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# The use of hybrid AHP-SWOT-fuzzy TOPSIS approach

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## ABSTRACT

*This paper aims at investigating the extent of maintenance and repairs preferences using multi-criteria decision making methods. To do this, making decision is examined in uncertainty conditions. All of the data is in the form of triangular fuzzy numbers at the strategy extraction stage. In the proposed method, first the indicators are calculated using SWOT method and ranked via AHP method. The identified strategies are then ranked by fuzzy TOPSIS approach considering the indicators. The efficiency of the model is evaluated through a case study conducted for an oil refining and distribution company. The results of using this model are presented for the studied company.*
*Keywords: Maintenance and Repairs Strategy, SWOT Method, Fuzzy TOPSIS, AHP Method*

**Introduction**

For the moment that factories are looking for continuous internal changes to adapt to the changes caused by globalization, the issue of maintenance and repairs can seriously and effectively direct the production path and strategy selection. Factories heavily concern matters such as cost reduction, high competitiveness, continuous improvement, increasing the quality and quantity of products, lack of natural resources, energy crisis, etc. In this regard, noticing maintenance as a strategic matter to achieve the goals is vital and inevitable [1].

Dynamic and structured military maintenance system consists of a coordinated set of activities that are established to maintain and repair facilities and equipment and are implemented based on customer satisfaction and compliance with his needs. However, the maintenance system is a continuous effort to ensure customer satisfaction at the lowest cost and at the right time [2].

Maintenance cost is a substantial part of production costs in manufacturing companies. Therefore, choosing the right maintenance and repair strategy is effective and reduces costs significantly. By traditional maintenance and repair policies equipment was repaired after a breakdown and in this way an excessive system downtime imposed severe financial shocks on the organization such the cost for lost production and repairs. To prevent severe breakdowns and high costs, organizations should choose appropriate maintenance and repair strategies for equipment [3].Hence, selecting and formulating appropriate strategies can be a suitable preventive approach to lessen the incidence and severity of accidents. To do this, consideration of safety risks as one of the important input criteria in selecting appropriate maintenance strategies seems to be a requirement [4, 5]. However, due to the multiplicity of factors influencing the selection of appropriate strategies, such as cost analysis, production quality, available spare parts and maintenance time, etc., the selection of such strategies and their justification for management is a complicated process [6 and 7]. Maintenance strategies are usually defined at two levels of the system and components. Maintenance and corrective maintenance, maintenance and preventive maintenance, periodic maintenance, and opportunistic maintenance are the main strategies.

Corrective maintenance (CM) is used when equipment fails. It is defined as failure-based maintenance. Since this type of maintenance might cost highly for critical equipment, they are often used for non-critical stand-alone equipment. Preventive maintenance can be classified into two major groups of time and condition-based maintenance (CBM). Preventive maintenance is performed before equipment downtime [8, 9]. It often works based on the failure (defect) date or condition of the equipment.

Selection of an appropriate maintenance strategy with a set of combined and uniform decisions helps the organization achieve its goal. Hence, the effectiveness of maintenance is evaluated only when a proper strategy is identified and assessed. Therefore, a proper strategy should be effective and compatible with trade and production goals [10]. Proper equipment maintenance might significantly reduce the overall cost of operations and improve factory efficiency. Although many management personnel considers maintenance operations expensive, but being optimistic and positive, it can be demonstrated that such activities provide profitability.

The main current challenges for maintenance professionals are not just learning maintenance techniques, but selecting the best option and the most effective maintenance techniques for their organization. An appropriate choice amends machine performance and at the same time decreases the maintenance costs. Conversely, in the case of wrong choice, the problem won't be removed, the previous problems won't be eliminated, and even new problems will appear for the organization [11]. Maintenance and repair is a serious matter in any industry that leads to increased yield and effectiveness in various ways. This happens because energy resources, manpower, capital, etc. can be a great help in achieving the goals. Further, the most (if possible) optimal use of available facilities, personnel and time are considered as the critical factors of maintenance and repairs issue [12].

## Review of the literature

Studies on strategy selection have mostly focused on the efficiency of complex operations research methods. Evaluation and selection of strategies can essentially be considered as a multi-criteria issue, because making decision on strategy should be assessed via various indicators.

Romlet introduced four indicators for strategy evaluation: alignment of strategy with the organization's goals, directing the organization's resources to the main tasks, solving sub-problems along with the main problems by the strategy, and satisfying the stakeholders.

Rahman Seresht has identified the following indicators for strategy evaluation: adaptability to the activity environment, adaptability to human resources, cultural adaptability, acceptability in terms of profitability, acceptability in terms of risk, acceptability in terms of stakeholder satisfaction, possibility in terms of resources, possibility of in terms of procurement, and feasibility in terms of appropriate response to competitors [13].

Johnson has proposed sustainability, coordination, advantage and feasibility indicators for strategy evaluation [14]. However, Robinson and Pierce have included the role of the past strategies, environmental compatibility, risk, internal political considerations, time and competitors reaction to choose appropriate strategies [15].

Among all Persian researchers, perhaps the most comprehensive set of criteria was presented by Pari Azar, Zaeri and Shahrabi in 2007. Their criteria include: service quality, equipment depreciation, personnel training, software cost, hardware facilities, product failure, software facilities, equipment installation time, skilled manpower, customer satisfaction, equipment security, personnel injuries, hardware cost, product quality, environmental impact, personnel and equipment efficiency, personnel wages, risk and reliability. They presented these criteria based on the views of Al-Najjar and Alsyouf (2003), Bevilcaquaand Braglia (2000), and Wang et al. (2006). Using factor analysis techniques, they labeled the mentioned criteria in four main sections of cost, value added, feasibility and safety. They finally selected the appropriate strategy from the five strategies of corrective maintenance, preventive maintenance, opportunistic maintenance, conditional maintenance and predictive maintenance using hierarchical analysis method. Another group of researchers, however, used another method to choose the optimal strategy. Combining hierarchical analysis process methods with ideal planning, Arunraj and Maiti designed a model for selecting the optimal maintenance strategy. They considered cost and risk of failure as the two main indicators for ranking strategies, and reported separate results for cost and risk, without considering both indicators [16].

