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A Hybrid Model for Supply Chain Risk Management Based on Five-dimensional Sustainability Approach in Telecommunication Industry

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ABSTRACT

Sustainability of supply chain risk management is one of the main competitive advantages of every organization for long-standing. There are several models in the research literature to manage sustainability risks of the supply chain. Considering that critical risks have the highest impact and have the largest share of risk management resources, they need to be identified using special techniques to make risk management more accurate and more reliable. In this paper, a new three-phase model is presented to supply chain sustainability risks management. This model includes the failure mode and effects analysis phase for identifying and assessing all risks and classification them, fuzzy VIKOR phase for ranking critical risks, and management phase to deal with critical risks. The categorization of risks was conducted according to a new five-dimensional approach to sustainable progress, including environmental, economic, social, technical, and organizational aspects on various sectors of the supply chain. The telecommunication industry of Iran is considered to show the model performance. The results indicated that consideration of the fuzzy VIKOR phase is necessary in order to accurately assess critical risks because of the priority of critical risks is not correctly identified through Failure mode and effects analysis due to the shortcomings of this method and cause errors. It was also found that the technical risks initiated by the organization are the most dangerous risk that threatens the sustainability of the supply chain.

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1. INTRODUCTION

Development of sustainability, risk management and supply chain management are among the most important management concepts that guarantee the competitive advantage of organizations in the long run, in which risk analysis is one of the most important tools to maintain and improve the level of safety in the society and especially in industry [1]. The interconnected scope of these three scopes is "Supply chain sustainability risk management (SCSRM)", which means the management of risks that threaten the sustainability of the supply chain as illustrated in Figure 1. In comparison with traditional supply chain management, which emphasizes on logistical and economic performance [2-6], Supply Chain Sustainability Management (SCSM) is defined by integrating environmental and social ob-jectives alongside the expansion of economic dimensions [7]. Today, Sustainable Supply Chain is a crucial head of cost reduction, increased profitability and resource allocation across the supply chain in the long term [8-12]. While one of the most key research titles is supply chain risk management, recently and it is still under development [13,14], but Supply Chain Sustainability Risk Management (SCSRM) is relatively rare in academic literature [9].

Apart from the typical supply chain risks, raising public awareness about sustainability of business practices has created more or different risks for organizations [15-16]. Based on the research background [10,17,18], the sustainability risks of the supply chain include environmental, economic and social risks [19] such as environmental impacts on natural ecosystem, pollution of environmental resources, shortage of natural

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Figure 1. Supply Chain Sustainability Risk Management (SCSRM)

resources, drought, corporate reputation, social responsibility, social inequalities, child labor, financial statements, compliance with rules, tax evasion, sanctions, bribes, fluctuations in energy prices, financial crises, demographic challenges, and so on. The potential results of the risks can possess devastating impacts for the company that the supply chain management cannot simply cope with [20].

One of the most useful and effective methods for assessing the risk is the FMEA method [21]. Failure mode and effects analysis (FMEA) was first designed in the 1960s by the NASA program as an official method for evaluating reliability risks and safety requirements. This approach provides a framework for decision-making in risk management by identifying potential risks at a single level and examining their effects on higher levels of the system [22]. Today, FMEA has been widely used as a powerful tool for analyzing the safety and reliability of systems, products, and processes in a wide range of industries such as aerospace, nuclear, automotive, electronics and medical industries [23,24].

Recently, multi-criteria decision-making methods (MCDM) have been used for risk assessment in several studies [25-30] due to their ability to consider many factors with special weight and rank risks with professional techniques. VIKOR is one of the most popular MCDM methods that has been widely used in various scientific studies [31-38] due to its ability to solve MCDM problems with conflicting and non-commensurable criteria and present a compromise ranking list.

However, the VIKOR method focuses on ranking of a set of alternatives in the presence of conflicting criteria. It determines a compromise solution that could be accepted by the decision makers. Also, FMEA is often influenced by uncertainty in real-life applications, and in such situation fuzzy set theory is an appropriate tool to deal with this kind of problems [39]. In fact, the numerous shortcomings of FMEA published in recent studies (will be described in section 2.2), have led researchers to consider alternative approaches to risk assessment. Even scholars who referred to the limitations of FMEA method and presented several models to compensate it, have used the FMEA method in their models and then, by combining the FMEA with methods such as decision-making approaches (MCDM), have attempted to eliminate the FMEA shortcomings [25,40,41] etc. In fact, combining other methods with the FMEA method is to complement this technique and to resolve its deficiencies, and in general none of the studies conducted so far denies this method. Wang et al. [42] proposed a hybrid MCDM model in this study for improving FMEA. Liu et al. [43] propose a new model using interval 2-tuple hybrid weighted distance measure to improve the performance of the traditional FMEA. In order to assess the risk of delays of metro stations in Tehran based on the FMEA criteria, Hajiagha et al. [41] have used the VIKOR method in fuzzy environment. Safari et al. [44] evaluated enterprise architecture risks for managing all components of an enterprise using FMEA and fuzzy VIKOR.

The review of the research literature revealed some important points. First, there are some important shortcomings of FMEA and MCDM addresses to risk management when used alone. Aiming to take advantage of both methods and to cover their weaknesses, we have proposed a hierarchical approach by a combination of FMEA and fuzzy VIKOR for risk management to cover their limitations. It should be mentioned that, the approach is proposed in this paper has some differences between the works in the literature. First, the studies that have been conducted yet based on the combination of Fuzzy VIKOR and FMEA techniques, have been more focused on developing and improving the risk ranking. As a result, there is no functional and comprehensive framework for decision makers and industry experts to use FMEA's developed techniques in risk management. But in this research, by considering the managerial phase (the last phase of the three-phase model), the root causes and potential implications of each of the risks are identified and strategies to counter with them will be presented. Therefore, this study will be an operational framework for decision makers and the supply chain managers to properly manage their industry's sustainability risks based on the developed rating techniques. Second, most studies conducted on the basis of the combination of fuzzy VIKOR technique and the FMEA, have only considered the three criteria in calculating RPN (S, O & D) (section 2.1). Meanwhile, one of the limitations of the FMEA method is the lack of effective metrics. Also, according to the industry experts, more criteria should be considered to cover all aspects of risk. As a result, in this study, according to the industry experts, more criteria are considered in addition to the three criteria (S, O & D) (section 5.2). Third, the studies that have been performed so far based on the combination of the fuzzy VIKOR and FMEA technique, have implemented the calculations of the fuzzy VIKOR method by using the three criteria proposed in calculating RPN (S, O & D). In fact, these models do not categorize any critical, semicritical, and normal risks, and only rank the identified risks. While the industry decision makers are often interested in separating critical risks from other risks and managing them in a particular way. On the other hand, these models will be operational and usable if the number of risks is low, because complex and time-consuming calculations of fuzzy VIKOR for a large number of risks, many of which are not very important, is not operational and cost effective. Regarding these points, in this study, by using the simple and fast FMEA technique, critical risks were identified and then, for accurate rating of them, the fuzzy VIKOR technique would be implemented only on the critical risks.

