E-ISSN: 2676-6167 | P-ISSN: 2538-5100

Journal of Applied Research on Industrial Engineering

www.journal-aprie.com

J. Appl. Res. Ind. Eng. Vol. 8, No. 2 (2021) 129–149.

Paper Type: Research Paper

# Proposing an Integrated Model for Evaluation of Green and Resilient Suppliers by Path Analysis, SWARA and TOPSIS

**Ali Mansory[1],*, Abbas Nasiri[1], Nabiollah Mohammadi[1]**

[1] Department of Management, University of Zanjan, Zanjan, Iran; mansory.ali@znu.ac.ir; abbas.nasiri@gmail.com; nabi_mohammadi@yahoo.com.

**Citation:**

Mansory, A., Nasiri, A., & Mohammadi, N. (2021). Proposing an integrated model for evaluation of green and resilient suppliers by path analysis, SWARA and TOPSIS. *Journal of applied research on industrial engineering*, *8*(2), 129-149.

Received: 07/09/2020 Reviewed: 06/11/2020 Revised: 06/01/2021 Accepted: 20/02/2021

## Abstract

The main purpose of this paper is to identify the traditional, green and effective resilience criteria in the performance of green and resilient suppliers and their ranking with path analysis, SWARA and TOPSIS combined approach in Fanavaran Petrochemical Company. The research method is applied in terms of goal and descriptive-survey in terms of data collection. By a comprehensive review of the literature, first a set of key performance criteria and sub-criteria (traditional, green, and resilience) were extracted. Then, using the path analysis approach, the effectiveness of these criteria was evaluated in Fanavaran Petrochemical Company. The statistical population included 55 experts of the mentioned company, which due to the limited size of the population, all members were considered as the research sample. The path analysis result showed that all identified criteria affect the company's supplier's performance. Then, using new SWARA decision-making technique and also the opinions of 30 experts, the criteria and sub-criteria were evaluated and their weight (importance) was extracted. In the final evaluation of the main criteria, the criterion of "resilience" was in the first rank, the criterion of "green" in the second rank and the criterion of "traditional" in the last rank. Subsequently, due to the sensitivity of the ranking of green and resilient suppliers in the company, using the TOPSIS decision-making technique and based on the extractive weight of the criteria, seven suppliers of the company were evaluated by the experts and the final ranking of the suppliers in terms of performance was determined. Thus, the proposed approach of this research provides a valuable conceptual framework for company' managers to improve the situation of the suppliers in terms of the environmental issues and resilience. Also, the development and improvement of traditional criteria and selection of suppliers of the company based on green standards and resilience were the main goals of this research.

**Keywords**: Performance, Green and resilient suppliers, Path analysis, SWARA, TOPSIS.



## 1 | Introduction

In recent years, the advent of new technologies and shifts in global markets have necessitated the supply chain management, so that different organizations use supply chain management inevitably to create and maintain their competitive position. Some company strategies in managing business that can be implemented are Supply Chain Management (SCM).

Corresponding Author: mansory.ali@znu.ac.ir

10.22105/jarie.2021.256316.1206

Supply chain includes all activities related to the flow and exchange of goods and services ranging from the consumable raw material stage to the final product stage. In addition to the material flow, these interactions include information flow and financial discussions [11, 34]. This system acts as a connection between the inputs of an organization and its outputs.

The primary goal of a chain is to provide and meet the customer needs in the value production process. The purpose of each chain is to maximize its total value production in a defined time interval. Chain profitability is the total profit that should be divided in all stages of the chain. Therefore, the success of a chain is defined in terms of its profitability, and supply chain management requires managing the flows between and within the steps of a chain to maximize its total profitability.

Nowadays, sustainable development depends on the optimal preservation and use of limited and non-replaceable resources in countries. Various measures have been taken by governments to deal with this issue including the use of environmental-friendly raw materials in production and industrial centers, reducing the use of fossil and petroleum resources and reusing waste [19].

Observing government regulations to meet the environmental standards and growing consumer demand for green products in the supply chain, which cover all activities related to the flow of goods from the raw material stage to the delivery of goods to end consumers, including the flow of information across the chain, have led to the emergence of a new concept of "green supply chain management" that includes the stages of the product life cycle from design to recycling [17].

Srivastava [40] defines green supply chain management as considering the environmental issues in supply chain management, such as product design, material selection and sourcing, final product delivery to the customer, and product management after consumption and its useful life. Accordingly, green supply chain management is similar to the product life cycle. Global organizations are always seeking to achieve competitive advantage through the creation of innovations and new approaches. Some of these organizations gain competitive advantage by improving the environmental performance by adhering to environmental laws and standards, enhancing customer knowledge and reducing negative environmental impacts on their products and services.

Selection of supplier refers to the issue of multi-criteria decision making in evaluating the performance of suppliers by several criteria with the aim of purchasing items from the most suitable supplier. Despite the importance of price, other evaluation criteria affecting the efficiency and productivity of the production environment and the overall costs of companies, such as timely delivery and other elements should also be considered. Ha and Krishnan [15] updated these criteria and added several traditional criteria. According to their research, the most traditional criteria for business performance in supplier evaluation include quality, cost, and delivery. The general green standards also include the environmental management systems for resource consumption, the environmental design, and waste management [29]. Purchasing management usually considers traditional and green performance appraisal criteria and may ignore resilience criteria [24] and [29]. Resilience in the sense of system capability to adapt efficiency and expected and predictable performance disorders and return the system to the natural process, is considered as an essential aspect of any supply chain management system [29].

In the present study, a new approach has been proposed to integrate the three main and fundamental criteria for evaluating suppliers (traditional business, green and resilience criteria). Despite extensive studies, none of them met all the criteria simultaneously with the combined approach to path analysis and decision-making techniques. Considering the research gap, this study has examined all the performance criteria (traditional, green and resilience) simultaneously in selecting the suppliers of Fanavaran Petrochemical Company. The petrochemical industry is one of the leading and biggest industries by employment that, as a feeder for other sectors of the industry, can play a key role as the engine of the country's economy. Iran has an effective role in the petrochemical industry due to its vast oil and gas resources and being located on the world's energy highway. On the other hand, due to the high added value of the petrochemical industry, this industry has a high position in the national economy and is considered a competitive advantage. Also, according to the upstream and downstream connection of this industry with other industries, the expansion of its capacities makes it possible to have a positive impact on the growth and economic development of the country. In addition, considering the effects of the petrochemical industry on the environment and its various pollutants, the development of this industry is not possible without considering the above-mentioned cases and will have irreparable consequences for the country.

Fanavaran Petrochemical Company (Public Joint Stock) was established on 1998/4/28 and registered with registration number of 2017.02 in the Office of Corporate Registration and Industrial Property. The company is active in the establishment, startup and operation of methanol, acetic acid and carbon monoxide units for export, utilization in the petrochemical industry and downstream industries and is consistent with the industry's major export goals, policies, employment creation, transfer of technical knowledge, specialist training and production of high value-added petrochemical products from natural gas. Given the importance of green supply chain management at Fanavaran Petrochemical Company, the necessity for operational implementation of this system in this industry is obvious. For doing so, at first, designing and explaining the model of key factors affecting the implementation of green supply chain management in Fanavaran Petrochemical Company is essential. Main purposes of present research are: 1. Identification the effective factors on implementation of GSCM at the Company in Iran by using statistical methods 2. Evaluating the factors by using a new method of MADM by topic SWARA and finally ranking them based on weight and importance.

SWARA is one of the new methods of MCDM which was used in 2010 to develop analysis of the differences between the criteria. In SWARA, each expert ranks the criteria at first. The most important criterion is scored one and the least important one receives low score. Finally, the criteria are prioritized according to average values of the relative importance [2].

To this end, this research aims to answer the basic question: what factors have a significant impact on the implementation of green supply chain management in Fanavaran Petrochemical Company and how is the rank (weight & importance) of these factors?

The organization of the remaining sections in this paper is as follows: Section 2, reviews the research literature and proposes conceptual model; Section 3, presents the research questions; the research methodology is presented in Section 4. Section 5, presents the findings of research; finally, conclusion and recommendations are presented in Section 6.

## 2 | Literature Review and Conceptual Model

In this section, review of literature and background is discussed in two parts: 1- traditional and green performance criteria, 2- resilience criteria in supplier evaluation and then an integrated conceptual model including selection criteria for green and resilient suppliers is presented.