In a case study for Shahid Salimi power plant in Neka, Nourifar, Emadi (2009) emlpoyed fuzzy development analysis. By defining four criteria of safety, cost, added value and feasibility (acceptance of maintenance method by employees) obtained from an interview with employees and managers, they selected the appropriate strategy from the timed-base, corrective, conditional, and predictive strategy.

Safari, Sayyahzadeh and Sadeghi (2010) conducted a study on water heaters and gas appliances production factory in northern Iran and mentioned only two criteria: risk and cost. Using hierarchical analysis and ideal planning methods, they selected the appropriate strategy out of four corrective, condition-based, risk and extinction-based strategies.

Ebrahimi, Hemmati and Rostamian (2010) carried out a study on the activists of wire and cable equipment production of the intended company. They selected the best maintenance method according to the opinions of five experts and by using fuzzy hierarchical analysis. The researchers considered criteria such as service, on-time delivery, flexibility, price and quality to make the best decision on choosing AHP. They selected the optimal strategy based on reliability and out of the business-based, condition-based, inclusive productive, time-based, and feature-based strategies.

Shahin, Bolandi and Baloui (2011) conducted a study on the selection of appropriate maintenance and repair policy in Isfahan Qapanchi Brick Company. They defined the criteria of flexibility, training requirements, failure components and environmental conditions based on the theory presented by Shijitz et al (2008). Then, they selected the appropriate strategy out of predictive, preventive, reliable, and conditional strategies by using the fuzzy AHP method.

Veisi, Sadeghian and Fattahi (2012) used AHP and fuzzy TOPSIS approaches to detect the machinery status in order to compile the program. They included six criteria for their purpose: process sensitivity, average time between two failures, average repair time, availability of repairs personnel, and workload.

Ahmadi, Karbasian, Alavi and Pari Zanganeh (2012) considered safety, continued production, reduced maintenance and inspection costs, increased equipment capability, and equipment reliability as the most important achievements of proper maintenance strategy components for equipment with different degrees of risk.

Ahmadi et al (2012) included four criteria of cost, value added, feasibility and safety to select the appropriate strategy for drilling rig equipment. Using hierarchical analysis and from corrective, reliability-based, condition-based, and preventive strategies, they selected the most appropriate policy for the subject under study.

Aghaei and Fazli (2012) used DEMATEL-ANP hybrid approach to choose the maintenance and repair strategy. They did a case study for the automotive industry and defined the criteria of safety, cost, strategic, and technical requirements. Then, they selected the appropriate strategy from preventive, comprehensive efficiency, condition-based, corrective, and reliability-based strategies.

Sufiabadi, Daraei and Jamali Firoozabadi (2013) emphasized on applying the five criteria of safety, value added, feasibility, cost and implementation.

Aghasizadeh Zahra, 2016; selection of appropriate maintenance strategy by using Analytic Hierarchy Process (AHP) (Case Study: Tabarok Factory, Mashhad).

Vise Alireza and Afarand Ali, 2015; selection of maintenance strategy for industries using a combined multi-criteria decision approach.

Shafiee Nikabadi Mohsen, Faraj Pour khanapashtani Habib, Eftekhari Hossein, and Saadabadi Ali Asghar, 2015; applying FA, AHP and TOPSIS hybrid approach to select and rank appropriate maintenance strategies.

Taghipour, Razieh; Avakh Darestani, Soroush, 2018, Fall; choosing the appropriate maintenance strategy with a fuzzy hierarchical approach

## Method

- **Strategic management**

Strategic management can be defined as the science and art of developing, implementing, and evaluating multiple task decisions that enable an organization to achieve its long-term goals. The strategic management process consists of three stages: developing, implementing, and evaluating the strategies.

Strategy development determines the company's mission, which includes identifying factors that threaten the organization in the external environment, factors that create opportunities, identifying the strengths and weaknesses of the organization, setting long-term goals, considering a variety of strategies, and selection of specific strategies to continue activities [17].

- **SWOT analysis**

SWOT is one of the strategic management tools for matching internal strengths and weaknesses with external opportunities and threats. SWOT provides a systematic analytical approach for identifying the factors mentioned and for selecting the strategy that best matches them. Using SWOT, it is possible to first experience and analyzes internal and external environments and secondly makes strategic decisions that balance the strengths of the organization according to the environmental opportunities [18].

- **Analytic Hierarchy Process (AHP)**

Several instruments and techniques have already been proposed to solve multi-criteria problems. Analytic Hierarchy Process (AHP), as an efficient technique, was developed by Thomas L. Saati in 1980. AHP enables the analyst to analyze critical aspects of a problem with a hierarchical structure. Hierarchical analysis not only helps the analyst determine the best decision, but also help the logic of the choice. In 1994, Pareto praised the AHP tactics, also turned the decision-making issue into a hierarchical structure with different levels, each level containing a limited number of decision-making elements. The upper level of the proposed hierarchy represents the overall goal and the lower level represents the feasible alternatives. One or more intermediate levels represent decision criteria or sub-criteria. The weight of the prioritized criterion and the score of the alternative are examined with decision elements. The decision maker identifies priorities by pairwise comparisons [19].

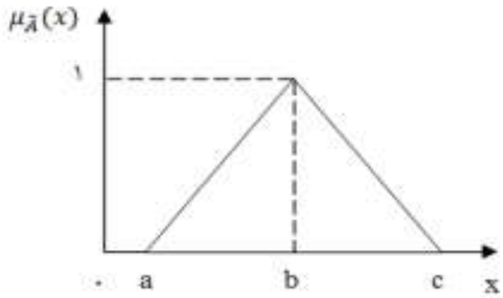
- **Fuzzy set approach**

Bastzadeh (1965) introduced the theory of fuzzy sets to solve problems that were not well defined and formulated. When human beings engage in the process of decision analysis, they express their judgment by ambiguous language, such as "strong", "very strong" and "extremely strong". By using such language, they quantify real-world events and topics. Fuzzy set theory enables decision makers to deal with the hidden ambiguity of the evaluation process.

