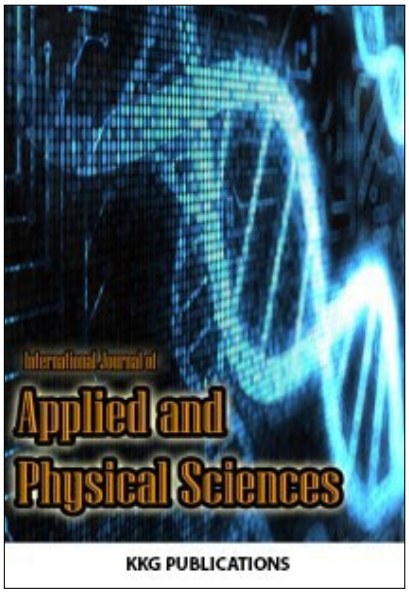


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# A DELPHI-AHP MODEL OF CONSULTANTS EVALUATION FOR AIRLINE OPERATION SYSTEMS

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**Abstract**. Information technologies have been widely used in almost all business industries. Airlines to be a high-tech industry require many different information systems to support their daily operations, such as the Flight Operation Control System (FOCS) and the Crew Scheduling System (CSS) focused on in this study. Not all airlines have enough abilities to develop the tailored systems for their operations. Most parts of airlines must evaluate appropriate vendors with the ability to introduce professional systems. In our study case, FOCSs and CSSs concern many tasks and functions among various departments in airlines. The studied company intends to entrust a specialized and experienced consultant company to evaluate ideal operation systems. This study aims to propose a systematic analysis process to evaluate professional consultants for the studied company. Based on an Analysis Hierarchy Process (AHP), all respondents were asked to repeatedly express the pair-comparison results, according to the design of the Delphi method, until reaching the preset consistency thresholds. This process assists the studied airline in selecting an ideal consultant after a two-round investigation.



## INTRODUCTION

The past decades have witnessed making a great progress in information techniques. Information technologies have been widely used in almost all business industries. Airlines to be a high-tech industry also require many kinds of information systems to support their daily operations. The studied company is facing to replace the Flight Operation Control System (FOCS) and Crew Scheduling System (CSS). Introducing new systems with full competence can maintain a reliably regular operation and then enhance the competitiveness for this airline. In particular, these systems are normally costly and much variant with functions. Airlines sometimes need professional consultants to assist them to evaluate appropriate system vendors. Hence, it is a vital step to consider how to select a suitable consultant. The motivation of this study stems from the consignment of the studied airline for the evaluation of system consultants. Any systematic approach can be applied to meet the internal opinions of the company in all aspects.

In response to globalization strategy and environmental change, most of operators prefer to purchase appropriate software than develop systems by their own for the reduction of development cost and introduced time. However, purchasing ready-made software is costly and risky [1]. Furthermore, criteria for selecting system may easily become subjective and difficult to measure [2]. The approaches of Multiple Criteria Decision Making (MCDM) are systematic analysis tools that have been widely applied to decision making and system selection frequently. The key to success is to identify factors or activities in corporation operations through a series of interviews [3]. The MCDM techniques like Delphi method and Analytic Hierarchy Process (AHP) were commonly used for information system research, introduction of new systems, and project management to corporation reorganization [4]. Some theoretical methods like Fuzzy Multi-Criteria Decision Making (FMCDM) were developed to strengthen theoretical basis. Chien, Wang and Wei applied AHP method to selecting most suitable Enterprise Resource Planning (ERP) systems [5]. Rao and Rajesh used Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) along with AHP and fuzzy theory to select system for manufacturing industry [6]. Pitchipoo set up criteria for selecting system vendor based on AHP method, grey relation analysis and sensibility analysis [7].

The purpose of this study is to develop a systematic evaluation approach to respond to the requirement of the studied airline on the selection of system consultants. In considering to converge the internal opinions of the studied company, a Delphi-AHP model is specially constructed to combine two approaches and a Rank Pair-Wise Comparison (RPC) in questionnaire design. To be worth mentioning is that many data collection efforts in this study have been done by members of the Improvement Task Force (ITF) of the studied company. The remaining parts of this paper introduce the basic concept for the applied methodologies in section 2. Section 3 presents

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research design for the proposed Delphi-AHP model. Section 4 discusses the evaluation results for the case of the studied airline. The final section summarizes our study and provides some suggestions for the future research.

## APPLIED METHODOLOGIES

This section reviews the operations of three methodologies applied in this study. First part is the basic concept of the AHP. Pair-wise comparisons implemented in a traditional AHP normally distorted experts' opinions because of a complicated hierarchical structure. This study employs a RPC concept to implement the survey. Furthermore, the Delphi method is involved to design the whole investigation procedure for seeking a higher consentient result.

### Analytic Hierarchy Process (AHP)

The analytic hierarchy process is a multi-criteria decision making method proposed by [8]. In an AHP, decision makers are allowed to construct a hierarchical structure with goal, criteria, sub-criteria and alternatives. The process attempts to obtain relative weights between all of criteria and all of sub-criteria through pair-wise comparisons. An AHP can be simplified by placing the analysis steps into three phases as follows:

- Define the problem and build up hierarchical structure.
- Construct pair-wise comparison matrices.
- Obtain relative weights of specific criteria, sub-criteria and then evaluate the most appropriate alternative.