### 2.1 | Traditional and Green Criteria

Most previous studies have focused on evaluating and selecting suppliers based on traditional performance criteria and fewer studies have identified green performance and resilience criteria and evaluation based on these criteria [29] and [13]. On the other hand, in none of the previous researches, all the functional criteria (traditional, green and resilience) have been studied simultaneously. Therefore, the selection of suppliers by decision makers is based on only one of these criteria. Tirkolaee et al. [6] presented a novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echelon supply chain design. This paper applies the Fuzzy Analytic Network Process (FANP) method to ranking criteria and sub-criteria, the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) is applied to identification of the relationships among the main criteria, and the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to prioritizing the suppliers. After prioritizing the suppliers, the obtained weights are considered as the input of a tri-objective model designed to optimize the proposed supply chain. Vafaei et al. [43] examined the mediating role of innovation and sustainable process management on the relationship between sustainable supply chain management and sustainable competitive advantage. The statistical population consists of 20 companies involved in the production of banking equipment. Since the size of the statistical population is very small, structural equations model and partial least squares approach were used to analyze the research data and to test the hypotheses of the research. The results showed that there is a positive and significant relationship between sustainable supply chain management and sustainable competitive advantage. Moreover, it was found that innovation and sustainable process management variables play a mediating and moderating role on the relationship between sustainable supply chain and sustainable competitive advantage. Amani et al. [4] identified barriers to green supply chain acceptance using Fuzzy DEMATEl Technique. Extracted factors in this research were Outsourcing, technology, knowledge, finance and support. Govindan and Sivakumar [14] developed an integrated multi-criteria decision-making and multi-objective linear programming approach as an aid to select the best green supplier. Gandhi et al. [12] evaluated the important factors associated with the successful implementation of GSCM. This paper proposes a DEMATEL approach to develop a structural model for evaluating the influential factors among recognized factors. To show the real-life applicability of the proposed DEMATEL based model, an empirical case study of an Indian manufacturing company is conducted. Research findings indicate that Top Management Commitment, Human Technical Expertise, Financial Factors, has obtained the highest influential power for accomplishing the successful GSCM adoption. Conclusions and implications for managers are also discussed. Tyagi et al. [42] identified seven green criteria (including saving energy, design for environment, waste minimization, reuse of hazardous waste, awareness about green concept, information sharing regarding environmental regulations and proper mode of transport) and three mutually important alternatives namely as suppliers, web-based technologies and advanced manufacturing technologies. On the basis of considered criteria and alternatives, a hierarchy type performance model has been developed and analyzed using Fuzzy TOPSIS approach to select the best alternative in order to improve the performance of GSCM system. The findings suggested that alternative 'web-based technologies' is more desirable among considered alternatives and insert a significant role in enhancing the green supply chain performance of an industry.

Given the literature review, traditional key criteria in evaluating suppliers' performance are: Costs (TC1); quality (TC2); delivery reliability (TC3); performance history (TC4); turnover (TC5); lead time (TC6); operating capacity (TC7) were considered [29]. Also, key green criteria in evaluating suppliers' performance were proposed as *Table 1* [29] and [41]).

**Table 1. Key green criteria in evaluating suppliers' performance.**

| | |
|---|---|
| Adherence to the required standards (GC1) | Government participation and regulations and standards.<br>Materials and compliance with the standards required for the purchase of raw materials.<br>Designing products to reduce energy and material consumption.<br>Green production and packaging.<br>Procurement, distribution and reverse logistics. |
| Compliance with environmental issues (GC2) | Recycling and reuse of waste inside and outside the company.<br>Environmental certificates.<br>Total environmental quality management. |
| Management Commitment and employees and customer requirements (GC3) | Human resources employment management and technical Assistance.<br>Top management commitment.<br>Customer requirements. |

## 2.2 | Resilience Criterion

Supply chain management involves a variety of complex set of activities established by unpredictable events. For doing so, improving the resilience of the supply chain is essential for the management of strong disorders. The concept of resilience, the ability of a company or supply chain to resist and improve at the same time against disruptions, is very important from supply chain management perspective. Supplier disruptions can impose significant losses on the entire supply chain by cutting off supply flows. Resilience criteria refer to the ability of suppliers to deal with risks and unexpected and unpredictable events that affect performance of the suppliers [29]. A review of the literature shows that studies are limited to using quantitative approaches to solving supplier selection problems. Mitra et al. [27] identified several criteria in selecting resilient suppliers. Haldar et al. [16] developed a fuzzy multi-criteria decision-making approach by considering the degree of importance of scientific indicators in the form of linguistic variables formulated with triangular and trapezoidal fuzzy numbers. Sahu et al. [37] proposed a supportive decision support system for suppliers using the Vikor method and taking into account general criteria and resilience. Pramanik et al. [32] suggested a fuzzy multi-criteria decision-making approach to develop and select resilient suppliers. Mohammed et al. [29] evaluated Green and Resilient Supplier Performance using AHP-Fuzzy TOPSIS Decision-Making Approach. They ranked suppliers with respect to their Traditional, Green and Resilience characteristics (TGR). A set of criteria/sub-criteria were identified within a unified framework and their relative importance weighted using the Analytical Hierarchy Process (AHP) algorithm. In addition, the suppliers were evaluated and ranked based on their performance towards the identified TGR criteria using the fuzzy TOPSIS algorithm through a real case study. The study provides a noteworthy aid to management who understand the necessity of building supply chain resilience while concurrently pursuing 'go green' responsibilities.

Following the review of the literature, the resilience criteria in evaluating the performance of suppliers were proposed as *Table 2*.

Table 2. The resilience criteria in evaluating the performance of suppliers.

| | |
|---|---|
| Redundancy (RC1) | Mohamed et al. [29]; Kamalahmadi et al. [22] |
| Agility of Supply Chain (RC2) | Mohamed et al. [29]; Purvis et al. [33]; Rajesh and Ravi [35] |
| Complexity (RC3) | Carvalho et al. [8]; Blackhurst et al. [7] |
| Visibility of Supply Chain (RC4) | Kamalahmadi et al. [22]; Rajesh and Ravi [35] |
| Flexibility (RC5) | Rajesh and Ravi [35]; Jayaram et al. [21] |



### 2.3 | The Integrated Conceptual Model

In this study, considering the extensive review of literature, the main and key criteria (traditional, green, resilience) in evaluating the performance of suppliers were identified and extracted. *Fig. 1* shows the conceptual model of the hierarchical series of criteria (traditional, green and resilience) and sub-criteria for selecting suppliers.

## 3 | Research Questions

Given the proposed conceptual model, the following questions arise:

- *What are the factors affecting the implementation of "traditional, green and resilient" suppliers integrated performance evaluation in Iranian petrochemical company?*
- *What is the importance (weight) of the identified factors in this company?*
- *What is the performance rating of the company's suppliers in terms of all criteria (traditional, green and resilience)?*
- *What effective solutions can be provided for managers to deal with the obstacles to the establishment of an integrated system and to improve the status of this system for implementation in the Iranian petrochemical company?*

## 4 | Research Methodology

This study is an applied research in terms of purpose and descriptive-survey in terms of data collection. This research, as survey studies, systematically describes the current situation through a questionnaire tool and studies its characteristics. Data collection was performed through questionnaires and interviews. This research was conducted for studying the impact of identified factors and finally extracts the final factors in Fanavaran Petrochemical Company's Green Supply Chain Management System with mean statistical test. The statistical population consisted of the experts and managers and specialists with useful experience and expertise in this system (55 people). All members of the community were participated because of their limitations. In sum, the research approach proposed in this study was developed in four stages. In the first step, the traditional and green key criteria and sub-criteria and effective resilience on the supply chain management system were identified and presented as a conceptual model. In the second step, using the path analysis approach, the final criteria affecting the integrated supply chain management system in Fanavaran Petrochemical Company were specified. Then, in the third step, the weight (importance) of the criteria and sub-criteria was calculated and extracted using the SWARA decision-making technique. Finally, in the fourth section, using the TOPSIS decision-making technique, the suppliers of the company were evaluated and ranked based on performance.