It is the perfect tool for modeling the uncertainty, ambiguity, and inaccuracy that emerges from the human mind in evaluation and expression of his judgments and preferences in decision-making situations, which are neither random nor probable. A fuzzy set is defined by a membership function. It is a group of objects with a continuum of membership degrees; membership degree can range from zero to one. A fuzzy subset A of a global set X is defined by a membership function $f_A(x)$ in which each element x by X is represented by a real number [0,1]. If the membership degree for an element is equal to 1, $\mu_A(x)$, that element belongs to A. If the membership degree is zero, $(\mu_{\tilde{A}}(x) = 0)$, that element does not belong to that set. In cases of ambiguity, values are assigned between zero and one.

Triangular fuzzy numbers are used as a membership function corresponding to elements in a set. The reason for using a triangular fuzzy number is the ease of use and calculations by the user. A fuzzy number will be a triangular fuzzy number, if its membership function can be represented as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a}{b-a} & a \le x \le b \\ \frac{c-x}{c-b} & b \le x \le c \\ 0 & otherwise \end{cases}$$




**Figure**

Triangle fuzzy number membership function

The parameter b is the strongest degree of membership, that is $f_{\tilde{A}}(b) = 1$, while a and c are lower and higher boundaries.

Principles introduced by Bastzadeh can be used to compute a membership function after representing fuzzy sets through a function. Considering two triangular fuzzy numbers $\tilde{A} = (a_1, b_1, c_1)$ and $\tilde{B} = (a_2, b_2, c_2)$, addition, subtraction, multiplication and division operations are defined as follows [20]:

$$\tilde{A} + \tilde{B} = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$$
$$\tilde{A} - \tilde{B} = (a_1 - c_2, b_1 - b_2, c_1 - a_2)$$
$$\tilde{A} * \tilde{B} = (a_1.a_2, b_1.b_2, c_1.c_2)$$
$$\frac{\tilde{A}}{\tilde{B}} = (\frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_3})$$

- **Methodology and integrated approach**

The integrated AHP, SWOT and F-TOPSIS method is presented in this study to identify and prioritize maintenance strategies in an oil refining and distribution company. The steps are described in the figure below.

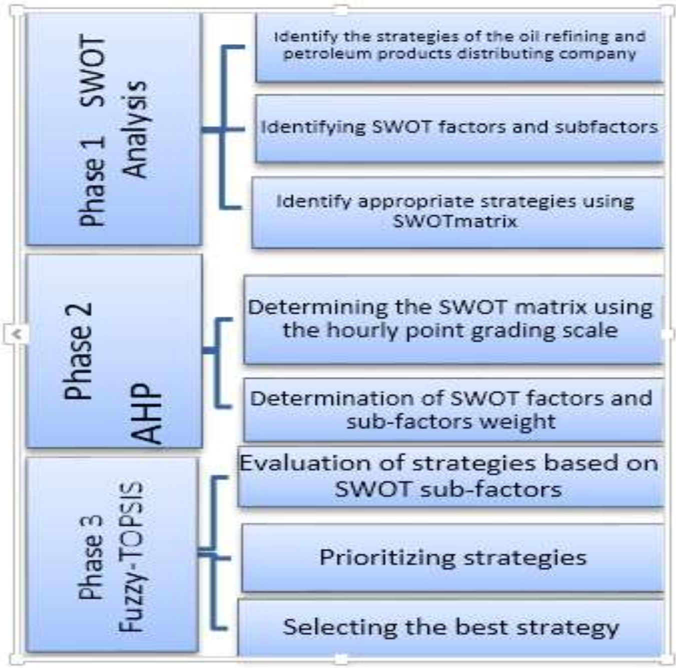



**Figure 1: Integrated AHP, SWOT and FTOPSIS methods**

In this method, SWOT analysis is used to determine internal and external factors to identify and prioritize maintenance policies in the oil refining and distribution company. However, AHP is used to gain the weight of each of the factors and sub-factors identified in the SWOT analysis. Finally, the F-TOPSIS approach is used to select and rank maintenance strategies.

**Table 1: SWOT matrix for developing maintenance strategies in the oil refining and distribution Company**

| | | | |
|---|---|---|---|
| Internal factors | Weaknesses (W) | W1 | Lack of management for network organization, supply chain and cost of services |
| | | W2 | Lack of proper infrastructure for research, development and knowledge management |
| | | W3 | Weak maintenance and development system and increased outflow of specialists |
| | | W4 | Low liquidity due to supply problems |
| | Strengths (S) | S1 | Holding specialized courses and having a coherent operational system |
| | | S2 | Having sufficient experience, expertise and knowledge in the field of maintenance and repairs |
| | | S3 | Having maintenance operations, overhaul and the ability to repair tools and equipment |
| | | S4 | Having multi-skilled specialists |
| | | S5 | |
| External factors | Threats (T) | T1 | Unsafe environmental conditions due to imported equipment |
| | | T2 | Unbalanced growth of parts supply chain elements due to sanctions, inflation and currency supply problems |
| | | T3 | Increased greenhouse gas emissions and climate change |
| | opportunities (O) | O1 | Providing equipment maintenance services at the regional level |
| | | O2 | Prosperity of overhaul market with old technology due to the sanctions |
| | | O3 | Quality improvement, inventory management, and focus on talents and facilities by setting long-term goals |
| | | O4 | Increased opportunities for regional cooperation |

For the intended company, ten maintenance and repair strategies are presented according to the SWOT table identified in the previous step.

**Table 2: Extracted strategies**

| | | | | | |
|---|---|---|---|---|---|
| WO strategies | WO1 | Development of domestic equipment in the field of oil and gas refining to reduce the need for imports | SO strategies | SO1 | Maximizing multi-skill forces in line with international cooperation |
| | WO2 | Maximizing research and development services according to regional potentials | | SO2 | Increased maintenance and repairs operations by in-house specialists to reduce the impact of sanctions |
| | WO3 | Use of facilities and asset management to retain professionals in the system | | SO3 | More specialized courses for infrastructure development |
| ST Strategies | ST1 | Reducing environmental challenges by increasing multi-skilled professionals and reducing dependency | WT strategies | WT1 | Minimizing financial losses |
| | ST2 | Reducing the need for imported parts by increasing preventive maintenance and repairs at the best possible time | | WT2 | Maximizing research and development activities and reducing the risk of unsafe environmental conditions |

- **Hierarchical analysis process**

AHP is one of the most appropriate methods for selecting and prioritizing strategies [21].