On the other hand, based on the literature, few studies have been managed on the supply chain sustainability risks and sustainability risk management [10]. To the best of our knowledge, no comprehensive study has analyzed the all aspects of the supply chains in view of the different dimensions of sustainability. This research gap encouraged us to develop a comprehensive model for managing the supply chain sustainability, critical risks in different echelons, which is a completely new approach and there is not any similar case in the research literature especially in telecommunication companies. The main contributions and innovations of this paper are:

- A new three-phase model for supply chain sustainability risk management is proposed
- The risks were classified based on a five-dimensional approach to sustainability
- The risks were classified based on the four parts of the supply chain
- The FMEA method is used for identifying and assessing all risks and filter critical risks
- An extended fuzzy VIKOR method with more criteria than RPN criteria is used for ranking critical risks
- The proposed model is applied to the telecommunication industry of Iran

The risk of supply chain sustainability in service organizations is far more complex than that of manufacturing organizations. Supply of telecommunication companies for which little research has been done as well as their management strategy, which is one of the main objectives of the present research.

The rest of this paper is organized as follows. In sections 2 and 3, we describe the literature review and the model development. Then, in section 4 we introduce the result presentation of the research, and find the steps of the three-phase model with respect to the studied companies. In section 5, the discussion and managerial insights are presented. Finally, the conclusion is reported in section 6.

2. LITERATURE REVIEW

2. 1. Failure Modes and Effects Analysis (FMEA)

2. 1. 1. Implementation of FMEA To implement this method, a team of experts is formed to examine the relationship between error states, effects, causes, current controls and necessary corrective actions [45]. In order to allocate limited resources to address the most dangerous risks, each of the identified risks should be evaluated and prioritized. Typically, Risk Priority Number (RPN) is used to prioritize risks, which is the product of three risk factors (1);

$$RPN = S \times O \times P \quad (1)$$

where O is the probability of occurrence of the risk, S is the severity of the risk, and D is the probability of not de-tecting the risk.

According to research literature [46-48], the three risk factors are evaluated by experts using the 10-point scale de-scribed in Table 1. The risk with a higher RPN is more important and requires a higher priority to take corrective action.

2. 1. 2. Limitations of FMEA As mentioned, FMEA is one of the most important and strong preventive measures in risk management; however, according to the

TABLE 1. Traditional FMEA scale for S, O and D

Occurrence	Rank	Severity	Rank	Detection	Rank
Very high (>1 in 2)	10	Hazardous without warning	10	Absolute uncertainty	10
Very high (1 in 3)	9	Hazardous with warning	9	Very Remote	9
High (1 in 8)	8	Very high	8	Remote	8
High (1 in 20)	7	High	7	Very Low	7
Moderate (1in 80)	6	Moderate	6	Low	6
Moderate (1in 400)	5	Low	5	Moderate	5
Moderate (1in 2000)	4	Very Low	4	Moderate high	4
Low (1 in 15,000)	3	Minor	3	High	3
Low (1 in 150,000)	2	Very Minor	2	Very high	2
Remote (<1 in 1,500,500)	1	None	1	Almost certain	1

research literature [23,24,39,40,43,45,49], this method has been severely criticized for several reasons:

1. In calculating the RPN, the relative importance of all three factors is considered to be the same, but in real applications, it is possible that each factor affects the risk ranking with a different weight.
2. Different sets of O, S, and D ranking can create similar values of RPN, but the hidden implications of these risks may be completely different, causing resource and time losses in the risk management process or in some cases lead to ignoring some risks. Small changes in the rank of each of the three parameters may lead to very different effects on the RPN.
4. The data used in risk assessment are often unclear or ambiguous, and can be expressed using descriptions such as likely, important or very high and so on. The ranking of risk factors with crisp numbers (absolute numbers 1 to 10) is often difficult and error-prone.
5. The three O, S, and D parameters are evaluated based on discrete scales, where numerical operations on a discrete scale, especially multiplication, are meaningless. Therefore, the RPN results are not only meaningless, but actually misleading.
6. RPN considers only three factors O, S and D for risk assessment and ignores other effective factors such as economic aspects, which will result in the loss of a significant amount of information and reduce the accuracy of risk assessment results.
7. The 10-point scale using to evaluate each of the O, S, and D factors is questionable; For example, a linear transformation is used to evaluate D, while a non-linear transformation is used to evaluate O.

Due to the above shortcomings of FMEA for risk assessment, a multi-criteria decision making (MCDM) methods in fuzzy environment can be used as more systematic methods to cover FMEA weakness [43]. These methods can consider many factors with special weight and rank risks with professional techniques. Also, fuzzy environment can overcome the limitations caused by crisp values in proses of RPN calculation.

2. 2. Fuzzy VIKOR

One of the MCDM methods is VIKOR technique that used to handle multi-criteria problems with conflicting and non-commensurable criteria. In the VIKOR method, a compromise solution is the closest solution to the ideal one, and the purpose of compromising is obtaining a response based on the mutual agreement between the criteria.

To implement the VIKOR method in fuzzy environment and with the presence of a group of decision makers, the following steps have been proposed in the literature of the study [30,31].

Step 1: First, a linguistic diagram is defined in accordance with the problem and decision makers weighted each criterion and evaluated each alternative using proposed description (VL, L, ML, M, MH, H and V). Then, qualitative points considered by decision makers will be converted into fuzzy numbers using these charts (see Figure 2).