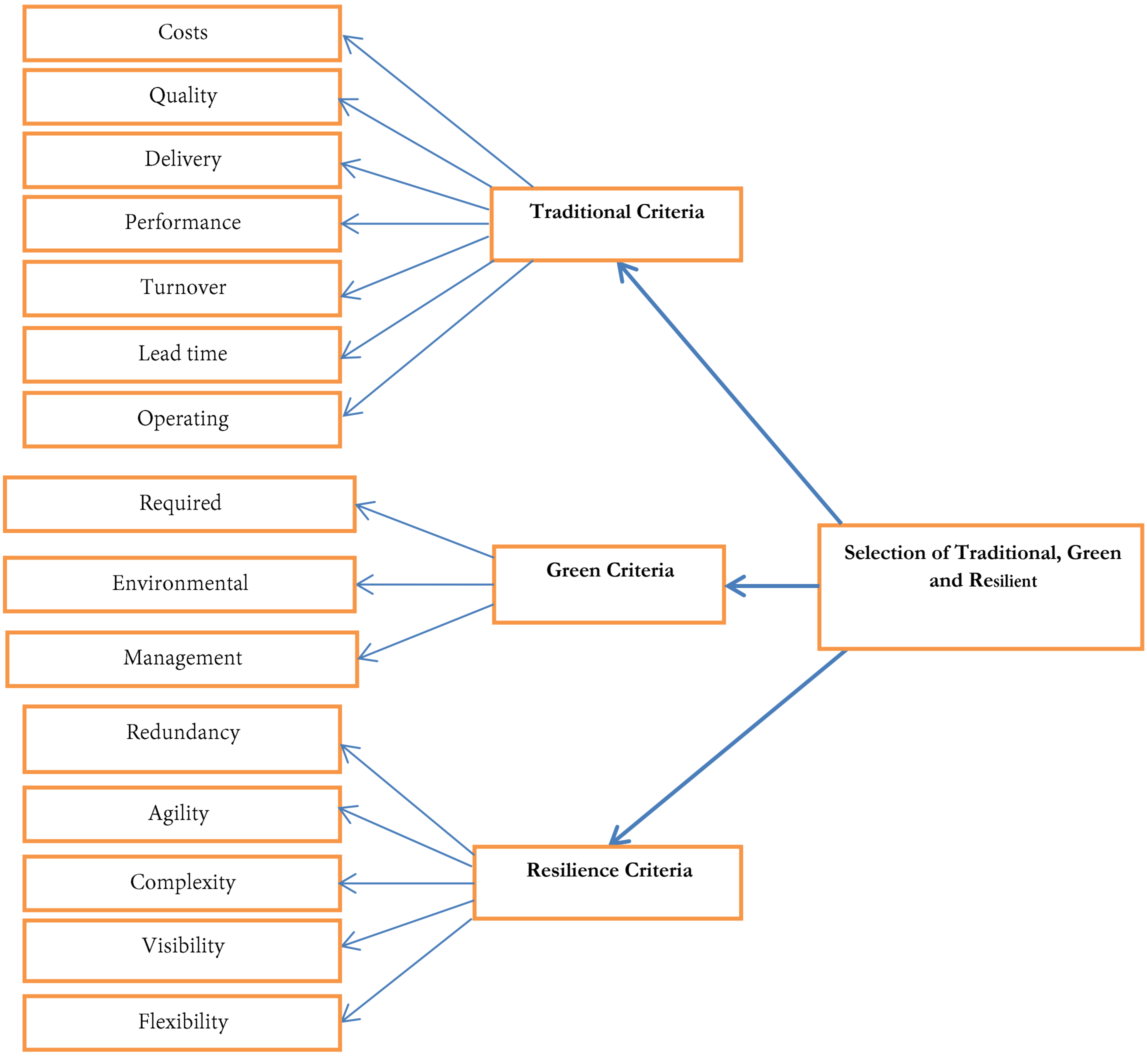


**Fig. 1. The conceptual model of the hierarchical series of criteria (traditional, green and resilience) and sub-criteria for selecting suppliers.**

In order to implement the SWARA decision making technique, the viewpoints of at least 10 experts of the studied company (30 people in this study) were used in a second questionnaire designed for this purpose. This type of sampling is a non-probability random sampling method and usually 10 to 20 people are considered sufficient. In this study, the researchers achieved this number of experts with theoretical saturation in the field because theoretical saturation occurs when the data that helps to define a class characteristics is no longer entered into the research and all comparisons are made. In fact, these experts are all first rank managers of Fanavaran Petrochemical Company and are fully knowledgeable on the subject. Then, these criteria were entered into the present research questionnaire and were given to experts to express their views on the importance of criteria in terms of impact. Next, using the SWARA technique steps, the questionnaire data were analyzed to weight these key criteria and rank them. In this technique, the expert assesses the calculated weights. In addition, each expert specifies the importance of each criterion according to tacit knowledge, information and experience. Then, according to the average value of the group's ranks obtained by experts, the weight of each criterion is determined. Therefore, in this study, the interviews of 20 Iranian Industries experts were used. The weight of each criterion indicates its importance. Measuring of weight is an important topic in many issues of decision-making. SWARA is one of the weighting methods in which professionals play an important role in the calculation of their weight and final assessment [2].

In order to rank the performance of green and resilient suppliers, the TOPSIS technique is used using the opinions of 30 experts. This technique is one of the most cost-effective compensating methods for alternative rankings. This technique is a compromise subgroup of compensatory models. In this method, the $m$ option is evaluated by $n$ index and each issue can be considered as a geometric system including $m$ point in a subsequent $n$ space. This technique is based on the concept that the selected option should be the shortest distance from the solution of the positive ideal (best possible state, $A_i^+$) and the longest distance from the solution of the negative ideal (worst possible solution, $A_i^-$). It is assumed that the utility of each indicator is uniformly increasing or decreasing. In analyzing complex multi-criteria problems, TOPSIS is a well-known technique used to rank options by scoring them to arrive at a desirable solution. The main advantages of this method compared to similar methods such as AHP is that if the decision criteria include reducing cost and purpose or increasing profit, this method easily finds the ideal answer, which is a combination of the best values to meet all criteria. *Fig. 2* shows the flowchart methodology presented in this study.

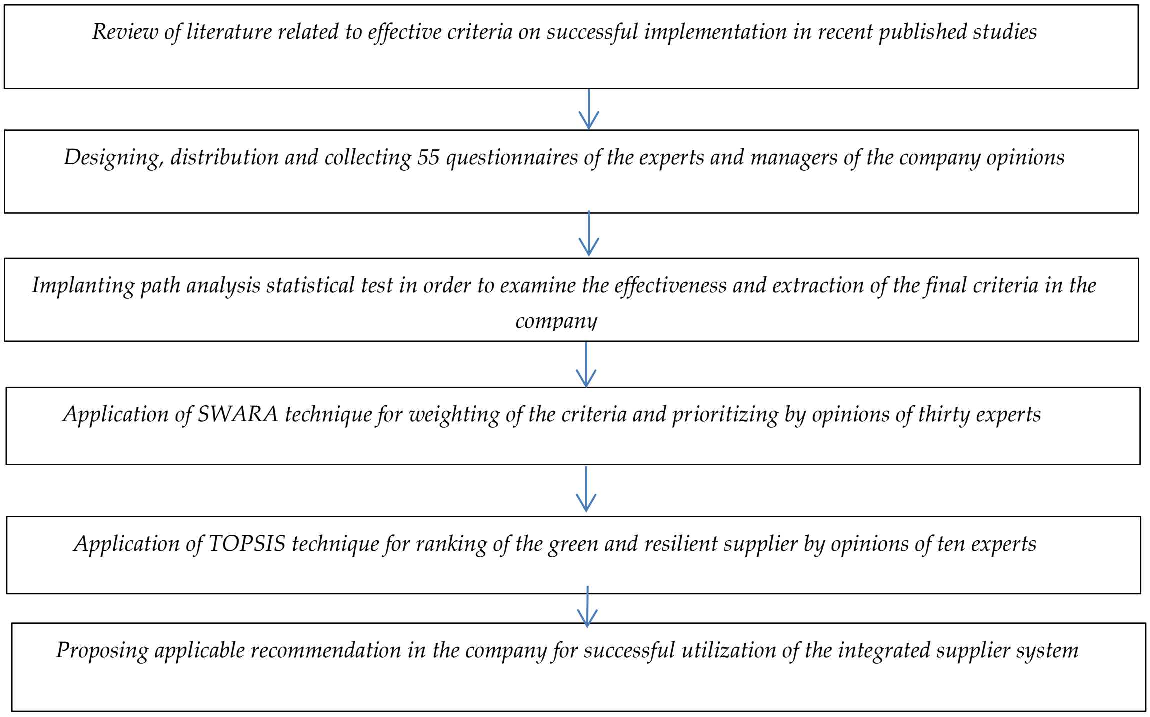


**Fig. 2. Research methodology flowchart.**

In summary, the steps for conducting this research are as follows:

- *Identify key factors affecting the integrated performance evaluation system of "traditional, green and resilient" suppliers with a comprehensive overview of the literature.*
- *Testing the proposed conceptual model to confirm the impact of key factors affecting the integrated system in the Iranian Fanavaran Petrochemical Company through interviewing, distributing and collecting the company's expert opinion questionnaire and using the path analysis approach and finally extracting the final research model in the company.*
- *Distribution and collection of questionnaires among the company's experts in order to implement the SWARA technique and extract the weight of the factors.*
- *Distribution and summarization of the company's experts' opinion questionnaire and use of the TOPSIS technique to rank the company's suppliers.*
- *Proposing effective solutions and suggestions for managers to strengthen key factors affecting the suppliers integrated performance evaluation system and prevent or refer to the barriers of establishment and implementation of this system in the company.*

# 5 | Findings

## 5.1 | Path Analysis and Study of the Effect of Key Factors in Fanavaran Petrochemical Company

After designing the conceptual model, using SPLS software, the path coefficients between the determined relationships were calculated. The values of the coefficients mentioned in *Table 3* indicate that the reliability and validity of the research factors are appropriate. In other words, the components (factors) specified in *Table 3* are well able to measure the concept under consideration.

