# Efficiency of Domestic and Foreign Maintenance Checks in Mahan Airline Planes

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**Abstract**

Companies and organizations have increasingly recognized the need to concentrate more on their core competences to remove non-essential conducts from their daily programs. As a result, activities outsourcing has become an inevitable part of management tasks in organizations. In this paper, efficiency of domestic and foreign maintenance checks for Mahan aircrafts are comparred, and decision-making about insourcing or outsourcing the maintenance checks are studied. For this purpose, a questionnaire was designed and in order to assess the criteria, a combination of AHP method with TOPSIS and ELECTRE techniques were employed and analyzed.

The results revealed that trained human resources have the utmost influence on the efficiency of aircraft maintenance checks with a significant difference in comparison with the other factors. After human resources, tools and equipment have been stated as the second most effective criterion on the efficiency of maintenance checks. Moreover, according to the results obtained, there is no significant difference between domestic and foreign aircraft maintenance checks. In other words, the advantage of outsourcing and insourcing this type of maintenance checks is fairly similar.

Keywords**:** Outsourcing, Maintenance check, AHP, TOPSIS, ELECTRE

## 1- Introduction

Outsourcing in many of today's organizations (including western, eastern, or Iranian organizations) has become a commonplace activity, rather than being an unusual and strange one. Contemplating about these terms can direct us to study the concepts, such as organizational structures, public and private enterprises, competitive and monopolistic marketing, higher added value, cost reduction and profit increase, project management, risk management, agility and flexibility, penetrating new markets, and many other specialized tools and knowledge.

Nowadays, outsourcing has been presented as a method to delegate a part of the work to the outside or inside of an organization in format of a contract. Like any other approach, it can provide useful outcomes for an organization; however, if this approach does not enclose the well-defined conditions and standards, it may bring many disadvantages. Today, many companies have focused on specific expertise and skills in order to only and only provide their services to the external clients. Some researchers have shown that the benefits of outsourcing for many companies are quite extensive and the most important advantages refer to the savings in time and cost, improvement of quality, and liberation of their internal resources, which can enable the companies to make use of their resources more efficiently.

In spite of the aforementioned facts, due to various reasons in our country, outsourcing has not been widely considered and exercised by managers and authorities. Therefore, researchers and industry executives need to study outsourcing in order to apply it. On the other hand, the outsourcing pros and cons should be scrutinized, in a way to clearly and scientifically clarify when, how, to who, and what should be delegated.

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## 2- Literature review

Searching through information centers and libraries made it clear that up to now, not many researches have been completed on outsourcing aircraft maintenance checks in Iran. However, some studies have been carried out in the field of outsourcing goods and services and other related subjects, which are cited as follows:

- McKenna and Walker (2008). "A study of out-sourcing versus in-sourcing tasks within a project value chain".

Purpose of this study was to examine and demonstrate the importance of outsourcing as a standard and imperative method for telecommunications companies in North America. This paper shows how new perspectives in decision-making process can facilitate the access to competitive advantage through cost reduction. This research provides a framework focusing on creating value-added products and services. The results exhibited that concentrating on the main and important aspects of insourcing is a tool to gain a competitive advantage and improves decision-making in production of goods and services.

- Schniederjans and Zuckweiler (2004). "A quantitative approach to the outsourcing- insourcing decision in an international context"

In order to make decision of manufacturing a product inside or outside a country, several considerations should be made. In fact, such decisions are accompanied with many risks, especially when decision making is about outsourcing of goods and services. Because of that, this study conducted a profound investigation on the Fortune 500 companies and reviewed international risk of managers' decisions on production of goods and services. In this research, by using a quantitative model, the decision-making on outsourcing-insourcing of goods and services was surveyed. The results demonstrated that if managers consider the risks associated with their decisions (particularly the risk of data collection costs), the decisions in the issue can be better made. Advantage of using quantitative model of this study has been outlined in below:

1. Consideration of the causes of risks involved in outsourcing-insourcing decisions.
2. Quantitative measurement of the goals of outsourcing-insourcing decisions with respect to the target market's needs.
3. Offering practical solutions based on real data of research population in order to reach a proper decision on outsourcing-insourcing of goods and services.