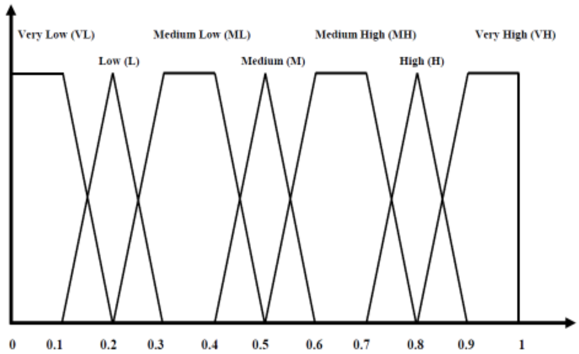

Figure 2. Linguistic variables for rankings (Sanayei et al. [31])

Step 2: Suppose that a group multi-criteria decision making (GMCDM) problem has K decision makers DMk (k = 1, 2, ..., K), m alternatives Ai (i = 1, 2, ..., m), and n decision criteria Cj (j = 1, 2, ..., n); then the aggregated fuzzy weights (w ̃_j) of each criterion can be calculated as follows [31]:

$$\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4}) \quad (2)$$

where

$$w_{j1} = \min\{w_{jk1}\}, w_{j2} = \frac{1}{k}\sum_{k=1}^{K} w_{jk2}, \quad w_{j3} = \frac{1}{k}\sum_{k=1}^{K} w_{jk3}, w_{j4} = \max\{w_{jk4}\} \quad (3)$$

Also, the aggregated fuzzy ratings (x ̃_ij) of alternatives with respect to each criterion can be calculated as follows:

$$\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4}) \quad (4)$$

where

$$x_{ij1} = \min\{x_{ijk1}\}, x_{ij2} = \frac{1}{k}\sum_{k=1}^{K} w_{ijk2}, w_{ij3} = \frac{1}{k}\sum_{k=1}^{K} w_{ijk3}, w_{ij4} = \max\{w_{ijk4}\} \quad (5)$$

Step 3: Then, using the COA defuzzification method to convert the fuzzy values ($\widetilde{w}_j$ and $\tilde{x}_{ij}$) to crisp values (w_j and x_{ij}) [36].

Step 4: Based on the defuzzied matrix in the previous step, the VIKOR method is implemented as follows [31]:

- Determine the best f_i^* and the worst f_i^-

$$f_i^* = max\ x_{ij},\ f_i^- = min\ x_{ij} \quad (6)$$

- Compute values S_i, R_i and Q_i

$$S_i = \sum_j W_i(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-}), \quad R_i = \max\{(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-})\}W_i \quad (7)$$

$$Q_i = \left(\frac{S_i - S^*}{S^- - S^*}\right)v + \left(\frac{R_i - R^*}{R^- - R^*}\right)(1 - v) \quad (8)$$

where

$$S_i^* = min\, S_i, S_i^- = max\, S_i\, , R_i^* = min\, R_i, R_i^- = max\, R_i \quad (9)$$

And v is introduced as a weight for the strategy of maximizing group utility, whereas $1 - v$ is the weight of the individual regret. The value of v is set to 0.5 in this study.

- The result of ranking: Based on the VIKOR method, the ranking of alternatives is arranged according to the ascending Q trend, and alternatives with lower Q will be given a higher priority.

3. THE MODEL DEVELOPMENT

According to the literature of the study, risk management generally includes five stages of identification, assess-ment, analysis, treatment and monitoring [10]. In this section, a three-phase model is presented for supply chain sustainability risk management based on the FMEA and fuzzy VIKOR techniques shown in Figure 3.

The reason for combining the FMEA and VIKOR techniques in this model is to use the benefits of each of the two methods and to avoid the limitations of each of them. The FMEA technique is a recognized and well-known methodology among industry experts, which is very useful for early screening of the risks due to the comprehensi-bility of the criteria and the simplicity of the calculations. From the expert's point of view, all the identified risks are not important and it is necessary to identify high and more dangerous risks, by using a simple and fast filter, so that the risk management resources are properly allocated and waste of time and money should be prevented. Therefore, by using the FMEA technique, all the identified risks are ranked to separate critical risks.

But, as discussed in section 2.2, the FMEA technique has some limitations that somewhat makes doubt about the accuracy of the results. Although the FMEA technique is valid enough to be used in the initial filtering of the risk and identifying high risk, but due to the existing deficiencies, this technique does not have the necessary accuracy to rank critical risks. Because critical risks are in fact the strategic bottlenecks for the risk management, and any errors in their identification and rating, encounters the risk management with a failure. In addition to the deficiencies, according to our industry experts, the criteria considered in the FMEA technique are not sufficient and do not cover all of the important dimensions of the industry risks. As a result, the model should include more criteria in order to achieve to the desired results. Therefore, it is proposed in this model in the continue, taking into account further criteria, by using a MCDM (fuzzy VIKOR method) approach, which is a complex and accurate ranking technique, in which the critical risks are carefully included. On the other hand, although the fuzzy VIKOR method has a high-ranking accuracy, but due to the complexity and time-consuming of the calculations, it is not possible to use it from the beginning to rank all the identified risks. Because the identified risks are too much and the use of a complex and long-lasting fuzzy method to rank all risks, practically makes the model unusable for the industrial users. In this way, by combining the FMEA and fuzzy VIKOR techniques, we take advantage of each of the two methods, and avoid any constraints, so that risk management can be implemented quickly and accurately.

The first phase is related to FMEA technique, which includes research configuration, risk identification and risk assessment using the RPN formula. Our purpose of implementing the FMEA phase is to identify all risks and seg-regate critical risks. Given the RPN shortcomings in prioritizing risks, the critical risks that have the most impact and the largest share of risk management resources, should be prioritized using a special ranking technique [40]. So, the second phase is a fuzzy VIKOR phase that ranks the critical risks in order to risk management will be conducted more accurately. The third phase is the managerial phase that defines strategies to deal with critical risks.

3. 1. FMEA Phase

FMEA phase, including five steps that named from F1 to F5;

Step F1 - Research configuration: Each risk management project has dimensions and objectives that the project framework needs to be defined at the beginning of the FMEA phase. In other words, it should be determined that the identification of risks should take place in what field and with what goals.

Step F2 - Industry identification and selection a sample: After designing the project framework, by holding interviews with experts, the industry is carefully identified and the appropriate sample is selected.

Step F3 - Risk identification: To identify the risks, brainstorming sessions and interviews with the presence of various levels of industry experts (managers, experts, technicians, etc.) are held to provide the list of all potential risks.