**Table 3. The reliability and validity of the research factors.**

| Factors | Alpha Coefficient | AVE | CR |
|---|---|---|---|
| Costs | 0.738 | 0.784 | 0.792 |
| Quality | 0.763 | 0.785 | 0.806 |
| Delivery reliability | 0.634 | 0.662 | 0.681 |
| Performance history | 0.702 | 0.759 | 0.764 |
| Turnover | 0.629 | 0.646 | 0.683 |
| Lead time | 0.761 | 0.794 | 0.832 |
| Operating capacity | 0.716 | 0.742 | 0.773 |
| Required standards | 0.749 | 0.783 | 0.803 |
| Environmental issues | 0.683 | 0.695 | 0.739 |
| Management Commitment | 0.778 | 0.795 | 0.839 |
| Redundancy | 0.692 | 0.728 | 0.756 |
| Agility | 0.751 | 0.784 | 0.829 |
| Complexity | 0.612 | 0.636 | 0.687 |
| Visibility | 0.706 | 0.738 | 0.796 |
| Flexibility | 0.637 | 0.684 | 0.718 |

The output values of the T-test are shown in *Fig. 3*.

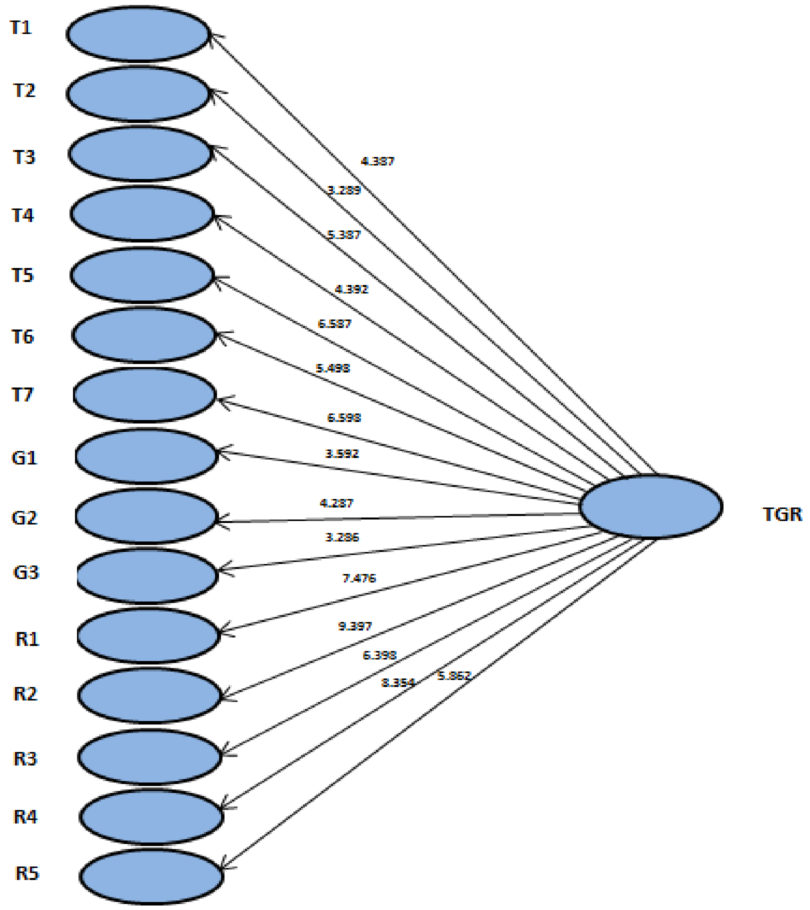


**Fig. 3. Values of the T-test.**

As *Fig. 3* shows, the T-value values for all paths are higher than the absolute standard value of 1.96 (outside the specified range) and depict that the identified factors are well measured in the integrated supply chain (traditional, green and resilient) management system influence the company. In other words, this shows the significance of all factors and relationships between variables at the 95% confidence level, and finally all model relationships are acceptable. The results (*Fig. 4*) also show that the relationship between all variables is very high and significant.

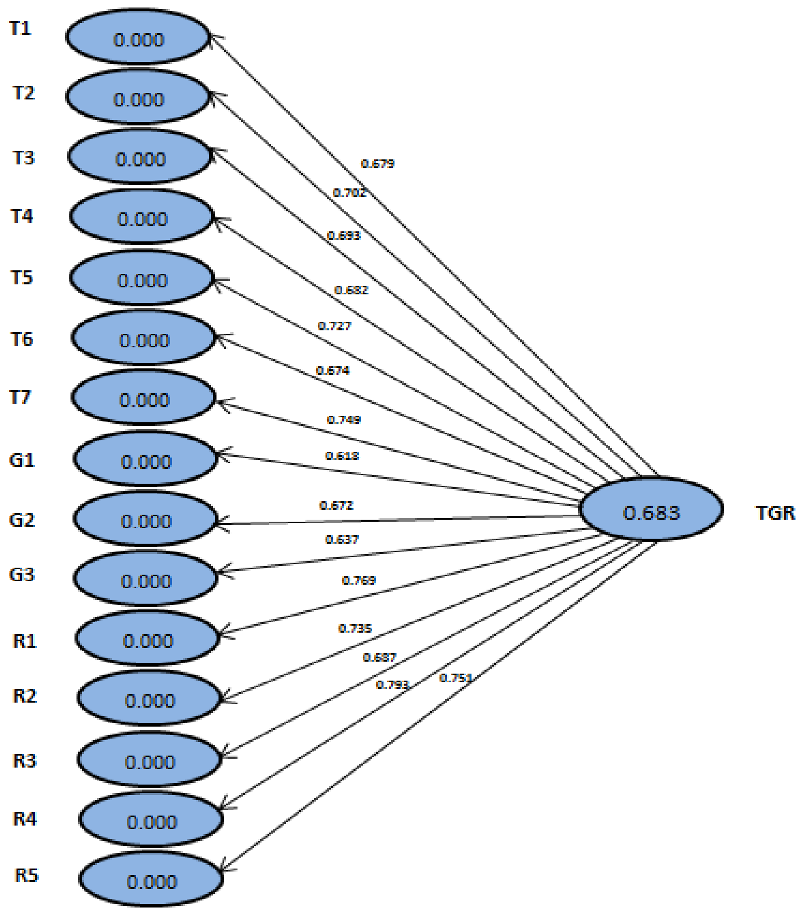


**Fig. 4. The path coefficients and factors coefficient.**

Therefore, according to *Fig. 4* and the path coefficients, the positive and strong impact of all factors in the management of the traditional, green and resilient integrated supply chain of this company are confirmed. Finally, after calculating all the fitting criteria of the measurement models and the structural model of the research, GOF should be calculated. The criterion shown by GOF is a number between zero and one, if it closes to one, it means the higher fitness of the model. Three values of 0.01, 0.25 and 0.36 have been introduced as weak, medium and strong values for GOF [9], are obtained from the redundancy of the mean values of the adjustment coefficient and the average of the additional values for the endogenous structures of the model. By calculation of the software output, the GOF value was 0.317, which is a good value and indicates the strong fitness of the structural model, so the GOF of the model is also confirmed.

## 5.2 | SWARA Technique and Calculating the Weight (Importance and Rank) of the Criteria and Sub-Criteria

In order to calculating of weight, the factors, SWARA (Stepwise Weight Assessment Ratio Analysis) technique is used. In this method, the expert assesses the calculated weights. In addition, each expert specifies the importance of each criterion according to tacit knowledge, information and experience.

Mansory et al. | J. Appl. Res. Ind. Eng. 8(2) (2021) 129-149

Then according to the average value of the group's ranks obtained by experts, the weight of each criterion is determined [1]. SWARA is one of the weighting methods in which professionals play an important role in the calculation of their weight and final assessment [2]. In this study, the interviews of 30 Iranian experts in Fanavaran Petrochemical Company were used. The weight of each criterion indicates its importance. Measuring of weight is an important topic in many issues of decision-making.