It usually consists of two parts: a) making pairwise comparisons, b) ranking levels of criteria importance [22].

The criteria are scored using the 1-9 L Hour scale.

The details of the AHP method are as follows:

Step 1: The hierarchical structure of the decision-making model

At this stage, the purpose and the decision matter are hierarchically related to each other.

Step 2: Creating a matrix of pairwise comparisons for the decision model

After formulating the decision problem, a pairwise comparison matrix is designed for each criterion using the 1-9 hour point scale presented in Table....

Step 3: Calculating the Compatibility Index (CI)

AHP method provides a suitable method for analyzing and testing the compatibility of the pairwise comparison matrix. CI measures the stability between pairwise comparisons and is expressed as follows [23]:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where λ represents the eigenvalue and n are the number of matrix criteria.

Step 4: Calculating the compatibility rate

$$CR = \frac{CI}{RI}$$

RI represents a random index. The value of RI is shown in Table .... The acceptable range of CR is usually less than 0.1

**Table 3: Criteria scales**

| Thomas L. Hour scales for binary criteria comparison | | |
|---|---|---|
| Description | Comparison of i with j | Preferred value |
| Option or index i is as important as j or they are of the same preference. | Same importance | 1 |
| The option or index i is slightly important than j. | Slightly important | 3 |
| The option or index i is more important than j. | More important | 5 |
| Option or index i has much higher priority than j. | Very important | 7 |
| The option or index i is absolutely important than j and is not comparable to j. | Absolutely important | 9 |

- RI randomness index

| The number of competing options | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| randomness index | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

- **Fuzzy TOPSIS**

In the TOPSIS method, the elements of the decision matrix or the criteria weight, or both, are evaluated by linguistic variables represented by fuzzy numbers.

- **Fuzzy TOPSIS steps**

Chen and Huang present the steps for using the fuzzy TOPSIS method in a multi-criteria decision problem with *n* criteria and *m* options:

Step 1: Forming a decision matrix

According to the number of criteria, the number of options and the evaluation of all options for different criteria, the decision matrix is formed as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & . & . & . & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & . & . & . & \tilde{x}_{2n} \\ . & . & & & & . \\ . & . & & \dots. & & . \\ . & . & & & & . \\ \tilde{x}_{m1} & \tilde{x}_{m2} & . & . & . & \tilde{x}_{mn} \end{bmatrix}$$

If triangular fuzzy numbers are used, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ represents the function of option i, $(i = 1,2,\dots,m)$ in relation to the criterion$(j = 1,2,\dots,n)$.

If the decision-making committee has k members and the fuzzy ranking of the kth decision-maker is $\tilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ (triangular fuzzy number) for i = 1,2,…, m and j = 1,2,…, n, according to the combined fuzzy ranking criteria, $\tilde{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$, the options will be obtained based on the following relations:

$$a_{ij} = Min\,\{a_{ijk}\}$$

$$b_{ij} = \frac{\sum_{k=1}^{k} b_{ijk}}{k}$$

$$c_{ij} = Max\{c_{ijk}\}$$

Step 2: Determining the criteria weight matrix

At this stage, the significance coefficient of different decision making criteria is defined as follows:

$$[\widetilde{W} = [\widetilde{w}_{1,}\widetilde{w}_{2},\dots,\widetilde{w}_{1}\,]$$

If triangular fuzzy numbers are used in the above relation, every $w_j$ (weight of every criterion) will be as $\widetilde{w}_j = \left(w_{j1}, w_{j2}, w_{j3}\right)$

Step 3: Unscaling the fuzzy decision matrix

When $x_{ij}$ are fuzzy, surely $r_{ij}$ will also be fuzzy. To do unscaling, instead of complex calculations in the classical TOPSIS method, linear scale change is used at this stage to convert different comparable criteria.

If the fuzzy numbers are triangular, the elements of the unscaled decision matrix for the positive and negative criteria are calculated from the following equations, respectively:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right)$$
$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right)$$

Where

$$c_j^* = \max c_{ij}$$
$$a_j^- = min\ a_{ij}$$

According to the weight of different criteria, the weighted fuzzy decision matrix is obtained by multiplying the significance of each criterion by the following unscaled fuzzy matrix:

$$\tilde{V}_{ij} = \tilde{r}_{ij} * \widetilde{w}_j$$

Where $\widetilde{w}_j$ represents the significance coefficient of the criterion $C_j$.
Thus, the weighted fuzzy matrix will be as follows:

$$\tilde{V} = \left[\tilde{v}_{ij}\right] \qquad i=1, 2, \dots, m, \quad j=1,2,\dots,n$$

Step 5: Finding fuzzy positive and negative ideal solutions
Fuzzy positive and negative ideal solutions are defined as follows:

$$A^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*\}$$
$$A^* = \{\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-\}$$

$\tilde{v}_i^*$ is the best value of $i$ and $\tilde{v}_1^-$ is the worst value among all of the potions that are obtained from the following equations:

$$d_v(\widetilde{M}_1, \widetilde{M}_2) = \sqrt{1/3[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

Step 6: Calculating the distance from fuzzy positive and negative ideal solution
The distance of each option from the fuzzy positive and negative ideal solutions are calculated from the following equations, respectively:

$$S_i^* = \sum_{j=1}^{n} d\left\{\tilde{v}_{ij}, \tilde{v}_j^*\right\}, \ \ i = 1,2, \dots, m$$
$$S_i^{*-} = \sum_{j=1}^{n} d\left\{\tilde{v}_{ij}, \tilde{v}_j^-\right\}, \ \ i = 1,2, \dots, m$$

*D* is the distance between two fuzzy numbers. If $(a_1, b_1, c_1)$ and $(a_2, b_2, c_2)$ are two triangular fuzzy numbers, the distance between them is:

$$d_v(\widetilde{M}_1, \widetilde{M}_2) = \sqrt{1/3[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

Step7: The similarity index is calculated from the following equation:

$$CC_i = \frac{S_i^-}{S_i^* + S_i^-} \qquad i= 1,2,\ldots,m$$

Step8: Ranking options

At this stage, according to the similarity index, the options are ranked so that the options with more similarity index are preferred.