- Caputo and Palumbo (2005). "Manufacturing re-insourcing in the textile industry: A case study"

Today's modern markets have the ability to respond quickly, qualitatively, and combinatorially for their produced goods. For this reason, the concern of most managers is to whether outsource or insource their products, which is associated with high costs for them. Purpose of this study was to re-assess the decision making methods in this industry, particularly during insourcing of goods and services. To do this, a methodology was offered to managers to enable them to examine the aims for re-assessing their outsourcing decisions, in order to achieve the continuous improvement of goods and services production. An economic analysis of the existing methods was conducted, and the obtained results indicated that insourcing in re-engineering is an appropriate solution for managers in producing goods and services.

- Yahaya and Abu-Bakar (2007). "New product development management issues and decision-making approaches"

Purpose of this study was to present the findings related to new product development management and also the decision-making viewpoints of senior managers. In total, 16 senior managers in Malaysian organizations were analyzed. The results suggested four important issues in new product development management, which are strategic, project management, structure and process, and human resource management issues. The findings also revealed that senior managers employ different decision-making patterns in each of these decision-making categories for producing their goods and services.

- Rajabzadeh et al. (2008). "Designing a generic model for outsourcing process in public sector: evidence of Iran"

Objective of this study was to evaluate the outsourcing process, determine the effective factors in the process, and prioritizing them in public sector. This investigation sought to present a model in the context. The proposed model of succeeded to increase the efficiency and effectiveness of outsourcing process in governmental organizations.

- Ho et al. (2006). "Multiple criteria decision-making techniques in higher education"

Purpose of this study was to examine the issues and problems involved in decision-making process in higher education institutions. Findings of this paper disclosed that problems largely refer to resource allocation, performance measurement, budgeting, and planning. In general, this study was grounded on the following questions:

1. Which multi-criteria decision-making techniques have been recently studied?
2. What are the most important weaknesses of these methods?
3. What issues should be considered more extensively in decision-making?

The MADM method was utilized in this investigation. The results exhibited that in order to mitigate these weaknesses, appropriate measures need to be taken and continuous improvement in activities should be made. Finally, an optimal resource allocation model has been proposed based on some factors. The results suggested a targeted knowledge-based planning technique, which merges some of hierarchical process operations.

- Czeipel (2003). "Practices and perspectives in outsourcing aircraft maintenance"

Objective of this study was to evaluate the most important methods that airline companies apply for selection, evaluation, and assessment of the performance of facilities and also the functioning of outsourcing methods for repair and maintenance checks. The overall goal of this study was to focus on the outsourcing of the main repairs of aircrafts to large maintenance corporations. Data for this study was collected from interviews made with managers of airlines and maintenance companies. The most important risk indicators and measurement indices obtained have been divided into three general categories. The main measurement indices in maintenance part included trained human resources, experience level of employees, and tools and equipment of these centers. The performance indicators related to maintenance centers were consisted of auditing procedures, time savings, and number of labor disputes. From the perspective of centers' managers, the most important criteria for outsourcing are financial status of maintenance centers and changes in management of these companies and centers. In conclusion, the most important indices considered for outsourcing were: service quality in maintenance centers, experience level of employees, and total costs of the provided services.

- Choobineh et al. (2007). "A multiple-factor decision analysis framework for manufacturing outsourcing"

Main purpose of this study was to investigate different outsourcing models and decision-making methods, to propose a decision-making framework in the context of outsourcing with the aid of multi-criteria decision-making model.

In this investigation, the value-based thinking method was utilized to define the outsourcing goals and analyze the hierarchical process to prioritize them. In addition, the collective theory method was employed to model the behavioral risk of decision makers. The results proposed a model based on cost-benefit approach of insourcing and outsourcing services and goods, which helps managers choose the best method according to the available options in various circumstances.

- Bertolini et al. (2004). "An analytical method for maintenance outsourcing service selection"

This paper analyzes outsourcing of maintenance checks, by using multi-criteria decision-making (MCDM) method as well as analytic hierarchy process as a support system for management decisions to select different methods for outsourcing maintenance checks. The proposed methodology was applied for Italian brickwork centers. Based on the findings obtained, it was claimed that AHP method has increased the rate of selecting the right decision-making methods. In particular, this method has desirably incorporated all the factors that should be examined in any decision-making problem.