In this section, using SWARA technique, the criteria and sub-criteria are evaluated and their weight was determined in four sections. All computational steps were presented in the first section and a summary of the final output of the sub-criteria and criteria was given below. The middle tables were neglected due to the high volume of calculations.

### 5.2.1 | Determining the weight of sub-criteria related to the traditional criterion

For this purpose, seven traditional sub-criteria effective on the evaluation of suppliers in Fanavaran Petrochemical Company were extracted, which are given in *Table 4*.

**Table 4. Keys traditional sub-criteria effective on the evaluation of suppliers.**

| Traditional sub-criteria | T1 | T2 | T3 | T4 | T5 | T6 | T7 |
|---|---|---|---|---|---|---|---|
| Description | Costs | Quality | Delivery reliability | Performance history | Turnover | Lead time | Operating capacity |

Then, 30 expert opinions were evaluated to examining the factors. Fanavaran Petrochemical Company (*Table 5*) was used in this field.

**Table 5. Information of experts.**

| Group | Classification | Number |
|---|---|---|
| **Age** | Lower of 40 years | 5 |
| | Between 40 to 50 years | 7 |
| | Between 50 to 60 years | 15 |
| | Upper of 60 years | 3 |
| **Position** | Managers | 8 |
| | Assistant and Engineers | 22 |
| **Education** | Diploma | -- |
| | Bachelor | 11 |
| | Master | 17 |
| | P.H.D. | 2 |
| **Record of service** | Lower of 10 years | 3 |
| | Between 10 to 20 years | 7 |
| | Between 20 to 25 years | 12 |
| | Upper of 25 years | 8 |
| **Sexuality** | Male | 28 |
| | Female | 2 |

In the following, the step-by-step and executive procedure of this technique for calculating the weight of the sub-criteria and their ranking is explained.

**Implementation of Steps.**

**Step 1.** By dividing the number of opinions on each sub-criterion by the number of experts (30), the percentage of opinions on each sub-criterion was calculated (*Table 6*).

Table 6. Percentage of opinions and rank of each sub-criterion.

| Key sub-criterion | T1 | T2 | T3 | T4 | T5 | T6 | T7 |
|---|---|---|---|---|---|---|---|
| **Description** | Operating capacity | Lead time | Turnover | Performance history | Delivery reliability | Quality | Costs |
| **Number of opinions** | 17 | 27 | 23 | 14 | 8 | 19 | 11 |
| **Percentage of opinions** | 0.57 | 0.90 | 0.77 | 0.47 | 0.27 | 0.63 | 0.37 |
| **Rank** | 4 | 2 | 2 | 5 | 7 | 3 | 6 |
| | | | | | | Number of experts | 30 |

**Step 2.** Sort the sub-criteria in order of importance in *Table 7*.

Table 7. Sort of sub-criteria in order of importance.

| Rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Sub-criterion** | T2 | T3 | T6 | T1 | T4 | T7 | T5 |
| **Percentage of opinions** | 0.90 | 0.77 | 0.63 | 0.57 | 0.47 | 0.37 | 0.27 |

**Step 3.** Calculate the relative difference of each subscale's opinion on the next subscale, $s_j$, for each subscale (other than the first); a number as $s_j$ does not belong to the first subscale, and $S_2$ equals 0.90-0.77=0.13 (*Table 8*).

Table 8. The value of $s_j$.

| Sub-criterion | T2 | T3 | T6 | T1 | T4 | T7 | T5 |
|---|---|---|---|---|---|---|---|
| $s_j$ | …. | 0.13 | 0.13 | 0.07 | 0.10 | 0.10 | 0.10 |

**Step 4.** The growth rate of $k_j$ is equal to 1 for the first sub-criterion and $1 + s_j$ for the other subscale. These values are given in *Table 9*:

Table 9. $k_j$ Growth values for each sub-criterion.

| Sub-criterion | T2 | T3 | T6 | T1 | T4 | T7 | T5 |
|---|---|---|---|---|---|---|---|
| $k_j$ | 1 | 1.13 | 1.13 | 1.07 | 1.10 | 1.10 | 1.10 |

**Step 5.** Set the recovered value of the first sub-criterion (T1) that set the $q_1 = 1$ and by dividing $q_j$ from the previous sub-criterion to $k_j$ of that sub-criterion, we calculate the values of $q_j$ for the other sub-criteria; for example, $q_1 = 1$ and $k_2 = 1.13$.

So: $q_2 = \frac{1}{1.13} = 0.88$ and $q_3 = \frac{q_2}{k_3} = \frac{0.88}{1.13} = 0.78$.

The extracted values of $q_j$ are given in *Table 10*.

Table 10. Values of $q_j$ for each sub-criterion.

| Sub-criterion | T2 | T3 | T6 | T1 | T4 | T7 | T5 |
|---|---|---|---|---|---|---|---|
| $q_j$ | 1 | 0.88 | 0.78 | 0.73 | 0.66 | 0.60 | 0.55 |

**Step 6.** Divide the $q_j$ by their sum to calculate the weight of each sub-criterion. For example, $w_1$ equals to:

Mansory et al. | J. Appl. Res. Ind. Eng. 8(2) (2021) 129-149

$$w_1 = \frac{1}{5.21} = 0.192.$$

The weight of the following criteria is given in *Table 11*:

**Table 11. The weight of each sub-criterion.**

| Sub-criterion | T2 | T3 | T6 | T1 | T4 | T7 | T5 |
|---|---|---|---|---|---|---|---|
| $w_j$ | 0.192 | 0.169 | 0.150 | 0.140 | 0.127 | 0.116 | 0.105 |

**Step 7.** Finally, the weight of the sub-criteria was presented in *Table 12* after sorting.

**Table 12. The weight of the sub-criteria after sorting.**

| Key sub-criterion | T1 | T2 | T3 | T4 | T5 | T6 | T7 |
|---|---|---|---|---|---|---|---|
| Description | Operating capacity | Lead time | Turnover | Performance history | Delivery reliability | Quality | Costs |
| $w_j$ | 0.140 | 0.192 | 0.169 | 0.140 | 0.127 | 0.116 | 0.105 |

According to *Table 12*, the second sub-criterion, "quality", has been extracted with the highest weight as the most important traditional sub-criterion. Also, the third sub-criteria (delivery reliability) and the sixth (pre-order time) are in the next ranks in terms of importance in evaluating the traditional performance of suppliers. The fifth sub-criterion (trading volume) was also identified with the lowest weight as the least important sub-criterion in the traditional evaluation of the company's suppliers.

**Determining the weight of the sub-criteria related to the green criterion.**

**Step 1.** Step 1 output is presented in *Table 13*:

**Table 13. Percentage of opinions and rank of each sub-criterion.**

| Green key sub-criterion | G1 | G2 | G3 |
|---|---|---|---|
| Description | Required standards | Environmental issues | Management Commitment |
| Number of opinions | 23 | 14 | 19 |
| Percentage of opinions | 0.767 | 0.467 | 0.633 |
| Rank | 1 | 3 | 2 |

**Steps 2-6.** The final output of these steps is given in *Table 14*:

**Table 14. Values of $s_j$, $k_j$, $q_j$ and $w_j$.**

| Rank | 1 | 2 | 3 |
|---|---|---|---|
| Sub-criterion | G1 | G3 | G2 |
| Percentage of opinions | 0.767 | 0.633 | 0.467 |
| $s_j$ | --- | 0.133 | 0.167 |
| $k_j$ | 1 | 1.133 | 1.167 |
| $q_j$ | 1 | 0.882 | 0.756 |
| $w_j$ | 0.379 | 0.334 | 0.287 |

**Step 7.** The output of this step is also presented in *Table 15*:

**Table 15. The weight of the sub-criteria after sorting.**

| Sub-criterion | G1 | G2 | G3 |
|---|---|---|---|
| $w_j$ | 0.379 | 0.287 | 0.334 |

As can be seen in *Table 15*, the first sub-criterion, "compliance with the required standards" with the highest weight, has been extracted as the most important green sub-criterion. Also, the third sub-criteria (commitment and management of employees and customer needs) and the second (observance of environmental issues) are in the next ranks in terms of importance in evaluating the traditional performance of suppliers.