Step F4 - RPN calculation: After the risk list is prepared, the risk priority number (RPN) is computed.

Step F5 - Segregation of critical risks: Generally, in the FMEA method, there is no basis for RPN to determine critical risks. For this reason, in order to determine the critical level of risks, statistical methods have been used. For this purpose, a risk index is defined and then the critical level of risks is determined based on it. So, first, the average RPN will be calculated from the relation (10) and then their standard deviation will be calculated from the relation (11).

$$\bar{X} = \frac{1}{N}\sum_{k=1}^{n} X_i \quad (10)$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{k=1}^{n}(X_i - \bar{X})^2} \quad (11)$$

Based on the results obtained from the above relations, the classification of critical levels of risk based on RPN values are defined as Table 2.

3. 2. Fuzzy VIKOR Phase VIKOR phase, including five steps that named from V1 to V5;

Step V1 - Determining the ranking criteria: Due to the configuration of the project, the criteria affecting the ranking will be determined by the experts. One of the shortcomings of the FMEA methodology is to consider only three factors (S, O, and D), therefore, in this step, the criteria proportionate to the purpose of risk ranking should be set.

Step V2 - Forming the fuzzy group decision making matrix: At this stage, decision makers determine the weight of each criterion and complete decision-making matrix, based on the linguistic chart. Then, these qualitative points are converted to fuzzy values using the graph.

Step V3 - Aggregating group decision making matrix: Group decision making matrix is aggregated based on relations (2) to (5).

Step V4 - Defuzzification the aggregated matrix: Using the COA defuzzification method, aggregated fuzzy matrix convert to crisp matrix [32].

Step V5 - Implementation of the VIKOR method: Based on the crisp matrix in the previous step, the VIKOR method is implemented as follows:

- Determine the best f_i^* and the worst f_i^-
- Compute values S_i , R_i and Q_i
- Ranking alternatives, according to the ascending Q trend

TABLE 2. The critical levels of the identified risks

Level	Normal	Semi critical	Critical
Risk index	RPN $< \bar{X} - \sigma$	$\bar{X} - \sigma \leq$ RPN $\leq \bar{X} + \sigma$	$\bar{X} + \sigma <$ RPN
Control action	Neglected	Preventive measure	Urgent preventive measure

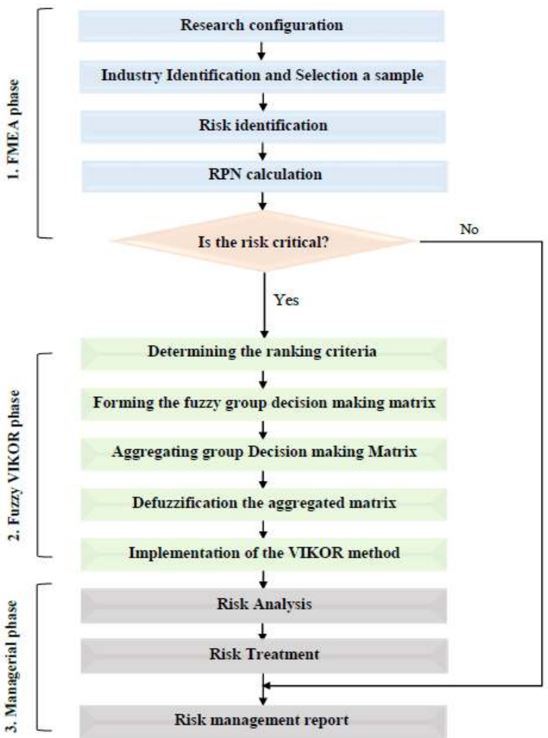

Figure 3. The flow chart of proposed model

3. 3. Managerial Phase Managerial phase, including three steps that named from M1 to M3;

Step M1 - Risk Analysis: The root causes and potential consequences of each of the risks are identified by holding interviews with industry experts. Risk analysis is an important step in the process of risk management. An or-ganization can take the most appropriate strategy to deal with those risks only if they understand the root causes and correctly predict the potential consequences of the risks.

Step M2 - Risk treatment: Four major responses or strategies have been proposed in the research literature for risk treatment which includes avoiding or eliminating root causes, controlling or reducing the impact of the risk and the probability of risk occurrence, transferring or sharing the impact of the risk and the acceptance of the po-tential damages. In this step, depending on the root causes or the possible results of each risk, the appropriate strategy is selected and the Control action will be defined in accordance with this strategy.

Step M3 - Risk Management Report: Finally, the critical risks list, along with the results of the ranking, root causes and potential consequences, as well as the strategy for coping with each risk, will be presented in the risk man-agement report. Risk Management Report in this step is the introduction of two stages of implementation and monitoring of risk management strategies.

4. CASE STUDY

The companies that work in Iranian telecom industry have engaged with many challenges and unpredictability such as a complicated sustainability risk management of the supply chain in comparison with those in rest of the world. Therefore, in this research the case study described by Valinejad and Rahmani [50] in the Iranian telecommunication industry is considered. They investigated 14 public and private sector companies operating internet service providing and bandwidth areas.

4. 1. FMEA Phase

Valinejad and Rahmani [50] used the FMEA approach to identify the mentioned supply chain sustainability risks of Iranian telecommunication companies. They designed a matrix based on the five dimensions of sustainable development and supply chain segments in Table 3 and named each cell of the table based on the first letters of the supply chain sectors and the dimensions of sustainable development.

The dimensions of the sustainable development include five dimensions of environmental, social, economic, technical and institutional that are more relevant to the business environment. Here is a brief overview of each of these five sustainability dimensions according to the literature studies [10,17]:

- Environmental dimension: Conservation of natural resources, the prohibition of waste production and environmental pollution, the proper use of non-renewable resources, etc.
- Social dimension: Reducing poverty, improving the quality of living conditions, observing ethical principles and human rights, etc.
- Economic dimension: Profitability and sustainable economic growth, avoidance of financial corruption, strict monitoring of financial statements, etc.
- Technical dimension: Technical abilities, equipment capabilities, quality of infrastructure and specialized industry issues, etc.
- Institutional dimension: Adherence to legal issues, lasting relationship with governments and partners, political stability, etc.

We have utilized the data reported by Valinejad and Rahmani [50]. They identified 15 critical risks based on the FMEA approach.