- Lua and Zhang (2006). "Drivers and obstacles of outsourcing practices in China"

There are many obstacles and problems for an organization that aims to re-focus on outsourcing. This study dealt with these issues in China and compared them with the problems in Western countries. Preliminary data for this study was collected through detailed interviews with six companies in China and the secondary data was gathered from the companies' documentations and reports. The gained results have been examined in all organizations to accurately analyze all the obstacles as well as the main results of outsourcing. The attained findings confirmed that economic factor is the most important factor for outsourcing in China. This is mainly because cost reduction, cost saving, and reduction of fixed investments are amongst the main concerns in China. Some of the strategic views in this context, including using outsourcing to achieve engineering benefits, focusing on the main competitions of the company, increasing flexibility, and facilitating market penetration, have been identified as the important factors in this regard. Moreover, environmental factors, such as development of information technology and suppliers' capabilities, can affect the organizations' outsourcing decisions. Overall, the most important outsourcing obstacles facing Chinese companies include the lack of competent professionals in supplying services, lack of control, structural weaknesses in transportation, lawful weaknesses in local security, and absence of general tools before outsourcing.

## 3- Methodology and Data

This research has aimed at developing practical knowledge in a particular field, and considering this fact that the necessity of authorities' attention to research variables is to be underscored. Based on the data collection method, this study is a survey research, because while it describes the data and determines the relationship, the data about one or several attributes are obtained by sampling from the population (Sarmad et al., 2006). Furthermore, as this study has been carried out in a particular period, it is considered as a period research. The following methods have been used for data collection:

Different sources including books, articles, internet, journals, dissertations, etc. were used to identify the efficient criteria for maintenance checks. The criteria identified in this section are as follow:

- Trained human resources
- Experience level of employees (efficiency)
- Tools and equipment (technology)
- Time savings
- Financial status of maintenance centers
- Changes in centers' management
- Service quality in centers
- Total costs of services

To provide the questionnaire and determine the indicators, and also to complete the information, a few of airlines' managers and some maintenance managers have been interviewed and also, the ideas of respective professors have been obtained to modify the questionnaire. For preparation of final data, the questionnaires have been filled by statistical sampling.

The statistical population of the research includes the experts in the field of outsourcing and maintenance checks of aircrafts in Mahan Airline Company and its subsidiary companies.

In order to assess the weights of indices, the AHP, ELECTRE, and TOPSIS techniques were used. The indices and criteria introduced were applied to analyze the data. The data attained from the first part of the questionnaire (criteria) were analyzed by using AHP method and the data gained from the second part of questionnaire (indices) were analyzed by using TOPSIS and ELECTRE methods.

### 4.1- Prioritization of effective indices by using AHP to assess efficiency of maintenance checks

AHP technique initially integrates 51 different matrices (completed questionnaires) for comparing the indices into a single matrix. To combine the pairwise comparison tables of all the respondents, one of the best methods is to use the geometric mean, since pairwise comparisons generate data in the format of ratios. Moreover, because of inverted comparison matrix, this method becomes more plausible, as the geometric mean preserves the reciprocal nature of the pairwise comparison matrix. If it is

presumed that $a_{ij}^{(k)}$ is the component related to the $k^{th}$ respondent for comparing criterion of i to j, the geometric mean for the corresponding components can be calculated from the following relation:
Using the above matrix, the comparison of indices in terms of the groups will be as follows:

$$\overline{a_{ij}} = (\prod_{k=1}^{n} a_{ij}^{k})^{1/n}$$

**Table 1** - The initial matrix of the pairwise comparison of indices after combining the data

| **Indices** | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ | $I_8$ |
|---|---|---|---|---|---|---|---|---|
| $I_1$ | 1 | 1.67 | 1.8 | 1.44 | 2.32 | 1.53 | 1.56 | 2.12 |
| $I_2$ | 0.6 | 1 | 1.08 | 0.86 | 1.39 | 0.91 | 0.93 | 1.26 |
| $I_3$ | 0.55 | 0.93 | 1 | 0.8 | 1.29 | 0.85 | 0.87 | 1.18 |
| $I_4$ | 0.69 | 1.16 | 1.25 | 1 | 1.61 | 1.06 | 1.09 | 1.47 |
| $I_5$ | 0.43 | 0.72 | 0.77 | 0.62 | 1 | 0.66 | 0.67 | 0.91 |
| $I_6$ | 0.65 | 1.1 | 1.18 | 0.94 | 1.51 | 1 | 1.02 | 1.38 |
| $I_7$ | 0.64 | 1.08 | 0.15 | 0.92 | 1.49 | 0.98 | 1 | 1.35 |
| $I_8$ | 0.47 | 0.79 | 0.85 | 0.68 | 1.1 | 0.72 | 0.74 | 1 |
| **Total of column** | 5.03 | 8.45 | 8.08 | 7.26 | 11.71 | 7.71 | 7.88 | 10.67 |