**Determining the weight of the sub-criteria related to the resilience criterion.**

**Step 1.** The output of this step is given in *Table 16*:

**Table 16. Percentage of opinions and rank of each sub-criterion.**

| Resilience key sub-criterion | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|
| **Description** | Redundancy | Agility | Complexity | Visibility | Flexibility |
| **Number of opinions** | 22 | 26 | 11 | 18 | 14 |
| **Percentage of opinions** | 0.73 | 0.87 | 0.37 | 0.60 | 0.47 |
| **Rank** | 2 | 1 | 5 | 3 | 4 |

**Steps 2-6.** The final output of these steps is given in *Table 17*:

**Table 17. Values of $s_j$, $k_j$, $q_j$ and $w_j$.**

| Rank | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Sub-criterion** | R2 | R1 | R4 | R5 | R3 |
| **Percentage of opinions** | 0.87 | 0.73 | 0.60 | 0.47 | 0.37 |
| $s_j$ | --- | 0.13 | 0.13 | 0.13 | 0.10 |
| $k_j$ | 1 | 1.13 | 1.13 | 1.13 | 1.10 |
| $q_j$ | 1 | 0.88 | 0.78 | 0.69 | 0.62 |
| $w_j$ | 0.252 | 0.222 | 0.196 | 0.173 | 0.157 |

**Step 7.** The output of this step is also presented in *Table 18*:

**Table 18. The weight of the sub-criteria after sorting.**

| Sub-criteria | R1 | R2 | R3 | R4 | R5 |
|---|---|---|---|---|---|
| $w_j$ | 0.222 | 0.252 | 0.17 | 0.196 | 0.173 |

As can be seen in *Table 18*, the second most important sub-criterion, agility, is the most important sub-criterion for resilience, and the first (surplus) and fourth (obvious) sub-criteria are the next most important in evaluating the resilience performance of suppliers. The fifth sub-criteria (flexibility) and the third (complexity) ranked last.

**Determining the weight of key criteria (traditional, green and resilience).**

In this section, in order to evaluate the key criteria and extract the weight of the criteria and rank them, the SWARA technique was used. The output of the executive steps is presented in *Tables 19, 20,* and *21*:

**Table 19. Percentage of opinions and rank of each sub-criterion.**

| Description | Traditional (T) | Green (G) | Resilience (R) |
|---|---|---|---|
| **Number of opinions** | 16 | 20 | 28 |
| **Percentage of opinions** | 0.533 | 0.667 | 0.933 |
| **Rank** | 3 | 2 | 1 |

Mansory et al. | J. Appl. Res. Ind. Eng. 8(2) (2021) 129-149

**Table 20. Values of $s_j$, $k_j$, $q_j$ and $w_j$.**

| Rank | 1 | 2 | 3 |
|---|---|---|---|
| **Sub-criterion** | R | G | T |
| **Percentage of opinions** | 0.933 | 0.667 | 0.533 |
| $s_j$ | --- | 0.267 | 0.133 |
| $k_j$ | 1 | 1.267 | 1.133 |
| $q_j$ | 1 | 0.789 | 0.697 |
| $w_j$ | 0.402 | 0.318 | 0.280 |

**Table 21. The weight of the sub-criteria after sorting.**

| Criterion | T | G | R |
|---|---|---|---|
| $w_j$ | 0.280 | 0.318 | 0.402 |

According to *Table 21*, the third criterion is "resilience" with the highest Weight as the most important criterion, the second criterion (green) in the second place and finally the first criterion (traditional) in the last rank in terms of importance in the integrated evaluation of the suppliers' performance. This output (the final weights of the main criteria) is considered in the ranking of the company's suppliers as the input of the TOPSIS decision-making technique, which is presented in the following steps of this technique.

## 5.2 | Ranking of the Company's Suppliers based on the Weight of the Criteria with TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is one of the well-known methods for classical MCDM. TOPSIS technique, as one of the known classical MCDM methods, was first developed for solving a MCDM problem. The underlying logic of TOPSIS is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. In short, the ideal solution consists of all the best values attainable of criteria, whereas the negative ideal solution is composed of all the worst values attainable of criteria. The optimal alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution [44]. In this study, in order to rank the Fanavaran Petrochemical Company, the TOPSIS decision-making technique including the following six steps has been used:

**Step 1.** Conversion of the D decision-making matrix to the ND matrix based on Euclidean norm.

$$r_{ij} = \frac{r_{ij}}{(\sum_{i=1}^{m} r_{ij})^{1/2}} \qquad (j = 1, \dots, n)$$

In order to implement the first step, in the beginning decision matrix was extracted from the opinions of 10 experts of the mentioned company and finally the last aggregation matrix was presented as *Table 22*.

Mansory et al. | J. Appl. Res. Ind. Eng. 8(2) (2021) 129-149

**Table 22. Collective matrix of expert opinions.**

| Decision-Making Matrix (DM) | C1 | C2 | C3 |
|---|---|---|---|
| A1 | 10 | 160 | 4 |
| A2 | 12 | 173 | 5 |
| A3 | 15 | 129 | 7 |
| A4 | 8 | 159 | 1 |
| A5 | 9 | 191 | 6 |
| A6 | 13 | 183 | 8 |
| A7 | 8 | 179 | 3 |
| $w_j$ | 0.28 | 0.318 | 0.402 |
| Alpha | 29.10 | 446.61 | 14.14 |

In the $w_j$ line, the weight of the main criteria (traditional, green and resilience) extracted from the final output of the SWARA technique is given. The following is a ND matrix in *Table 23*:

**Table 23. Normal Decision-Making Matrix.**

| Normal DM | C1 | C2 | C3 |
|---|---|---|---|
| A1 | 0.3436 | 0.3583 | 0.2828 |
| A2 | 0.4123 | 0.3874 | 0.3536 |
| A3 | 0.5154 | 0.2888 | 0.4950 |
| A4 | 0.2749 | 0.3560 | 0.0707 |
| A5 | 0.3092 | 0.4277 | 0.4243 |
| A6 | 0.4467 | 0.4098 | 0.5657 |
| A7 | 0.2749 | 0.4008 | 0.2121 |

**Step 2.** The matrix of the balanced scale is obtained by assuming the vector w:

$$V = N_D.W$$

Where V is the balanced scale matrix and W is the diameter matrix of the weights obtained for the criteria. *Table 24* shows the balanced ND decision making:

**Table 24. The balanced ND decision making.**

| The Balanced ND DM | C1 | C2 | C3 |
|---|---|---|---|
| A1 | 0.0962 | 0.1139 | 0.1137 |
| A2 | 0.1155 | 0.1232 | 0.1421 |
| A3 | 0.1443 | 0.0919 | 0.1990 |
| A4 | 0.0770 | 0.1132 | 0.0284 |
| A5 | 0.0866 | 0.1360 | 0.1706 |
| A6 | 0.1251 | 0.1303 | 0.2274 |
| A7 | 0.0770 | 0.1275 | 0.0853 |

**Step 3.** Identify the solution to the positive ideal and the solution to the negative ideal as follows:

$$A^+ = \{(\max V_{ij}, J \in j_1), (\min V_{ij}, J \in j_2), i = 1,2, \dots, m\}$$

$$A^- = \{(\min V_{ij}, J \in j_1), (\max V_{ij}, J \in j_2), i = 1,2, \dots, m\}$$

$$A_i^+ = \{v_1^+, v_2^+, \dots, v_n^+\}$$

$$A_i^- = \{v_1^-, v_2^-, \dots, v_n^-\}$$

For the positive elements of the criteria: $j_1 = \{j = 1,2, \dots . n\}$

For the negative elements of the criteria: $j_2 = \{j = 1,2, \dots . n\}$



According to the above relations, the values of the positive ideal solution and the negative ideal solution are calculated and given in *Table 25*:

**Table 25. The values of the positive and negative ideal solution.**

| Values | C1 | C2 | C3 |
|---|---|---|---|
| A+ | 0.1443 | 0.1360 | 0.2274 |
| A- | 0.0770 | 0.0919 | 0.0284 |

**Step 4.** Calculation of distances based on Euclidean norm:

$$d_i^+ = \left\{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2\right\}^{1/2}, \ (i= 1,2,\dots,m) \quad d_i^- = \left\{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\right\}^{1/2}$$

Considering the above relations, the distance between positive and negative ideas is presented in *Table 26*.

**Table 26. The distance between positive and negative ideas.**

| Distances | d+ | d- |
|---|---|---|
| A1 | 0.1254 | 0.0902 |
| A2 | 0.0909 | 0.1241 |
| A3 | 0.0525 | 0.1834 |
| A4 | 0.2113 | 0.0214 |
| A5 | 0.0810 | 0.1491 |
| A6 | 0.0201 | 0.2083 |
| A7 | 0.1575 | 0.0671 |

**Step 5.** Calculate the relative proximity of the option to the ideal solution as follows:

$$c_i = \frac{d_i^-}{(d_i^- + d_i^+)}, (i = 1,2, \dots, n)$$

If $A_i = A_i^+$ then $d_i^+ = 0$. So the closer the option is to the ideal solution, the closer it will be to one.