- **AHP Results**

Pairwise comparisons matrix, SWOT factors, and sub-factors were obtained regarding the decision-making goals and experts' judgment according to the AHP approach. Both arithmetic and geometric mean were used to accumulate individual priorities in group decision making. Then, the final priority matrix as well as the group decision ranking of SWOT factors and sub-factors was obtained.

**✓SWOT factors ranking**

The ranking of SWOT factors is shown in Figure 3-2. The results show that strengths (S) and weaknesses (W) are more important than opportunities (O) and threats (T). The strengths and weaknesses strategies weigh 0.32 and the opportunities and threats weigh 0.14 and 0.22, respectively. These results reveal the importance of noticing the strengths and weaknesses in the process of selecting strategies for the company under the study.

**Table 4: SWOT factors paired comparisons**

| | S | W | O | T |
|---|---|---|---|---|
| S | 1 | 5 | 3 | 0.2 |
| W | 0.2 | 1 | 5 | 7 |
| O | 0.33 | 0.2 | 1 | 5 |
| T | 5 | 0.14 | 0.2 | 1 |

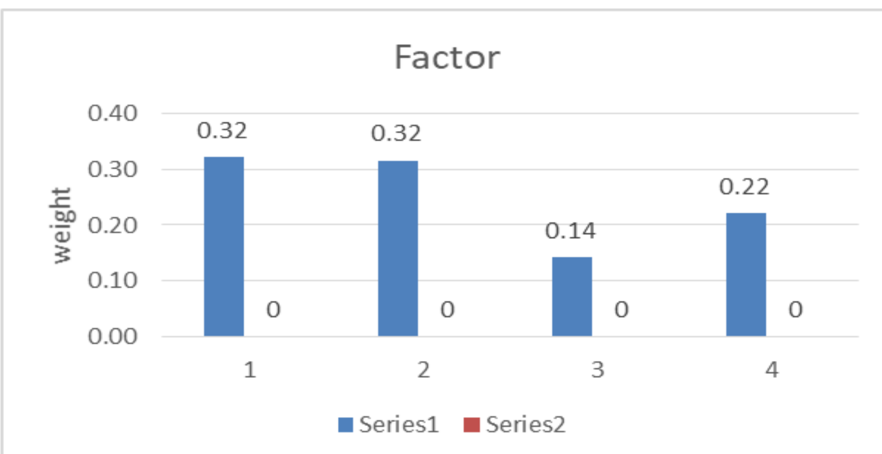



**Figure 2: Weight and ranking of SWOT factors**

**✓3-9-2 Strengths sub-factors ranking**

Table 3-3 displays the ranking of strength sub-factors under AHP. Sub-factor S4 (maintenance and repairs, overhaul, and ability to repair tools and equipment) has the highest priority. Then, the sub-factor S1 has the highest importance among the strengths. The second priority for the sub-factor of holding specialized courses and the existence of a coherent operational system shows the importance and concern of training in the oil refining and distribution Company.

**Table 5: Strengths (S) paired comparisons**

| | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|
| S1 | 1 | 3 | 2 | 3 | 5 |
| S2 | 0.33 | 1 | 1 | 5 | 2 |
| S3 | 0.5 | 1 | 1 | 2 | 3 |
| S4 | 0.33 | 0.2 | 0.5 | 1 | 2 |
| S5 | 0.2 | 0.5 | 0.33 | 0.5 | 1 |

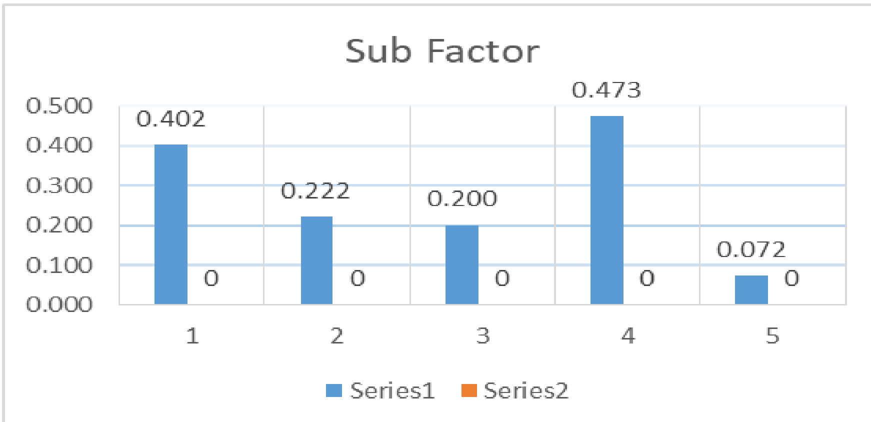



**Figure 3: Weight and ranking of strengths (S)**

### ✓3-9-3 Weaknesses (W) ranking

Figure 3-4 displays the weights and sub-factors of weaknesses. It is found that the lack of management in network organization, supply chain and cost of services (W1) with a weight of 0.592 is the most serious concern. Low liquidity due to parts supply problems with a weight of 0.216 is the second serious factor.

**Table 6: Weaknesses (W) paired comparisons**

| | w1 | w2 | w3 | w4 |
|---|---|---|---|---|
| w1 | 1 | 5 | 9 | 3 |
| w2 | 0.2 | 1 | 3 | 0.33 |
| w3 | 0.11 | 0.33 | 1 | 0.5 |
| w4 | 0.33 | 3 | 2 | 1 |