Where

$I_1$: Trained human resources
$I_2$: Experience level of employees (efficiency)
$I_3$: Time savings
$I_4$: Tools and equipment (technology)
$I_5$: Financial status of maintenance centers
$I_6$: Changes in centers' management
$I_7$: Service quality in centers
$I_8$: Total costs of services

In order to extract the priorities from the above table, the concept of normalization and weighted average is used. By applying the following equation, the figures of the above table are normalized:

$$r_{ij} = \frac{\overline{a_{ij}}}{i = \sum_{i=1}^{m} \overline{a_{ij}}}$$

Where $r_{ij}$ is the normal component. Given the above relation, the normalized values of the above table's matrix, are as below. After normalizing data, the weighted average of the obtained values are taken. The resultant values of the weighted averages reflect the priority of each one.

**Table 2** - The normalized matrix

| **Indices** | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ | $I_8$ | **Average of the row** |
|---|---|---|---|---|---|---|---|---|---|
| $I_1$ | 0.199 | 0.197 | 0.200 | 0.197 | 0.199 | 0.197 | 0.198 | 0.197 | 0.199 |
| $I_2$ | 0.119 | 0.118 | 0.119 | 0.117 | 0.119 | 0.121 | 0.119 | 0.118 | 0.119 |
| $I_3$ | 0.109 | 0.110 | 0.109 | 0.111 | 0.109 | 0.110 | 0.110 | 0.110 | 0.109 |
| $I_4$ | 0.137 | 0.137 | 0.137 | 0.138 | 0.137 | 0.137 | 0.139 | 0.137 | 0.137 |
| $I_5$ | 0.085 | 0.085 | 0.086 | 0.084 | 0.085 | 0.083 | 0.085 | 0.085 | 0.085 |
| $I_6$ | 0.129 | 0.131 | 0.129 | 0.131 | 0.129 | 0.127 | 0.129 | 0.130 | 0.129 |
| $I_7$ | 0.127 | 0.129 | 0.129 | 0.126 | 0.127 | 0.128 | 0.126 | 0.128 | 0.127 |
| $I_8$ | 0.093 | 0.093 | 0.094 | 0.096 | 0.094 | 0.091 | 0.094 | 0.093 | 0.093 |

Therefore, the below table shows the matrix of indices' priorities according to the obtained results:

**Table 3 -** The final matrix of prioritization of the criteria using the AHP method

| Indices | Criteria weights (the row average) |
|---|---|
| $I_1$ | 0.199 |
| $I_4$ | 0.137 |
| $I_6$ | 0.129 |
| $I_7$ | 0.127 |
| $I_2$ | 0.119 |
| $I_3$ | 0.109 |
| $I_8$ | 0.093 |
| $I_5$ | 0.085 |

Therefore, based on AHP method, prioritization of the criteria by using this method is as follows:

1. Trained human resources
2. Tools and equipment (technology)
3. Changes in centers' management
4. Service quality in centers
5. Experience level of employees (efficiency)
6. Time savings
7. Total costs of services
8. Financial status of maintenance centers

### 4.2- Consistency Ratio (CR)

In prioritization of elements and activities, to ensure the results and validate the operation procedure, a certain degree of consistency is required. In AHP, the overall inconsistency of judgments is calculated by consistency ratio. In general, consistency ratio specifies the consistency degree of comparisons and shows the extent to which, the resulting prioritization based on the defined criteria and combined tables can be trusted. In order to calculate this ratio, many studies have been accomplished and the best method is to apply the eigenvector method. Thus, according to this method, the consistency ratio is measured as follows:

First, the weighted sum vector (WSV) is calculated. To calculate this vector, the initial comparison matrix is multiplied by the final prioritization vector and then, sum of each row is calculated. By dividing each element of the above vector to the vector of criteria priorities, the consistency vector (CV) is calculated and then, the consistency index (CI) is calculated according to the following relation:

$$CI= \frac{\lambda_{min}-n}{N}$$

In the above relation, n is the number of options and $\lambda_{min}$ is the average of the consistency vector. Finally, the consistency ratio (CR) is obtained from the below relation:

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

Where RI represents the random index value. This index is extracted according to the number of options and through the table of random consistency indices. If the calculated consistency index is lower than 0.1, it can be stated that the matrix of pairwise comparisons has an acceptable consistency and the model is meaningful.