4. 2. Fuzzy VIKOR Phase

Step V1 - Determining the ranking criteria: Considering sustainable development concept, 6 criteria were introduced in order to ranking supply chain sustainability critical risks. The criteria which determined by holding interviews with experts, include two criteria used in the RPN calculation and four other criteria that were chosen with a view to sustainable development, triggered covering more dimensions of the issue of sustainability in the ranking in Table 4.

- Severity: Strength of risk in making the supply chain unsustainable
- Occurrence: The sequence of risk occurrence within a specified time period
- Uncontrollability of risk occurrence: The lack ability to prevent the risk occurrence
- The complexity of risk treatment: The difficulty in identifying, controlling and managing risk
- Comprehensiveness of risk impact: The ability of risking in making the greater parts of the supply chain un-sustainable
- Durability of risk impact: Risk capability in long-term impact on supply chain sustainability

Step V2 - Forming the fuzzy group decision making matrix: At this stage, four industry experts, as four decision makers, determined the weight of each criterion and score for each of the alternatives using qualitative terms. Table A1 (In Appendix) indicates the qualitative decision-making matrix and the weight of the criteria. In the results tables, critical risks are shown by HRi (High Risk).

Step V3 - Aggregating Group Decision making Matrix: The qualitative matrix in the previous step is converted to fuzzy matrix using the linguistic diagram as Figure 2. Then the fuzzy matrix aggregated based on relations (2) to (5). Table A2 (In Appendix) indicated the aggregated fuzzy matrix.

TABLE 3. The critical levels of the identified risks

Risks categories		The causes of sustainability risks in the supply chain			
		Suppliers (S)	**Organization (O)**	**Consumers (C)**	**Environment (E)**
The affected sustainability dimensions	Environmental (En)	S.En	O.En	C.En	E.En
	Economic (Ec)	S.Ec	O.Ec	C.Ec	E.Ec
	Social (S)	S.S	O.S	C.S	E.S
	Technical (T)	S.T	O.T	C.T	E.T
	Institutional (I)	S. I	O. I	C. I	E. I

TABLE 4. Research configuration

C_j	C_1	C_2	C_3	C_4	C_5	C_6
	Severity	Occurrence	Uncontrollability of risk occurrence	The complexity of risk treatment	Comprehensiveness of risk impact	Durability of risk impact

Step V4 -Defuzzification the aggregated matrix: Using the COA defuzzification method, aggregated fuzzy matrix convert to crisp matrix in Table A3 (Appendix).

Step V5 - Implementation of the VIKOR method: Based on the crisp matrix in the previous step, the VIKOR method is implemented as follows:

- Determine the best f_i^* and the worst f_i^- in Table 5.
- Compute values S_i , R_i and Q_i in Table 6.

Ranking alternatives, according to the ascending Q trend in Table 7.

4. 3. Managerial Phase

Step M1 - Risk Analysis: Root causes and potential result of each risk are presented in the risk management report in Table A4 (In Appendix).

Step M2 - Risk treatment: Strategies and control actions for each risk are presented in the risk management report in Table A4 (In Appendix).

Step M3 - Risk Management Report: The description of each risk and its position in the configuration (based on Table 3), along with the results of the ranking of VIKOR technique, root causes and potential consequences, as well as the strategy for coping with each risk, will be presented in the risk management report in Table A4 (In Appendix).

TABLE 5. The best and the worst values

Values	C_1	C_2	C_3	C_4	C_5	C_6
f_j^*	0.8625	0.84375	0.84375	0.84375	0.88125	0.73125
f_j^-	0.48125	0.35	0.5	0.43125	0.35	0.3125

TABLE 6. The values S_i , R_i and Q_i

HR	Q	R	S
HR1	0.173296	0.217647	0.980107
HR2	0.583692	0.567273	3.02006
HR3	0.416223	0.583428	1.11458
HR4	0.54001	0.63125	2.11927
HR5	0.604823	0.63125	2.81448
HR6	0.447854	0.482276	2.13726
HR7	0.647904	0.721107	2.6695
HR8	0.274703	0.304114	1.48365
HR9	0.389357	0.461076	1.65302
HR10	0.263481	0.240369	1.79395
HR11	0	0.068671	0.127762
HR12	0.660735	0.664549	3.18924
HR13	1	0.8625	5.49095
HR14	0.646066	0.565574	3.70058
HR15	0.29263	0.296926	1.72451

TABLE 7. The ranking of the critical risks by S, R and Q in ascending order

HR	by Q	by R	by S
HR1	2	2	2
HR2	10	9	12
HR3	7	10	3
HR4	9	11	8
HR5	11	12	11
HR6	8	7	9
HR7	13	14	10
HR8	4	5	4
HR9	6	6	5
HR10	3	3	7
HR11	1	1	1
HR12	14	13	13
HR13	15	15	15
HR14	12	8	14
HR15	5	4	6

5. DISSCUSION AND MANAGERIAL INSIGHTS

According to the risk management results the critical risks ranking based on fuzzy VIKOR is not consistent with prioritization of risks in terms of RPN (based on comparing "Ranking by fuzzy VIKOR" column with "RPN" column in Table 12). In other word, ranking critical risks based on the fuzzy VIKOR, does not approve the primary priority of critical risks based on the RPN. Due to the shortcomings of FMEA in calculating RPN in risk assessment on the one hand and strength of the fuzzy VIKOR to cover these limitations on the other hand, this inconsistency was predictable and validated the results of the ranking based on the fuzzy VIKOR. Furthermore, the results of the critical risk ranking by FMEA and Fuzzy VIKOR, were provided by experts. From the viewpoint of the industry experts and decision makers, rating of the critical risks based on the Fuzzy VIKOR technique was much more logical than the results of the FMEA approach.

Therefore, the need to use special ranking techniques for risk assessment, especially critical ones, is proven. However, in this study, it was attempted to use the both FMEA and Fuzzy VIKOR techniques to provide industry managers with a comprehensive and applicable framework to quickly, accurately and easily manage the sustainability risks of the supply chain. In the model presented in this paper, using the simplicity and speed of the FMEA method in risk assessment, it was attempted to identify critical risks, and then, by using the accuracy and power of Fuzzy VIKOR Method in ranking, critical risks are carefully ranked. Using this model, time and cost and risk management resources are focused on the critical risk and the strategic risks of the supply chain are properly managed.