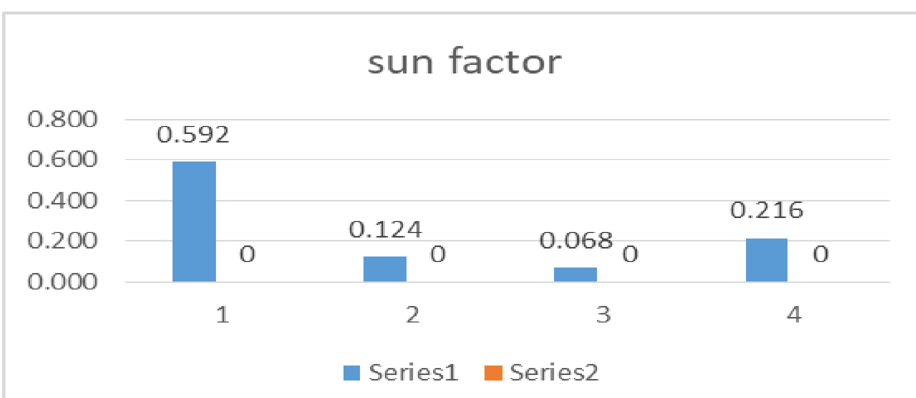



**Figure 4: Weight and ranking of weaknesses (S)**

**✓3-9-4 Threats (T) ranking**

The weights and rankings of the threats sub-factor are shown in Figure 3-5. It is found that u environmental conditions due to the import of equipment are the most important factor among external threats. This is mainly because of the sanctions and the impossibility of imports.

**Table 7: Threats (T) paired comparisons**

| | T1 | T2 | T3 |
|---|---|---|---|
| T1 | 1 | 5 | 7 |
| T2 | 0.2 | 1 | 0.33 |
| T3 | 0.14 | 3 | 1 |

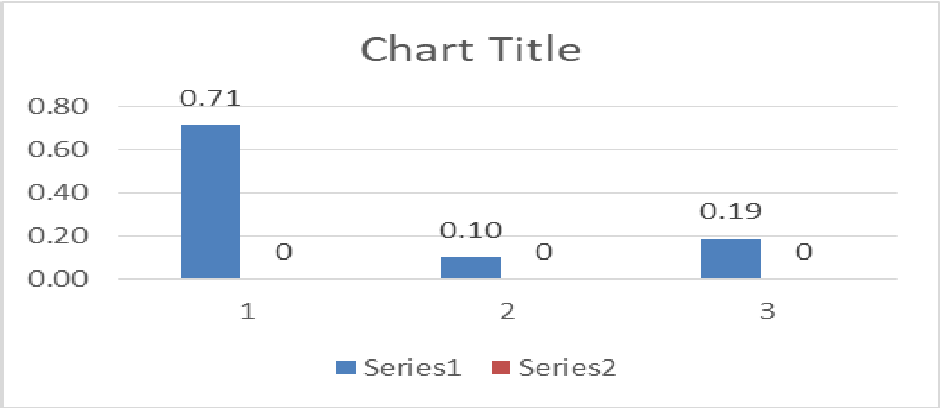



**Figure 5: Weight and ranking of threats (T)**

**✓3-9-5 Opportunities (O) ranking**

The weights and rankings of the opportunities sub-factor are shown in Figure 3-6. Providing equipment maintenance services in the region is ranked as the most important sub-factor. It weighs 0.41 and indicates that opportunities might allow a large share of the regional market.

**Table 8: Opportunities (O) paired comparisons**

| | O1 | O2 | O3 | O4 |
|---|---|---|---|---|
| O1 | 1 | 5 | 9 | 0.33 |
| O2 | 0.2 | 1 | 0.33 | 3 |
| O3 | 0.11 | 3 | 1 | 2 |
| O4 | 3 | 0.33 | 0.5 | 1 |

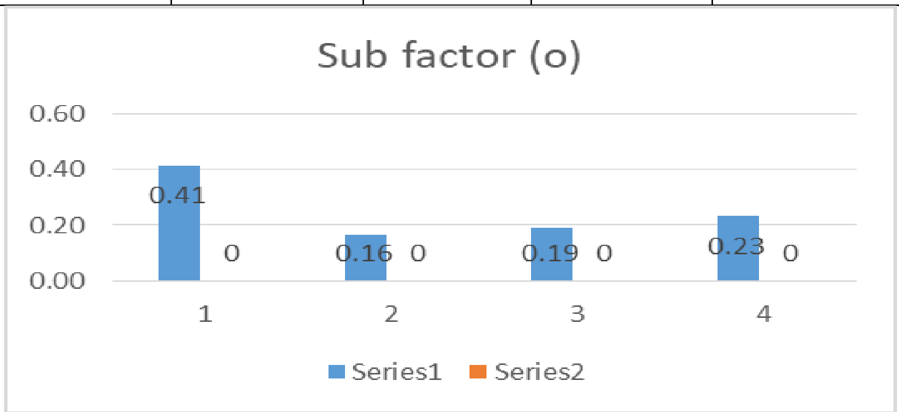



**Figure 6: Weight and ranking of opportunities (O)**

### ✓3-9-6 General ranking of SWOT sub-factors

In this section, all SWOT sub-factors are analyzed in a general form, regardless of their groupings. The weights and rankings of these sub-factors are shown in Figure 3-7. The results suggest that the sub-factor W3 has a high priority and then the factors S5 and T2 occupy the next ranks, respectively.

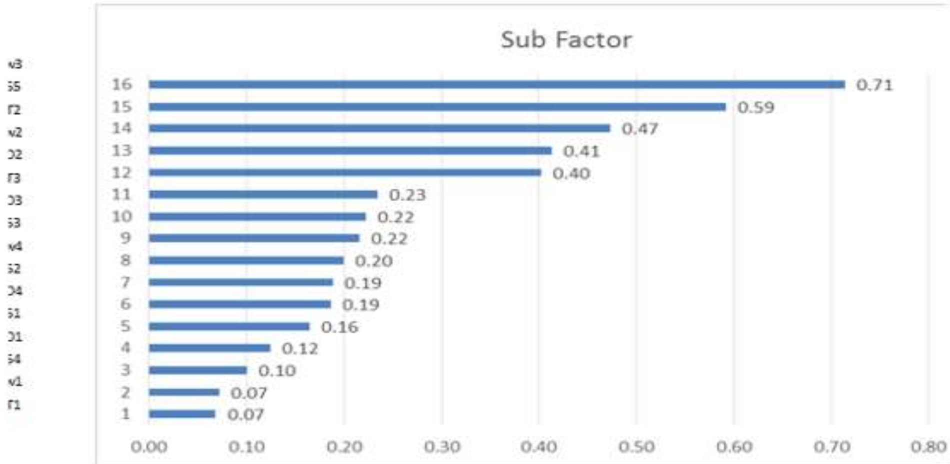



**Figure 7: SWOT sub-factors ranking**

- **Fuzzy TOPSIS Results**

In this section, using the fuzzy TOPSIS method and the results obtained from SWOT-AHP method in the previous step, the identified strategies are ranked and the steps of the method are presented below.