### 4.3- Calculating consistency ratio

First, the weighted sum vector (WSV) is calculated. To calculate this vector, the initial values for group comparisons (Table 1) are multiplied by the total priority vector (final weights of indices) and the sum of each row is calculated as:

$$WSV = \begin{bmatrix} 1.294 & 0.58 & 1.629 & 0.931 & 0.556 \end{bmatrix}$$

By dividing each element of the above vector to the vector of criteria priorities, the consistency vector (CV) is calculated:

$$C.V = \begin{bmatrix} 4.96 & 5 & 4.99 & 5 & 5.01 \end{bmatrix}$$

Then, the consistency index (CI) is calculated according to the following relation:

$$CI = \frac{\lambda_{\min} - n}{n-1} = \frac{4.99 - 5}{4} = 0.0025$$

In the above equation, n is the number of options and $\lambda_{min}$ is the average of the consistency vector. Finally, the consistency rate (CR) is obtained from the below relation:

$$C.R = \frac{C.I}{R.I}$$

Where RI represents the random index value. This index is extracted according to the number of options and through the table of random consistency index. Since in the above equation, n is equal to 5, according to the RI table, it is equal to 1.02. Hence:

$$C.R = \frac{C.I}{R.I} = \frac{0.0025}{1.02} = 0.0024$$

Considering this fact that the calculated consistency index is much lower than 0.1, it can be expressed that pairwise comparisons in the matrix of Table 3 have an acceptable consistency and the model is totally meaningful. After weighting the indices by using two other MADM methods, namely TOPSIS and ELECTRE techniques, ranking of options (6 options in this paper) is conducted. Therefore, the following two states occur:

1. Weighting based on AHP, ranking based on TOPSIS
2. Weighting based on AHP, ranking based on ELECTRE

**4.4- Ranking of options: first state (weighting based on AHP, ranking based on TOPSIS)**

In order to rank the options according to the eight indices outlined in the previous stage and the six existing options, an 8×6 decision-making matrix is created. In order to prioritize the 6 selected indices by TOPSIS, the following steps are performed:

**First step**: by using the collected information, the initial decision-making matrix is created:

$$D = \begin{bmatrix} 6.4 & 4.2 & 5.4 & 3.2 & 7.8 & 3.6 & 5.8 & 5.8 \\ 6.8 & 5.6 & 6.6 & 4.6 & 5.4 & 5.4 & 5 & 8.6 \\ 6.6. & 4.2 & 3.2 & 8 & 3 & 5 & 7.4 & 3.4 \\ 3.6 & 5 & 6.2 & 4.4 & 7 & 6.8 & 5.4 & 6.2 \\ 5.7 & 6.2 & 5.4 & 5.8 & 4.4 & 5.2 & 7.2 & 8.2 \\ 4.9 & 6.1 & 6.3 & 4.7 & 5.8 & 5.3 & 7.1 & 7..4 \end{bmatrix}$$

**Second step**: in this step, by using Euclidean norm, the decision-making matrix becomes a non-scale matrix (matrix D by using $N_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}}$ is converted to matrix ND).

$$ND = \begin{bmatrix} 0.45 & 0.32 & 0.39 & 0.25 & 0.55 & 0.28 & 0.37 & 0.35 \\ 0.48 & 0.43 & 0.48 & 0.35 & 0.38 & 0.42 & 0.32 & 0.51 \\ 0.47 & 0.32 & 0.23 & 0.61 & 0.21 & 0.39 & 0.47 & 0.20 \\ 0.25 & 0.39 & 0.45 & 0.34 & 0.49 & 0.52 & 0.35 & 0.37 \\ 0.40 & 0.48 & 0.39 & 0.44 & 0.31 & 0.40 & 0.46 & 0.49 \\ 0.35 & 0.47 & 0.46 & 0.36 & 0.41 & 0.41 & 0.45 & 0.44 \end{bmatrix}$$