Also, according to the results of the ranking, mismanagement and lack of strategic management system (the technical risk generated by the organization or O.T risk) is the most dangerous risk that threatens the supply chain sustainability. This necessitates the necessity of efficient and effective implementation of the strategic management system in the supply chain.

It should be noted that the model presented in this study will be generally applicable to managers and suppliers of the supply chain experts in other industries.

According to macro policies and the 20-year vision document of Iran's development, the issue of sustainable development has become one of the most important principles of micro and macro planning. Common supply chain risks are more aimed at increasing profits and reducing costs from an economic perspective, but supply chain sustainability risks are also emphasized in addition to the social and environmental dimensions. For the sustainability of the two social dimensions, attention is paid to improving the quality of social conditions of all stakeholders. In the economic dimension, the trend of profitability is considered. For environmental sustainability, the consumption of non-renewable resources and the production of waste to protect the environment must be minimized. One of the important points for telecom managers is to discover the root causes and determine the potential consequences of each of the risks in the four areas of suppliers, organizations, consumers, and the environment and to adopt an appropriate strategy to deal with the risks and their effects.

The types of supply chain sustainability risks of telecommunication companies under three headings of critical, semi-critical and normal risks form a normal curve, so that 70% of them are semi-critical risks that require preventive action, some of which are addressed. as follow: In semi-critical risks, the power of all components of the supply chain should be focused on increasing interaction and compliance with global and national laws, as well as improving the quality and quantity of technical equipment and specialized human resource capabilities. In order to maintain the stability of the supply chain in telecommunication companies, the organization should focus on increasing the specialized capabilities of human resources, improving the quality and quantity of technical equipment and increasing the capacity of its infrastructure, invested employee motivation, creativity and participation. Emphasizes the importance of increasing the organization's interaction with suppliers, consumers and the environment as a key factor in reducing supply chain risk.

From a managerial point of view, in relation to suppliers as the largest producer of critical risks, there should be more focus and cost for the organization to interact with suppliers. Emphasis should be placed on improving the social status within the organization in order to reduce supply chain risk. Government suppliers such as the Telecommunication Company and the Telecommunications Infrastructure Company and the Radio Regulatory Company should invest in improving telecommunication infrastructure and services and products such as the quality of bandwidth, insufficient capacity of telecommunication platforms and centers. Governance risks such as sanctions, political instability, multiple and unsustainable policies are aspects of sustainable development that are most threatened.

6. CONCLUSION

Summary: In this study, it was tried to combine the advantages of each of them with the combination of fuzzy VIKOR and FMEA Technique, by avoiding the limitations of each of the two methods. After identifying all risks in the FMEA phase, the critical risks were separated and entered the fuzzy VIKOR phase for more accurate ranking. In the fuzzy VIKOR phase, critical risks were ranked and the importance and priority of dealing with each of the critical risks was precisely determined.

Then, in the management phase (last phase), the root causes and potential outcomes of each of the risks were identified and, by using the opinion of the decision makers and industry experts, an appropriate strategy for managing each of the risks was determined.

Application of the paper: Regarding to the expansion of the subjects related to the sustainable development, risk management, supply chain management and the combination of FMEA and fuzzy VIKOR, the outcome of this study are reflective for researchers who are seeking study in these areas. Also, these results help people involved in the supply chain management in the supply chain of telecommunication companies, particularly.

Limitations and future researches: Furthermore, suggestions for future research will be proposed:

1. Due to the time limitation, the sustainability risk management strategy was not deployed completely and its results were not analyzed. The future research will focus on deploy it and assess its outcomes and measure success rate.
2. Many studies have been done to combine MCDM approaches with the FMEA technique, and to overcome FMEA constraints, various techniques have been used, such as VIKOR, TOPSIS, ELECTERE, AHP, and so on. In this study, the combination of the VIKOR method with the FMEA technique was used because of the attractive features of the VIKOR method (ranking and selection from a set of alternatives in the presence of conflicting criteria and determining a compromise solution that could be accepted by decision makers). But it will be very attractive and suitable for future studies about this case, used to combine other MCDM approaches with the FMEA technique, and the results of each model are compared in terms of industry experts to the validity of each technique in this case to be determined.

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Appendix:

TABLE A1. Qualitative rating of fifteen critical risks and qualitative weight of six risk factors.

DM1	C_j	C_1	C_2	C_3	C_4	C_5	C_6	DM2	C_j	C_1	C_2	C_3	C_4	C_5	C_6
	Wj	**H**	**H**	**MH**	**M**	**M**	**ML**		**Wj**	**VH**	**H**	**MH**	**MH**	**M**	**M**
	HR1	H	H	H	VH	MH	VH		HR1	H	MH	H	H	MH	MH
	HR2	M	M	M	L	ML	L		HR2	M	ML	M	ML	L	L
	HR3	H	H	H	M	M	H		HR3	MH	H	H	H	M	H
	HR4	MH	H	H	M	ML	M		HR4	H	H	MH	M	H	M
	HR5	M	M	MH	M	L	L		HR5	MH	M	MH	M	ML	L
	HR6	H	H	M	M	M	L		HR6	H	H	H	M	M	M
	HR7	M	M	H	M	ML	L		HR7	ML	M	MH	ML	ML	L
	HR8	H	MH	H	H	H	M		HR8	H	M	H	MH	MH	ML
	HR9	M	M	VH	H	H	MH		HR9	H	M	VH	H	H	H