According to the above relation, the relative proximity of the options to the ideal solution is calculated and given in *Table 27*.

**Table 27. The relative proximity of the options to the ideal solution.**

| Proximity | CC |
|---|---|
| A1 | 0.4182 |
| A2 | 0.5770 |
| A3 | 0.7774 |
| A4 | 0.0918 |
| A5 | 0.6480 |
| A6 | 0.9121 |
| A7 | 0.2978 |

Ranking options: At this stage, the options (suppliers) are ranked based on $c_i$ the values from largest to smallest. The results are shown in *Table 28*.

**Table 28. Ranking options.**

| | Rank |
|---|---|
| A1 | 5 |
| A2 | 4 |
| A3 | 2 |
| A4 | 7 |
| A5 | 3 |
| A6 | 1 |
| A7 | 6 |

## 6 | Conclusion and Recommendations

Nowadays, SCM has received a lot of attention in several organizations. Customers demand more environmentally-friendly products. There is a growing pressure from strict government norms on industries due to increased environmental disruption, shortage of material resources, and increased levels of pollution (essentially carbon footprints). Green supply chain management is a powerful way to compare an organization with competitors. This is the latest technique to improve supply chain management capabilities. Many companies have taken green steps in their day-to-day management. Green supply chain provides operational and financial benefits to an organization and at the same time benefits the sustainability of the work environment. Green supply chain management has a competitive advantage and improves the economic situation of an organization. It refers to improve the environmental performance of a product and process at every stage of the organization, for example purchasing, manufacturing, marketing, and presentation. Effective implementation of green supply chain management leads to reduced waste and environmental pollution, optimized resource utilization, and costs' reduction. The ultimate goal of selecting suppliers is to choose the right suppliers according to the resilience capabilities of the supply chain of companies. Just as suppliers are an irreplaceable vital resource, choosing a better supplier can help to build resilience to decrease supply chain risks as a whole. For this purpose, at first, by reviewing the literature and interviewing and discussing with the experts and purchasing managers of the mentioned company, the performance criteria have been extracted and proposed. Then, the suppliers of Fanavaran Petrochemical Company were evaluated and selected based on traditional, green and resilience criteria. To this end, after identifying and extracting the key sub-criteria related to each criterion with a comprehensive review of the literature, a questionnaire was designed and provided to 55 experts and managers of the company to express their views on the effectiveness of each of these criteria. After collecting the questionnaires, using the path analysis approach, the proposed conceptual model of the criteria was evaluated and tested. The results of this approach showed that all the proposed criteria are effective in implementing the integrated supply chain system (traditional, green and resilience) and evaluating the company's suppliers. Then, using the SWARA decision-making technique as one of the new techniques and gathering the opinions of experts, all the criteria and sub-criteria were compared and finally their weights were extracted. Based on the extraction weight, their importance (rank) was extracted and presented separately by table. Finally, based on the necessity and importance of ranking the company's suppliers of materials based on all criteria, the TOPSIS ranking technique was used. In order to implement this technique, the extraction weight of the criteria was applied to the TOPSIS technique as the input of the first stage through the SWARA technique. Then, based on the implementation steps, the suppliers of the company were evaluated and their ranking was extracted based on three key research criteria. The technical output showed that the sixth supplier of the best suppliers and the third supplier were in the next place (due to the preservation of research ethics and confidentiality of information, the names of the suppliers were not announced). The seventh and fourth suppliers also placed at last rank based on performance. Such generalization and interpretation were major limitations of this study. Studied sample in this research is a sample of


Mansory et al. | J. Appl. Res. Ind. Eng. 8(2) (2021) 129-149

employees, managers and experts in Fanavaran Petrochemical Company so that in finding generalization with other populations (including Petrochemical Companies), consideration on the cautious side is essential.

According to the conclusion of this research, the following recommendations are proposed to the company managers:

- *Based on the weight of the criteria and sub-criteria, sub-criterion "quality" as the most important traditional sub-criterion, sub-criterion "compliance with the necessary standards" as the most important sub-criterion green, sub-criterion "agility" as the most important sub-criterion of resilience and in the final analysis of general and key research the "resilience" criterion has been extracted as the most important criterion for evaluating the performance of suppliers. In order to realize these goals, in terms of quality, it is necessary to select suppliers by providing high quality materials among existing suppliers or to search and replace other higher quality suppliers. In terms of compliance with standards, improving government participation and regulations and standards, compliance with standards in the purchase of raw materials, machinery, equipment and tools, product design. Improving the agility and speed of suppliers, activities can also enhance suppliers' responsiveness to orders. Finally, improving resilience and adaptability in response to disruptions, and restoring it in selecting suppliers and tackling external disruptions and risks will reduce and enhance chain vulnerabilities.*
- *Based on the ranking of suppliers, it is recommended that the studied company reduce its communications and activities with the seventh and fourth suppliers (as the weakest suppliers) or replace them with other better suppliers in order to improve the performance of the supply recovery function. It will also increase the supply of more materials to sixth and third suppliers (as the strongest suppliers in terms of environmental and environmental issues).*
- *The proposed research approach will greatly assist the company's purchasing managers in achieving a green and productive purchasing strategy by evaluating suppliers.*
- *The proposed method of this research can be used in other companies as a tool to measure the unhealthiness of the supply chain in the components of green performance and resilience.*
- *Considering the uncertainty in the opinions of the experts of the studied company, it is recommended to use decision-making techniques in the fuzzy environment and by collecting and analyzing the opinions of experts in verbal phrases to conduct a more detailed study of the criteria and sub-criteria and extract the ranking of suppliers and compare it with the results of this research.*
- *Using other weighting techniques, such as AHP, ANP, BWM and etc. It is advised to re-extract the weight of the criteria and compare it with the results of this research and use other ranking techniques such as WASPAS, ELECTER, QUALIFLEX, PROMETEE, ORESTE etc., and rank the suppliers and compare them with the results of this study.*
- *Identify sustainability indicators in the supply chain and present a more comprehensive model based on four key criteria (traditional, green, resilience and sustainability) and implement and analyze the approach of the present study.*

## References


[1] Asgharizadeh, E., & Ajalli, M. (2016).Identification and ranking the key dimensions of lean manufacturing using new approach in gas industry. *Proceedings of international conference on science, technology, humanities and business management* (pp. 29-30). Bangkok. Retrieved from https://socrd.org/wp-content/uploads/2016/08/7BKK141-Identification-and-Ranking-the-Key-Dimensions-of-Lean-Manufacturing-using-NEW-Approach-in-Gas-Industry.pdf

[2] Ajalli, M., Mozaffari, M. M., & Salahshori, R. (2019). Ranking the suppliers using a Combined SWARA-FVIKOR approach. *International journal of supply chain management*, *8*(1), 907.

[3] Akman, G. (2015). Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods. *Computers and industrial engineering*, *86*, 69-82. https://doi.org/10.1016/j.cie.2014.10.013

[4] Amani, M., Ashrafi, A., & Dehghanan, H. (2017). Assessing the barriers to green supply chain adoption using fuzzy DEMATEL technique. *IT management studies*, *5*(19), 147-179.

[5] Maulidina, A. D., & Putra, F. E. (2018). Selection of tugboat gearbox supplier using the analytical hierarchy process method. *Journal of applied research on industrial engineering*, *5*(3), 253-262.