**Third step**: using the indices' weights based on the AHP method, the above matrix is converted to a weighted normal matrix:

$$ND = \begin{bmatrix} 0.089 & 0.038 & 0.043 & 0.034 & 0.047 & 0.036 & 0.047 & 0.032 \\ 0.057 & 0.051 & 0.052 & 0.048 & 0.032 & 0.054 & 0.041 & 0.047 \\ 0.094 & 0.038 & 0.025 & 0.084 & 0.018 & 0.050 & 0.060 & 0.019 \\ 0.050 & 0.046 & 0.049 & 0.047 & 0.042 & 0.067 & 0.044 & 0.034 \\ 0.080 & 0.057 & 0.043 & 0.060 & 0.026 & 0.052 & 0.058 & 0.046 \\ 0.069 & 0.056 & 0.050 & 0.049 & 0.035 & 0.053 & 0.057 & 0.041 \end{bmatrix}$$

**Fourth step**: ideal and anti-ideal solutions are specified here:

$$A^+ = \{MAXvi1, MAXvi2, ..., MAXvi8\}$$

$$A^+ = \{0.094, 0.057, 0.052, 0.084, 0.047, 0.067, 0.60, 0.047\}$$

$$A^- = \{MINvi1, MINvi2, ..., MINvi8\}$$

$$A^- = \{0.050, 0.038, 0.025, 0.034, 0.018, 0.036, 0.041, 0.019\}$$

**Fifth step**: distance of the i[th] option from the positive ideal solution is calculated according to the following formula:

$$d_i^+ = \left\{ \sum_{i=1}^{n} (V_{ij} - V_j^+)^2 \right\}^{1/2}, (i = 1,2,...,m)$$

Distance of the ith option from the negative ideal solution is calculated based on the following formula:

$$d_i^- = \left\{ \sum_{i=1}^{n} (V_{ij} - V_j^-)^2 \right\}^{1/2}, (i = 1,2,...,m)$$

According to the above formulas, the distances are calculated as follow:

$d_1^+ = 0.061 \ldots\ldots\ldots\ldots\ldots\ldots d_1^- = 0.053$

$d_2^+ = 0.059 \ldots\ldots\ldots\ldots\ldots\ldots d_2^- = 0.051$

$d_3^+ = 0.055 \ldots\ldots\ldots\ldots\ldots\ldots d_3^- = 0.071$

$d_4^+ = 0.062 \ldots\ldots\ldots\ldots\ldots\ldots d_4^- = 0.051$

$d_5^+ = 0.039 \ldots\ldots\ldots\ldots\ldots\ldots d_5^- = 0.060$

$d_6^+ = 0.047 \ldots\ldots\ldots\ldots\ldots\ldots d_6^+ = 0.053$

**Sixth step**: relative proximity index is calculated by using the following formula:

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

Thus, we have:

$C_1^+ = 0.465$

$C_2^+ = 0.464$

$C_3^+ = 0.563$

$C_4^+ = 0.451$

$C_5^+ = 0.606$

$C_6^+ = 0.530$

Therefore, the indices are prioritized as shown in the following table:

**Table 4** - Prioritization of indices by using the AHP-TOPSIS method

| Index | Final score |
|---|---|
| 300-hours foreign maintenance check | 0.465 |
| 600-hours foreign maintenance check | 0.563 |
| 1200-hours foreign maintenance check | 0.606 |
| 300-hours domestic maintenance check | 0.464 |
| 600-hours domestic maintenance check | 0.451 |
| 1200-hours domestic maintenance check | 0.503 |

Thus, based on the above-mentioned method, there is no significant difference between domestic and foreign aircraft maintenance checks. In other words, the advantage of outsourcing and insourcing of this type of maintenance checks is the same. The results also clarified that the 600-hours foreign maintenance checks (with a score of 0.563) are preferred to the 600-hours domestic maintenance checks (with a score of 0.451). In other words, outsourcing this type of maintenance checks is

recommended. Moreover, based on the findings, the 1200-hours foreign maintenance checks (with a score of 0.606) are preferred to the 1200-hours domestic maintenance checks (with a score of 0.503).

