria	The weight of the first criterion is reduced by10% and the weight of the second criterion is added by 10%	The weight of the first criterion is reduced by10% and the weight of the third criterion is added by 10%
Government restrictions	0.349	0.389	0.370
Natural disasters	0.814	0.794	0.790
Environmental and economic risks	0.277	0.314	0.303
Terrorist attacks	0.810	0.793	0.786
Unresponsive IT system	0.817	0.799	0.792
Risk of partner companies	0.645	0.607	0.627
Loading and transportation losses	0.713	0.671	0/691
Inventory shortage	0.285	0.315	0.306
Technology risk	0.305	0.326	0.321
Forecast error	0.427	0.458	0.441
Human error risk	0.565	0.552	0.558
Financial (cash) problems of suppliers	0.474	0.462	0.472
Order delivery delay by Suppliers	0.483	0.471	0.480
Machinery failure	0.525	0.512	0.519
Increase in prices for raw materials	0.773	0.742	0.750
Low quality of suppliers	0.681	0.639	0.660
Supplier responsiveness risk	0.710	0.693	0.694

In the Figure 2 shown radar chart of the sensitivity analysis. The results show that in the two scenarios of sensitivity analysis, except for the change of ranks of A12 and A13, there are no other changes in the ranking, and therefore this ranking is at least 10% robust.

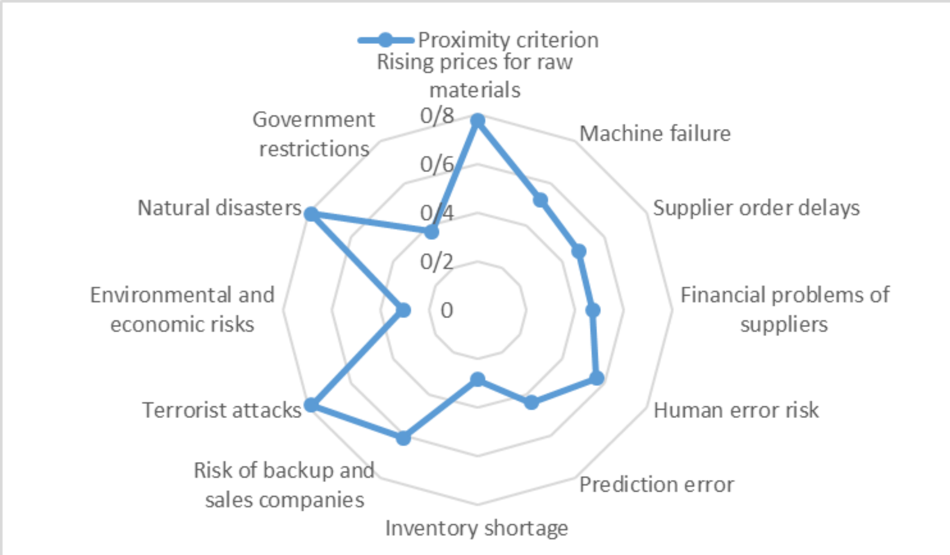

Fig. 2. Proximity criterion in sensitivity analysis.

5| Conclusion

The objective of this study was to rank the supply chain risk factors of Mobarakeh Steel Company of Isfahan with a combined approach of neutrosophic hierarchical analysis and TOPSIS. At first, three criteria of resilience, agility and robustness were ranked as general strategies of chain risk management. The approach used in this study was neutrosophic hierarchical analysis. Then, 17 identified risks in the supply chain were ranked based on their relationship with the criteria of resilience, agility and robustness using the TOPSIS method.

The research ranking shows that government restrictions are currently one of the most important risks for Mobarakeh Steel Company. To justify this issue, it should be noted that the current laws related to the sale of steel sheets in the commodities exchange and the application of price ceilings by the government can affect the total profitability and flexibility of the company. The second factor is environmental and economic risks. This group in particular includes economic sanctions, which restrict the flow of raw materials and equipment such as graphite electrodes and also impose high costs on the flow of exports to neighboring countries. The risk of environmental standards is justifiable due to the concerns about the company's impact on the climate of the region and the health of employees. Mobarakeh Steel Company is committed to minimize the environmental impacts of its activities and products by using appropriate methods and continuous improvement in operations observing general principles such as compliance with laws and regulations, effective establishment and continuous improvement of the environmental management system, sustainable development, product management, proper monitoring and reporting, and persuading and encouraging suppliers and contractors to protect the environment and consider environmental and social responsibilities. The fourth factor, the risk of inventory shortages, refers to the recent operations of the company in the supply of electric arc equipment, especially graphite electrodes. The issue of supplying raw materials needed by steelmakers, including iron ore, is one of the challenges of this industry. Existing mines have caused shortages in supplying raw materials for major steelmakers of the country, including Mobarakeh Steel Company, Zob-Ahan and due to developments beside the mines such as pelletizing and revival as well as steelmaking. Fifth rank belongs to the technology risk. The steel industry of the country is an export-oriented industry; therefore, planning to increase productivity and reduce costs is a key to its development. The next most influential risk is technology risk. Due to the importance of using up-to-date and advanced technologies in the country's steel units and keeping up with the global development of this industry, the issue of technology management has become an effective issue in the management of the steel industry. Mobarakeh Steel Company, as the largest steel unit in the country, has always tried to obtain production growth and increase the quality of its products by implementing appropriate models in the field of technology management and using advanced technologies in order to gain a greater share of international markets. Other risks with important ranks are forecast errors, especially in the field of the appropriate ratio of exports to domestic consumption, and financial problems of suppliers. The most important advantage of this research is the use of neutrophil logic. This modeling method is able to accept statements with uncertainty, incomplete information, ambiguity, quality and even inconsistencies in decisions. Also, another innovation of this research is the presentation of a hybrid method of hierarchical analysis of neutrophils and TOPSIS for risk rating. In addition, it is suggested that other decision-making methods such as ELECTRE, WASPAS, and ARAS be used for create hybrid method as further research.

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