### ✓Formation of decision matrix

Using the maintenance strategies identified for the oil company and the prioritization matrix for SWOT sub-factors, the decision-matrix is presented as follows.

**Table 9: Fuzzy decision matrix**

| | $S^+$ | $W^-$ | $O^+$ | $T^-$ |
|---|---|---|---|---|
| SO1 | (9,10,10) | (0,1,3) | (7,9,10) | (1,3,5) |
| SO2 | (3,5,7) | (1,3,5) | (7,9,10) | (0,1,3) |
| SO3 | (9,10,10) | (0,1,3) | (9,10,10) | (1,3,5) |
| WO1 | (0,1.3) | (7,9,10) | (7,9,10) | (0,1,3) |
| WO2 | (1,3,5) | (9,10,10) | (7,9,10) | (0,1,3) |
| WO3 | (0,1,3) | (7,9,10) | (9,10,10) | (1,3,5) |
| ST1 | (7,9,10) | (0,1,3) | (1,3,5) | (7,9,10) |
| ST2 | (9,10,10) | (1,3,5) | (1,3,5) | (7,9,10) |
| WT1 | (0,1,3) | (7,9,10) | (0,1,3) | (9,10,10) |
| WT2 | (1,3,5) | (7,9,10) | (1,3,5) | (7,9,10) |

The criteria weight matrix is presented in the table below:

**Table**

| W1 | | | W2 | | | W3 | | | W4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.7 | 1 | 0.9 | 1 | 1 | 0.9 | 1 | 1 | 0.5 | 0.7 | 1 |

### ✓Unscaling the decision matrix

The first and third criteria have a positive position and the second and fourth criteria have a negative position. Table 3-10 shows the unscaled fuzzy matrix:

**Table 10 Fuzzy unscaled matrix 3-10-3**

| | $S^+$ | | | $W^-$ | | | $O^+$ | | | $T^-$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SO1 | 0.90 | 1.00 | 1.00 | 0.20 | 0.33 | 1.00 | 0.70 | 0.90 | 1.00 | 0.20 | 0.33 | 1.00 |
| SO2 | 0.30 | 0.50 | 0.70 | 0.20 | 0.33 | 1.00 | 0.70 | 0.90 | 1.00 | 0.20 | 0.33 | 1.00 |
| SO3 | 0.90 | 1.00 | 1.00 | 0.20 | 0.33 | 1.00 | 0.90 | 1.00 | 1.00 | 0.20 | 0.33 | 1.00 |
| WO1 | 0.00 | 0.10 | 0.30 | 0.10 | 0.11 | 0.14 | 0.70 | 0.90 | 1.00 | 0.14 | 0.20 | 0.33 |
| WO2 | 0.10 | 0.30 | 0.50 | 0.10 | 0.10 | 0.11 | 0.70 | 0.90 | 1.00 | 0.20 | 0.33 | 1.00 |
| WO3 | 0.00 | 0.10 | 0.30 | 0.10 | 0.11 | 0.14 | 0.90 | 1.00 | 1.00 | 0.20 | 0.33 | 1.00 |
| ST1 | 0.70 | 0.90 | 1.00 | 0.20 | 0.33 | 1.00 | 0.10 | 0.30 | 0.50 | 0.10 | 0.11 | 0.14 |
| ST2 | 0.90 | 1.00 | 1.00 | 0.20 | 0.33 | 1.00 | 0.10 | 0.30 | 0.50 | 0.10 | 0.11 | 0.14 |
| WT1 | 0.00 | 0.10 | 0.30 | 0.10 | 0.11 | 0.14 | 0.00 | 0.10 | 0.30 | 0.10 | 0.10 | 0.11 |
| WT2 | 0.10 | 0.30 | 0.50 | 0.10 | 0.11 | 0.14 | 0.10 | 0.30 | 0.50 | 0.10 | 0.11 | 0.14 |

### ✓Weighted unscaled decision matrix

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.45 | 0.70 | 1.00 | 0.18 | 0.33 | 1.00 | 0.63 | 0.90 | 1.00 | 0.10 | 0.23 | 1.00 |
| 0.15 | 0.35 | 0.70 | 0.18 | 0.33 | 1.00 | 0.63 | 0.90 | 1.00 | 0.10 | 0.23 | 1.00 |
| 0.45 | 0.70 | 1.00 | 0.18 | 0.33 | 1.00 | 0.81 | 1.00 | 1.00 | 0.10 | 0.23 | 1.00 |
| 0.00 | 0.07 | 0.30 | 0.09 | 0.11 | 0.14 | 0.63 | 0.90 | 1.00 | 0.07 | 0.14 | 0.33 |
| 0.05 | 0.21 | 0.50 | 0.09 | 0.10 | 0.11 | 0.63 | 0.90 | 1.00 | 0.10 | 0.23 | 1.00 |
| 0.00 | 0.07 | 0.30 | 0.09 | 0.11 | 0.14 | 0.81 | 1.00 | 1.00 | 0.10 | 0.23 | 1.00 |
| 0.35 | 0.63 | 1.00 | 0.18 | 0.33 | 1.00 | 0.09 | 0.30 | 0.50 | 0.05 | 0.08 | 0.14 |
| 0.45 | 0.70 | 1.00 | 0.18 | 0.33 | 1.00 | 0.09 | 0.30 | 0.50 | 0.05 | 0.08 | 0.14 |
| 0.00 | 0.07 | 0.30 | 0.09 | 0.11 | 0.14 | 0.00 | 0.10 | 0.30 | 0.05 | 0.07 | 0.11 |
| 0.05 | 0.21 | 0.50 | 0.09 | 0.11 | 0.14 | 0.09 | 0.30 | 0.50 | 0.05 | 0.08 | 0.14 |