### 4.5- Ranking options: second state (weighting based on AHP, ranking based on ELECTRE)

In order to rank the options, according to the eight indices outlined in the previous stage and the six existing options, an 8×6 decision-making matrix is obtained.

**First step**: the decision-making matrix D is converted to a non-scale matrix:

$$ND = \begin{bmatrix} 0.45 & 0.32 & 0.39 & 0.25 & 0.55 & 0.28 & 0.37 & 0.35 \\ 0.48 & 0.43 & 0.48 & 0.35 & 0.38 & 0.42 & 0.32 & 0.51 \\ 0.47 & 0.32 & 0.23 & 0.61 & 0.21 & 0.39 & 0.47 & 0.20 \\ 0.25 & 0.39 & 0.45 & 0.34 & 0.49 & 0.52 & 0.35 & 0.37 \\ 0.40 & 0.48 & 0.39 & 0.44 & 0.31 & 0.40 & 0.46 & 0.49 \\ 0.35 & 0.47 & 0.46 & 0.36 & 0.41 & 0.41 & 0.45 & 0.44 \end{bmatrix}$$

**Second step**: the weighted non-scale matrix is created by using the weight vectors of the related indices:

$$ND = \begin{bmatrix} 0.089 & 0.038 & 0.043 & 0.034 & 0.047 & 0.036 & 0.047 & 0.032 \\ 0.057 & 0.051 & 0.052 & 0.048 & 0.032 & 0.054 & 0.041 & 0.047 \\ 0.094 & 0.038 & 0.025 & 0.084 & 0.018 & 0.050 & 0.060 & 0.019 \\ 0.050 & 0.046 & 0.049 & 0.047 & 0.042 & 0.067 & 0.044 & 0.034 \\ 0.080 & 0.057 & 0.043 & 0.060 & 0.026 & 0.052 & 0.058 & 0.046 \\ 0.069 & 0.056 & 0.050 & 0.049 & 0.035 & 0.053 & 0.057 & 0.041 \end{bmatrix}$$

**Third step**: the coordination criterion and coordination matrix are calculated. The coordination criterion reflects the relative importance of one component to another, and is obtained from sum of the weights of the available indices in the coordination set of the two options. The coordination matrix represents a coordination criterion between all pairs of options.

$$I = \begin{bmatrix} - & 0.41 & 0.29 & 0.41 & 0.28 & 0.28 \\ 0.59 & - & 0.54 & 0.66 & 0.42 & 0.33 \\ 0.71 & 0.46 & - & 0.46 & 0.46 & 0.46 \\ 0.59 & 0.34 & 0.54 & - & 0.32 & 0.21 \\ 0.72 & 0.58 & 0.54 & 0.68 & - & 0.67 \\ 0.72 & 0.67 & 0.54 & 0.79 & 0.32 & - \end{bmatrix}$$

**Fourth step**: incoordination criterion and incoordination matrix are calculated. The incoordination criterion reflects the degree of worseness of an option in comparison with another one. This criterion and its corresponding matrix can be obtained in a similar way to the previous step.

$$NI = \begin{bmatrix} - & 0.022 & 1 & 0.141 & 0.828 & 1 \\ 1 & - & 0.678 & 0.669 & 1 & 0.33 \\ 0.978 & 1 & - & 1 & 0.908 & 0.932 \\ 1 & 1 & 1 & - & 1 & 1 \\ 1 & 1 & 0.356 & 0.68 & - & 1 \\ 1 & 1 & 1 & 0.79 & 0.32 & - \end{bmatrix}$$

**Fifth step**: effective coordinated and effective uncoordinated matrices are created (Boolean matrix).

$$G = \begin{bmatrix} - & 0 & 0 & 0 & 0 & 0 \\ 1 & - & 1 & 1 & 0 & 0 \\ 1 & 0 & - & 0 & 0 & 0 \\ 1 & 0 & 1 & - & 0 & 0 \\ 1 & 1 & 1 & 1 & - & 1 \\ 1 & 1 & 1 & 1 & 0 & - \end{bmatrix} \qquad H = \begin{bmatrix} - & 1 & 0 & 1 & 0 & 0 \\ 0 & - & 0 & 0 & 0 & 1 \\ 0 & 0 & - & 0 & 0 & 0 \\ 0 & 0 & 0 & - & 0 & 0 \\ 0 & 0 & 1 & 0 & - & 0 \\ 0 & 0 & 0 & 0 & 1 & - \end{bmatrix}$$

By determining two (arbitrary) threshold values for the coordination and incoordination matrices and comparing their values with the corresponding threshold values, these values are converted to zero and one, and two matrices are resulted.