	HR10	H	H	VH	H	MH	M		HR10	MH	H	MH	MH	H	M
	HR11	H	H	H	H	VH	H		HR11	VH	H	H	H	VH	H
	HR12	M	H	VH	H	H	M		HR12	M	MH	H	MH	H	M
	HR13	ML	M	M	M	L	ML		HR13	M	L	M	M	L	M
	HR14	M	M	H	M	M	ML		HR14	M	ML	M	M	ML	M
	HR15	H	H	MH	H	M	ML		HR15	M	H	MH	H	M	M
DM3	C_j	C_1	C_2	C_3	C_4	C_5	C_6	**DM4**	C_j	C_1	C_2	C_3	C_4	C_5	C_6
	Wj	**VH**	**MH**	**H**	**H**	**MH**	**MH**		**Wj**	**H**	**MH**	**M**	**M**	**ML**	**L**
	HR1	VH	H	H	VH	H	H		HR1	H	MH	MH	M	M	ML
	HR2	MH	ML	ML	ML	L	L		HR2	H	VH	H	H	MH	MH
	HR3	H	H	MH	MH	H	MH		HR3	H	VH	H	H	MH	M
	HR4	MH	MH	MH	ML	H	H		HR4	M	M	MH	M	M	M
	HR5	MH	MH	MH	ML	ML	L		HR5	VH	VH	M	M	M	M
	HR6	H	H	M	MH	M	M		HR6	MH	MH	MH	M	M	M
	HR7	M	M	MH	M	M	M		HR7	H	VH	MH	H	MH	M
	HR8	MH	MH	H	H	MH	H		HR8	H	H	VH	H	VH	H
	HR9	H	MH	MH	MH	H	H		HR9	VH	MH	VH	MH	MH	MH
	HR10	MH	MH	MH	MH	MH	MH		HR10	VH	MH	MH	VH	VH	MH
	HR11	VH	H	H	VH	VH	H		HR11	H	H	VH	H	H	MH
	HR12	MH	MH	MH	MH	MH	M		HR12	M	M	ML	M	ML	ML
	HR13	ML	L	ML	ML	M	ML		HR13	MH	M	MH	M	M	M
	HR14	M	MH	M	M	MH	M		HR14	H	H	MH	MH	MH	M
	HR15	H	H	MH	H	MH	M		HR15	VH	VH	VH	VH	H	VH

TABLE A2. Aggregated fuzzy rating of fifteen critical risks and aggregated fuzzy weight of six risk factors

C_j	C_1	C_2	C_3	C_4	C_5	C_6
Wj	(0.7,0.4,0.45,0.8)	(0.7,0.4,0.45,0.8)	(0.7,0.4,0.45,0.8)	(0.7,0.4,0.45,0.8)	(0.7,0.4,0.45,0.8)	(0.7,0.4,0.45,0.8)
HR1	(.7, .825, .85, 1)	(.5, .7, .75, .9)	(.5, .75, .775, .9)	(.4, .775, .825, 1)	(.4, .625, .675, .9)	(.2, .65, .725, .9)
HR2	(.4, .6, .625, .9)	(.2, .575, .575, 1)	(.2, .525, .55, .9)	(.1, .4, .45, .9)	(.1, .325, .375, .8)	(.1, .03, .325, .8)
HR3	(.5, .75, .75, .9)	(.7, .825, .85, 1)	(.5, .75, .775, .9)	(.4, .675, .7, .9)	(.4, .6, .625, .9)	(.4, .675, .7, .9)
HR4	(.4, .625, .675, .9)	(.4, .675, .7, .9)	(.5, .65, .725, .9)	(.2, .45, .475, .6)	(.2, .6, .625, .9)	(.4, .575, .575, .9)
HR5	(.4, .65, .725, 1)	(.4, .625, .675, 1)	(.4, .575, .65, .8)	(.2, .45, .475, .6)	(.1, .325, .375, .6)	(.1, .275, .275, .6)
HR6	(.5, .75, .775,.9)	(.5, .75, .775, .9)	(.4, .6, .625, .9)	(.4, .525, .55, .8)	(.4, .5, .5, .6)	(.1, .425, .425, .6)
HR7	(.2, .525, .55, .9)	(.4, .6, .625, 1)	(.5, .65, .725, .9)	(.2, .525, .55, .9)	(.2, .425, .5, .8)	(.1, .35, .35, .6)
HR8	(.5, .75, .775, .9)	(.4, .625, .675, .9)	(.7, .825, .85, .1)	(.5, .75, .775, .9)	(.5, .725, .8, 1)	(.2, .6, .625, .9)
HR9	(.4, .75, .775, 1)	(.4, .4, .6, .8)	(.5, .825, .925, 1)	(.5, .7, .75, .9)	(.5, .75, .775, .9)	(.5, .7, .725, .9)
HR10	(.5, .725, .8, 1)	(.5, .7, .75, .9)	(.5, .675, .775, 1)	(.5, .5, .8, 1)	(.5, .5, .8, 1)	(.4, .55, .6, .8)
HR11	(.7, .85, .9, 1)	(.7, .8, .8, .9)	(.7, .7, .85, 1)	(.7, .825, .85, .1)	(.7, .875, .95, 1)	(.5, .75, .775, .9)
HR12	(.4, .525, .55, .8)	(.4, .625, .675, .9)	(.2, .65, .725, 1)	(.4, .625, .675, .9)	(.2, .625, .675, .9)	(.2, .45, .475, .6)
HR13	(.2, .425, .5, .8)	(.1, .35, .35, .6)	(.2, .475, .525, .8)	(.2, .45, .475, .6)	(.1, .35, .35, .6)	(.2, .4, .45, .6)
HR14	(.4, .575, .575, .09)	(.2, .55, .6, .9)	(.4, .6, .625,0 .9)	(.4, .525, .55, .8)	(.2, .5, .0575, .08)	(.2, .45, .475, .6)
HR15	(.4, .75, .775, 1)	(.7, .825, .85, 1)	(.5, .675, .775, 1)	(.7, .825, .85, .1)	(.4, .6, .6, .9)	(.2, .55, .6, 1)

TABLE A3. Crisp rating of fifteen critical risks and Crisp weight of six risk factors.

C_j	C_1	C_2	C_3	C_4	C_5	C_6
Wj	0.8625	0.775	0.65	0.63125	0.5	0.5875
HR1	0.84375	0.7125	0.73125	0.75	0.65	0.61875
HR2	0.63125	0.5875	0.54375	0.4625	0.4	0.38125
HR3	0.725	0.84375	0.73125	0.66875	0.63125	0.66875
HR4	0.65	0.66875	0.69375	0.43125	0.58125	0.6125
HR5	0.69375	0.675	0.60625	0.43125	0.35	0.3125
HR6	0.73125	0.73125	0.63125	0.56875	0.5	0.3875
HR7	0.54375	0.65625	0.69375	0.54375	0.48125	0.35
HR8	0.73125	0.65	0.84375	0.73125	0.75625	0.58125
HR9	0.73125	0.55	0.8125	0.7125	0.73125	0.70625
HR10	0.75625	0.7125	0.7375	0.7	0.7	0.5875
HR11	0.8625	0.8	0.8125	0.84375	0.88125	0.73125
HR12	0.56875	0.65	0.64375	0.65	0.6	0.43125
HR13	0.48125	0.35	0.5	0.43125	0.35	0.4125
HR14	0.6125	0.5625	0.63125	0.56875	0.51875	0.43125
HR15	0.73125	0.84375	0.7375	0.84375	0.625	0.5875