[6] Tirkolaee, E. B., Mardani, A., Dashtian, Z., Soltani, M., & Weber, G. W. (2020). A novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echelon supply chain design. *Journal of cleaner production*, *250*, 119517. https://doi.org/10.1016/j.jclepro.2019.119517

[7] Blackhurst*, J., Craighead, C. W., Elkins, D., & Handfield, R. B. (2005). An empirically derived agenda of critical research issues for managing supply-chain disruptions. *International journal of production research*, *43*(19), 4067-4081. https://doi.org/10.1080/00207540500151549

[8] Carvalho, H., Barroso, A. P., Machado, V. H., Azevedo, S., & Cruz-Machado, V. (2012). Supply chain redesign for resilience using simulation. *Computers and industrial engineering*, *62*(1), 329-341. https://doi.org/10.1016/j.cie.2011.10.003

[9] Davari, A., & Rezazadeh, A. (2013). *Structural equation modeling with PLS*. Jahad University. (**In Persian**). https://www.researchgate.net/profile/Arash-Rezazadeh/publication/264519454_Structural_Equation_Modeling_with_PLS /links/53e236d80cf2d79877aa19f1/Structural-Equation-Modeling-with-PLS.pdf

[10] Dickson, G. W. (1966). An analysis of vendor selection systems and decisions. *Journal of purchasing*, *2*(1), 5-17. https://doi.org/10.1111/j.1745-493X.1966.tb00818.x

[11] Feng, T., Sun, L., & Zhang, Y. (2010). The effects of customer and supplier involvement on competitive advantage: An empirical study in China. *Industrial marketing management*, *39*(8), 1384-1394. https://doi.org/10.1016/j.indmarman.2010.04.006

[12] Gandhi, S., Mangla, S. K., Kumar, P., & Kumar, D. (2015). Evaluating factors in implementation of successful green supply chain management using DEMATEL: A case study. *International strategic management review*, *3*(1-2), 96-109. https://doi.org/10.1016/j.ism.2015.05.001

[13] Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. *Journal of cleaner production*, *98*, 66-83. https://doi.org/10.1016/j.jclepro.2013.06.046

[14] Govindan, K., & Sivakumar, R. (2016). Green supplier selection and order allocation in a low-carbon paper industry: integrated multi-criteria heterogeneous decision-making and multi-objective linear programming approaches. *Annals of operations research*, *238*(1-2), 243-276. https://doi.org/10.1007/s10479-015-2004-4

[15] Ha, S. H., & Krishnan, R. (2008). A hybrid approach to supplier selection for the maintenance of a competitive supply chain. *Expert systems with applications*, *34*(2), 1303-1311. https://doi.org/10.1016/j.eswa.2006.12.008

[16] Haldar, A., Ray, A., Banerjee, D., & Ghosh, S. (2014). Resilient supplier selection under a fuzzy environment. *International journal of management science and engineering management*, *9*(2), 147-156. https://doi.org/10.1080/17509653.2013.869040

[17] Hosseini, S. A., Iranban, S. J., & Mirjahanmard, S. J. (2014). Identifying & prioritizing the effective factors on green supply chain management by using path analysis approach. *Journal of production and operations management*, *5*(2), 178-161.

[18] Masudin, I., Wastono, T., & Zulfikarijah, F. (2018). The effect of managerial intention and initiative on green supply chain management adoption in Indonesian manufacturing performance. *Cogent business and management*, *5*(1), 1485212. https://doi.org/10.1080/23311975.2018.1485212

[19] Imani, D. M., & Ahmadi, A. (2009). Green supply chain management: a new strategy for gaining competitive advantage. *Journal of Automobile Engineering and related industries*, *10*, 14-19.

[20] Ghahremani-Nahr, J., Nozari, H., & Najafi, S. E. (2020). Design a green closed loop supply chain network by considering discount under uncertainty. *Journal of applied research on industrial engineering*, *7*(3), 238-266.

[21] Jayaram, J., Xu, K., & Nicolae, M. (2011). The direct and contingency effects of supplier coordination and customer coordination on quality and flexibility performance. *International journal of production research*, *49*(1), 59-85. https://doi.org/10.1080/00207543.2010.508935

[22] Kamalahmadi, M., & Parast, M. M. (2016). A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. *International journal of production economics*, *171*, 116-133. https://doi.org/10.1016/j.ijpe.2015.10.023

[23] Muduli, K., Govindan, K., Barve, A., Kannan, D., & Geng, Y. (2013). Role of behavioural factors in green supply chain management implementation in Indian mining industries. *Resources, conservation and recycling*, *76*, 50-60. https://doi.org/10.1016/j.resconrec.2013.03.006

[24] Kannan, D., Govindan, K., & Rajendran, S. (2015). Fuzzy axiomatic design approach based green supplier selection: a case study from Singapore. *Journal of cleaner production*, *96*, 194-208. https://doi.org/10.1016/j.jclepro.2013.12.076

[25] Barker, K., Ramirez-Marquez, J. E., & Hosseini, S. (2016). An approach for modeling supplier resilience. *Proceedings of the thirteenth annual acquisition research symposium thursday sessions volume ii*.

[26] Kuo, R. J., & Lin, Y. J. (2012). Supplier selection using analytic network process and data envelopment analysis. *International journal of production research*, *50*(11), 2852-2863.

[27] Mitra, K., Gudi, R. D., Patwardhan, S. C., & Sardar, G. (2009). Towards resilient supply chains: Uncertainty analysis using fuzzy mathematical programming. *Chemical engineering research and design*, *87*(7), 967-981. https://doi.org/10.1016/j.cherd.2008.12.025

[28] Mohammed, A., & Wang, Q. (2017). Developing a meat supply chain network design using a multi-objective possibilistic programming approach. *British food journal*, *119*(3), 690-706. https://doi.org/10.1108/BFJ-10-2016-0475

[29] Mohammed, A., Harris, I., Soroka, A., Naim, M. M., & Ramjaun, T. (2018, January). Evaluating green and resilient supplier performance: AHP-fuzzy topsis decision-making approach. In *Proceedings of the 7th international conference on operations research and enterprise systems (ICORES 2018)*. DOI: 10.5220/0006619902090216

[30] Mohammed, A., & Wang, Q. (2017). The fuzzy multi-objective distribution planner for a green meat supply chain. *International journal of production economics*, *184*, 47-58. https://doi.org/10.1016/j.ijpe.2016.11.016

[31] Mohammed, A., Wang, Q., Alyahya, S., & Bennett, N. (2017). Design and optimization of an RFID-enabled automated warehousing system under uncertainties: a multi-criterion fuzzy programming approach. *The international journal of advanced manufacturing technology*, *91*(5), 1661-1670. https://doi.org/10.1007/s00170-016-9792-9

[32] Pramanik, D., Haldar, A., Mondal, S. C., Naskar, S. K., & Ray, A. (2017). Resilient supplier selection using AHP-TOPSIS-QFD under a fuzzy environment. *International journal of management science and engineering management*, *12*(1), 45-54. https://doi.org/10.1080/17509653.2015.1101719

[33] Purvis, L., Spall, S., Naim, M., & Spiegler, V. (2016). Developing a resilient supply chain strategy during 'boom'and 'bust'. Production planning and control, 27(7-8), 579-590. https://doi.org/10.1080/09537287.2016.1165306

[34] Qin, Y., & Geng, Y. (2013). Production cost optimization model based on CODP in Mass Customization. *International journal of computer science issues (IJCSI)*, *10*(1), 610-618.

[35] Rajesh, R., & Ravi, V. (2015). Supplier selection in resilient supply chains: a grey relational analysis approach. *Journal of cleaner production*, *86*, 343-359. https://doi.org/10.1016/j.jclepro.2014.08.054

[36] Pantha, R. P., Islam, M., Akter, N., & Islam, E. (2020). Sustainable supplier selection using integrated data envelopment analysis and differential evolution model. *Journal of applied research on industrial engineering*, *7*(1), 25-35.

[37] Sahu, A. K., Datta, S., & Mahapatra, S. S. (2016). Evaluation and selection of resilient suppliers in fuzzy environment. *Benchmarking: An international journal*, *23*(3), 651- 673. https://doi.org/10.1108/BIJ-11-2014-0109

[38] Shen, L., Olfat, L., Govindan, K., Khodaverdi, R., & Diabat, A. (2013). A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. *Resources, conservation and recycling*, *74*, 170-179. https://doi.org/10.1016/j.resconrec.2012.09.006

[39] Song, W., Xu, Z., & Liu, H. C. (2017). Developing sustainable supplier selection criteria for solar air-conditioner manufacturer: An integrated approach. *Renewable and sustainable energy reviews*, *79*, 1461-1471. https://doi.org/10.1016/j.rser.2017.05.081

[40] Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. *International journal of management reviews*, *9*(1), 53-80. https://doi.org/10.1111/j.1468-2370.2007.00202.x

[41] Lee, S. Y. (2008). Drivers for the participation of small and medium-sized suppliers in green supply chain initiatives. *Supply chain management: an international journal*, *13*(3), 185-198. https://doi.org/10.1108/13598540810871235

[42] Tyagi, M., Kumar, P., & Kumar, D. (2015). Parametric selection of alternatives to improve performance of green supply chain management system. *Procedia-Social and Behavioral Sciences*, *189*, 449-457. https://doi.org/10.1016/j.sbspro.2015.03.197

[43] Vafaei, S., Bazrkar, A., & Hajimohammadi, M. (2019). The investigation of the relationship between sustainable supply chain management and sustainable competitive advantage according to the mediating role of innovation and sustainable process management. *Brazilian journal of operations and production management*, *16*(4), 572-580.

[44] Wang, T. C., & Chang, T. H. (2007). Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. *Expert systems with applications*, *33*(4), 870-880. https://doi.org/10.1016/j.eswa.2006.07.003