**Sixth step**: the overall and effective matrix is determined as:

$$F = H \times G = \begin{bmatrix} - & 0 & 1 & 1 & 0 & 0 \\ 1 & - & 1 & 1 & 0 & 0 \\ 0 & 0 & - & 0 & 0 & 0 \\ 0 & 0 & 0 & - & 0 & 0 \\ 1 & 0 & 0 & 0 & - & 0 \\ 1 & 1 & 1 & 1 & 1 & - \end{bmatrix}$$

Therefore, the ranking of indices with their respective priorities will be as follow:

**Table 5** - Prioritization of indices using the AHP-ELECTRE method

| Index | Priority |
|---|---|
| 1200-hours domestic maintenance check | 1 |
| 600-hours foreign maintenance check | 2 |
| 300-hours foreign maintenance check | 3 |
| 600-hours domestic maintenance check | 4 |
| 300-hours domestic maintenance check | 5 |
| 1200-hours foreign maintenance check | 6 |

## 5- Results

According to the results achieved, the criteria effective on the efficiency of aircraft maintenance checks were prioritized by using the AHP method as shown below:

| Indices | Criteria weights (the row average) |
|---|---|
| Trained human resources | 0.199 |
| Tools and equipment (technology) | 0.137 |
| Changes in centers' management | 0.129 |
| Service quality in centers | 0.127 |
| Experience level of employees (efficiency) | 0.119 |
| Time savings | 0.109 |
| Total costs of services | 0.093 |
| Financial status of maintenance centers | 0.085 |

As it can be observed, trained human resources in comparison to other factors has the greatest effect on the efficiency of aircraft maintenance checks (with a significant difference). Tools and equipment after human resources have been introduced as the second most effective criterion on the efficiency of maintenance checks. After ranking the criteria by using AHP, different types of maintenance checks with the purpose of outsourcing or insourcing were studied by using TOPSIS. According to the results attained, there is no significant difference between domestic and foreign aircraft maintenance checks. In other words, the advantage of outsourcing and insourcing this type of maintenance checks is relatively similar.

**Table 6** - Prioritization of indices using the AHP-TOPSIS method

| Index | Final score |
|---|---|
| 300-hours foreign maintenance check | 0.465 |
| 600-hours foreign maintenance check | 0.563 |
| 1200-hours foreign maintenance check | 0.606 |
| 300-hours domestic maintenance check | 0.464 |
| 600-hours domestic maintenance check | 0.451 |
| 1200-hours domestic maintenance check | 0.503 |

The results also showed that the 600-hours foreign maintenance checks (with a score of 0.563) are preferred to the 600-hours domestic maintenance checks (with a score of 0.451). In other words, outsourcing this type of maintenance checks is appropriate and advised. Moreover, based on the results gained, the 1200-hours foreign maintenance checks (with a score of 0.606) in comparison with the 1200-hours domestic maintenance checks (with a score of 0.503) are preferred. In the next stage, after ranking the criteria by using AHP, different types of maintenance checks for the purpose of their outsourcing or insourcing were investigated by using ELECTRE.

**Table 7** - Prioritization of indices using the AHP-ELECTRE method

| Index | Priority |
|---|---|
| 1200-hours domestic maintenance check | 1 |
| 600-hours foreign maintenance check | 2 |
| 300-hours foreign maintenance check | 3 |
| 600-hours domestic maintenance check | 4 |
| 300-hours domestic maintenance check | 5 |
| 1200-hours foreign maintenance check | 6 |

The results presented that the 600-hours foreign maintenance checks are preferred to 600-hours domestic maintenance checks. In other words, outsourcing this type of maintenance checks is recommended. Based on the findings, the 300-hours foreign maintenance checks are preferred to the 300-hours domestic maintenance checks, while based on the method under study, the 1200-hours

domestic maintenance checks are preferred to the 1200-hours foreign maintenance checks.

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