TABLE A4. The result of propose method

Group	Rank	Description of the risk	Root factors	Potential consequences	Strategy	Performance
O.T	1	Inefficient management and lack of strategic management system	The lack of a strategic management system	Lack of successful provision and implementation of strategic and tactical plans	Avoid	Design and implement effective strategic management
E.I	2	Problems against the privatization of the industry	Anti-privatization approach and regulations	Inability of the organizations to use all of the internal and external capacities	Reduce	Interaction and conversation with the lawmakers The creation of mechanisms to make the supply chain flexible with regulations
E.Ec	3	The impact of currency fluctuations on contracts and projects	Domestic and foreign economic and political changes	Impose additional costs on contracts and irregularities in paying and receiving the receivables	Reduce	Long-term planning in network development, which leads to time estimation and the currency of buying facilities. Providing facilities through trading card
S.T	4	Deviation from the provision time of goods and services (customs problems, lack of transfer of equipment and services on due time, lack of on time delivery of outsourcing software by the contractors, etc.)	Restrictions caused by the sanctions, custom rules and lack of proper interaction with the contractors	Loss of proper opportunity to provide services to subscribers	Reduce	A true estimation and long-term planning to relatively control and overcome predicted problems Conversation and interaction with domestic and foreign suppliers
C.Ec	5	The high sensitivity of consumers to the price of products according to the competitiveness of industry and disloyalty	Competitiveness of industry and disloyalty of customers	High probability of declining market share	Reduce	Increasing customer loyalty and belonging of the subscribers to an organization's brand by creating key competitive benefits and mechanisms such as the formation of customers' club

E.I	6	Political changes and instability in macro decisions	Political changes	Irregularities in the rules imposed on the organization and supply chain	Accept	Interaction and conversation with the lawmakers - The creation of mechanisms to make the supply chain flexible with regulations
S.T	7	Inadequacy of existing infrastructures to provide services (failing to provide the required bandwidth)	Low quality of infrastructures	Inability to provide high quality service and desired quantity to subscribers	Accept	Planning to invest in higher-quality infrastructure
S.I	8	Products and exclusive services of suppliers and the higher bargaining ability of the origin company due to the provision of exclusive services	Providing exclusive services due to the integration of broadband	Reducing the ability to bargain and increasing vulnerability of the organization	Reduce	Interaction with the origin company with the accompaniment of all companies present in the industry
S.T	9	Low capacity for the development in telecommunication centers	Exclusiveness of the available capacity by the origin company	Reducing market share	Accept	Planning to invest in centers with greater capacity
S.Ec	10	The costs of licensing and inappropriate tariffs and multiple penalties	Rules and numerous restrictions of the origin company to provide exclusive services	Imposing heavy costs to the organization	Reduce	Strict compliance of requirements and legislation Interacting with origin to meet the needs of the organizations
S.Ec	11	Higher cost of providing the exclusive bandwidth of the origin company	Exclusiveness of bandwidth by the origin company	Imposing heavy costs to the organization	Reduce	Interaction with origin company with the accompaniment of all companies present in the industry to reduce the cost of broadband
O.S	12	Problems in capabilities of human resources (Lack of motivation, lack of job satisfaction, lack of creativity and accountability, problems in work ethics and competition culture)	Problems of individuals and organizations and society	Reducing the efficiency of human force and increased absenteeism and leave of the organization	Avoid	Efforts in providing facilities and creating motivating incentives to increase creativity and involvement of employees
S.I	13	Disapproval or delay in approving the requested licenses by the origin company (intensive bureaucracy)	Intensive bureaucracy	Loss of opportunity to provide services to subscribers	Reduce	Interaction with the origin company with the accompaniment of all companies present in the industry
E.I	14	Continuation and intensification of sanctions	Problems in international relations and foreign policies	Increased economic and technological vulnerability of the organization and supply chain	Reduce	-Relying on domestic capabilities and capacities -Providing through foreign trade intermediaries -Making contracts with new supply sources of original equipment
S.T	15	Scientific dependence of the company due to problems for production, transfer and knowledge registration for the company	The lack of contractor's tendency to produce, transfer and knowledge registration for the company	Increasing technological vulnerability of the organization	Avoid	Including the act of registering and transferring knowledge in the contracts

Persian Abstract

چکیده

پایداری مدیریت ریسک زنجیره تامین، یکی از اصلی ترین مزیت های رقابتی برای هر سازمان بصورت پایدار است. چندین مدل در ادبیات تحقیق برای مدیریت ریسک های پایداری زنجیره تامین وجود دارد. با توجه به اینکه ریسک های بحرانی بیشترین تأثیر و سهم را از منابع مدیریت ریسک دارند، باید با استفاده از تکنیک های خاص شناسایی گردند تا مدیریت ریسک دقیق تر و قابل اطمینان تر شود. در این مقاله، یک مدل سه فازی جدید برای مدیریت ریسک های پایداری زنجیره تامین ارائه شده است. این مدل شامل فاز تحلیل حالت شکست و اثرات برای شناسایی و ارزیابی تمامی ریسک‌ها و طبقه‌بندی آن‌ها، مرحله VIKOR فازی برای رتبه‌بندی ریسک‌های بحرانی و فاز مدیریت برای مقابله با ریسک‌های بحرانی است. طبقه‌بندی ریسک‌ها بر اساس یک رویکرد پنج بعدی جدید برای پیشرفت پایدار، شامل جنبه‌های زیست‌محیطی، اقتصادی، اجتماعی، فنی و سازمانی در بخش‌های مختلف زنجیره تامین انجام شد. صنعت مخابرات ایران برای نشان دادن عملکرد مدل در نظر گرفته شده است. نتایج نشان داد که در نظر گرفتن مرحله VIKOR فازی برای ارزیابی دقیق ریسک‌های بحرانی ضروری است، زیرا اولویت ریسک‌های بحرانی به‌دلیل کاستی‌های این روش و ایجاد خطا از طریق تحلیل حالت شکست و اثرات به درستی شناسایی نمی‌شود. همچنین مشخص شد که ریسک های فنی آغاز شده توسط سازمان خطرناک ترین خطری است که پایداری زنجیره تامین را تهدید می کند.