### ✓Calculating positive and negative ideal solutions

The fuzzy ideal positive solution for different criteria is obtained as follows:

| | | | |
|---|---|---|---|
| $\tilde{V}_1^*$ | 1.00 | 1.00 | 1.00 |
| $\tilde{V}_2^*$ | 1.00 | 1.00 | 1.00 |
| $\tilde{V}_3^*$ | 1.00 | 1.00 | 1.00 |
| $\tilde{V}_4^*$ | 1.00 | 1.00 | 1.00 |

$A^{*} = [(1,1,1), (1,1,1), (1,1,1), (1,1,1)]$

The fuzzy ideal negative solution for different criteria is obtained as follows:

| | | | |
|---|---|---|---|
| $\tilde{V}_1^-$ | 0.00 | 0.00 | 0.00 |
| $\tilde{V}_2^-$ | 0.09 | 0.09 | 0.09 |
| $\tilde{V}_3^-$ | 0.00 | 0.00 | 0.00 |
| $\tilde{V}_4^-$ | 0.05 | 0.05 | 0.05 |

$A^{-} = [(0,0,0), (0.09,0.09,0.09), (0,0,0), (0.05,0.05,0.05)]$

✓**etermining the distance of each option from the positive and the negative ideal solutions ($S_i^-$, $S_i^*$) and the similarity index**

The distance of different options from the fuzzy ideal solution of every criteria is calculated as follows:

**Table 11: Distance from the positive and negative ideal solutions**

| | | | |
|---|---|---|---|
| $S_1^*$ | 1.99 | 2.714 | $S_1^-$ |
| $S_2^*$ | 2.63 | 2.423 | $S_2^-$ |
| $S_3^*$ | 1.77 | 2.798 | $S_3^-$ |
| $S_4^*$ | 2.84 | 1.24 | $S_4^-$ |
| $S_5^*$ | 2.57 | 1.745 | $S_5^-$ |
| $S_6^*$ | 2.59 | 1.711 | $S_6^-$ |
| $S_7^*$ | 2.69 | 1.655 | $S_7^-$ |
| $S_8^*$ | 2.55 | 1.694 | $S_8^-$ |
| $S_9^*$ | 3.61 | 0.43 | $S_9^-$ |
| $S_{10}^*$ | 3.3 | 0.744 | $S_{10}^-$ |

✓**Calculating the similarity index for different options**

Similarity index

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CC3 | CC1 | CC2 | CC5 | CC8 | CC6 | CC7 | CC4 | CC10 | CC9 |
| **0.612** | **0.577** | **0.480** | **0.404** | **0.398** | **0.398** | **0.381** | **0.304** | **0.184** | **0.107** |
| SO3 | SO1 | SO2 | WO2 | ST2 | WO3 | ST1 | WO1 | WT2 | WT1 |

**Fuzzy TOPSIS Results**

After analyzing the SWOT sub-factors via AHP, maintenance and repair strategies of the oil refining and distribution company were prioritized using fuzzy TOPSIS. Doing an analysis by a group of experts led to the formation of a fuzzy evaluation matrix using linguistic variables. Therefore, this research determines the evaluation matrix according to different options. This follows the development of fuzzy decision matrix that is a weighted fuzzy decision matrix according to the factors of this study. Then, SWOT factors and sub-factors ranking were evaluated. Finally, the prioritization order of 10 maintenance strategies was obtained (Table 1-4).

**Table 12: Final ranking of maintenance strategies**

| Strategy | | Distance from the positive ideal solution | Distance from the negative ideal solution | Similarity index | Rank |
|---|---|---|---|---|---|
| SO1 | Maximizing multi-skilled staff in line with international cooperation | 1.99 | 2.714 | 0.577 | 2 |
| SO2 | Increased maintenance operations by in-house specialists to reduce the impact of sanctions | 2.63 | 2.423 | 0.480 | 3 |
| SO3 | Holding specialized courses for infrastructure development | 1.77 | 2.798 | 0.612 | 1 |
| WO1 | Development of domestic equipment in the field of oil and gas refining to reduce the need for imports | 2.84 | 1.24 | 0.304 | 8 |
| WO2 | Maximizing research and development services according to regional potentials | 2.57 | 1.745 | 0.404 | 4 |
| WO3 | Use of facilities and asset management to retain professionals in the system | 2.59 | 1.711 | 0.398 | 6 |
| ST1 | Reduced environmental challenges by increasing multi-skilled professionals and reducing dependency | 2.69 | 1.655 | 0.381 | 7 |
| ST2 | Reducing the need for imported parts by increasing preventive maintenance and repairs at the best possible time | 2.55 | 1.694 | 0.399 | 5 |
| WT1 | Minimizing financial losses | 3.61 | 0.43 | 0.107 | 10 |
| WT2 | Maximizing research and development activities and reducing the risk of uncertain environmental conditions | 3.3 | 0.744 | 0.184 | 9 |

To hold specialized courses for infrastructure development is the most important strategy for a company. This strategy will eliminate the company's need for foreign experts and will bring independence to the organization. Due to the increased skills of employees and having multi-skilled employees to do repairs, financial payments will remain in the organization and will bring profitability.

To maximize the multi-skilled workforce with regard to international cooperation is the second strategy presented for the company. It is also presented in line with the first strategy and confirms the high importance of training. To increase maintenance operations by in-house specialists to reduce the impact of sanctions is the third strategy. It leads to timely repairs and subsequently no unwanted delayed repairs.

## Conclusion

Decision making and therefore prioritization of maintenance and repair strategies is a very complex process that includes various positive and negative factors. This study adopted an integrated SWOT-AHP analysis and F-TOPSIS approach to determine sub-factors and prioritize maintenance strategies. We introduced 10 strategies and highlighted the high importance of training specialized personnel in order to have multi-skilled personnel, which minimizes the organization's dependence on foreign specialized personnel. Moreover, the use of native multi-skilled personnel potentials results in reduced dependence on foreigners, the need for imports, reduced risk, and less financial losses. This, in turn, results in reduced costs, increased competitiveness, continuous improvement, increased quality and quantity of the product, adequate natural resources, reduced energy crisis, and so on. It also leads to customer satisfaction with the lowest possible cost and at the right time; hence, companies can adapt to the globalization developments.

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