A 9-point scale is normally used to express the judgment of participants, ranging from 1 (equal importance) to 9 (extreme importance) [8]. According to the judgment given by each participant, decision maker can set up a set of pair-wise comparison matrices. Suppose A is pair-wise comparison matrix, an nn positive reciprocal matrix, formed by $a_ij(i, j = 1, 2, , n,$ n is the set of criteria analyzed). To ensure the consistency, Saaty employed an equation $Aw = \lambda_{max}w = nw$, where $\lambda_{max}$ is the largest eigenvalue of A and weight vector w is found by solving the equation Aw=Iw (I is an identity matrix). The consistency ratio (C.R.) is obtained by comparing the consistency index (C.I.) with random index $(R.I.), C.I. = (\lambda_{max} - n)/(n - 1)$ and $C.R. = C.I./R.I..R.I.$ is related to the order of matrix. C.R. value must be lower than 0.1 to be accepted. If each matrix met an acceptable consistency, then we can estimate eigenvector for relative weights of involved elements and obtain the rankings of these elements [8].

### Rank Pair-wise Comparison (RPC)

Large quantities of elements to pair-wisely compare always confuse participants in implementing a traditional AHP. It may increase the difficulty to achieve the consistency. A RPC approach [9, 10] is developed to overcome these shortcomings as this approach can ensure the total consistency for each pair-comparison matrix. A RPC asks the participants to judge the priority of involved elements first, then to evaluate the relative weights between consecutive elements. Suppose that there are n elements to be assessed. The participants prioritized the elements as $r_1$ to $r_n$ and assessed the comparative weights for consecutive ranks, i.e., the values of $p_{r_1,r_2} = w_{r_1}/w_{r_2}, p_{r_2,r_3} = w_{r_2}/w_{r_3}, \ldots, p_{r_{n-1},r_n} = w_{r_{n-1}}/w_{r_n}$.

Then, according to the transitivity of judgment, other comparative weights for inconsecutive ranks can be assessed as follows:

$p_{r_1,r_3} = \frac{w_{r_1}}{w_{r_3}} = \frac{w_{r_1}}{w_{r_2}} \times \frac{w_{r_2}}{w_{r_3}} = p_{r_1,r_2} \times p_{r_2,r_3}, p_{r_1,r_4} = p_{r_1,r_3} \times p_{r_3,r_4}, \ldots, p_{r_1,r_n} = p_{r_1,r_{n-1}} \times p_{r_{n-1},r_n}$,

$p_{r_2,r_4} = \frac{w_{r_2}}{w_{r_4}} = \frac{w_{r_2}}{w_{r_3}}, \frac{w_{r_3}}{w_{r_4}} = p_{r_2,r_3} \times p_{r_3,r_4}, p_{r_2,r_5} = p_{r_2,r_4}, p_{r_4,r_5} \ldots, p_{r_2,r_n} = p_{r_2,r_{n-1}} \times p_{r_{n-1},r_n}, \ldots,$

$p_{r_{n-2},r_n} = \frac{w_{r_{n-2}}}{w_{r_n}} = \frac{w_{r_{n-2}}}{w_{r_{n-1}}} \times \frac{w_{r_{n-1}}}{w_{r_n}} = p_{r_{n-2},r_{n-1}} \times p_{r_{n-1},r_n}$

After calculating, the remaining elements in the matrix can be determined by the reciprocal property and the matrix will comply with consistency. So far, if the scales used are s-point, the values in matrix will range from 1 to $s^{n-1}$. In order to narrow down the range and have all values falling between 1 and s, the range between consecutive linguistic variables must be adjusted. Let $d$ be the adjusted range, so that $d \times (s^{n-1} - 1) = s - 1$, or $d = (s - 1)/(s^{n-1} - 1)$ [10].

### Delphi Method

The Delphi method is also known as expert investigation method. It is a group decision making process developed by Rand Corporation in 1950s [11]. A Delphi study can assemble opinions from a panel of experts by conducting rounds of questionnaire to reach a consensus of opinions. They are mostly used for predicting future events, generating a quick consensus by a group, making a policy survey, and so forth [12, 13]. To conduct a Delphi method, surveyors are supposed to define the problem first and design questionnaire against the issue for collecting experts' opinions. Suppose that the latest round of questionnaire resulted in no consensus, another round of questionnaire conducting is required. However, former responses must be appended in the following questionnaires for converging experts' consensus. Three main principles when implementing Delphi method are anonymity, repeating, and responding.

## RESEARCH DESIGN

This section first introduces the evaluation procedure of proposed Delphi-AHP model. Then, the analysis hierarchy

framework is defined and followed by the questionnaire design and preset conditions for consensus.

**Delphi-AHP Model**

The research processes of the proposed Delphi-AHP model can be divided into 4 main phases that include a general survey with the studied company, the establishment of hierarchy and methodologies, investigation by the questionnaires, and results analysis. The whole conceptual framework for steps of this model is shown in Figure 1. The implementation of questionnaire investigation is repeated, following the Delphi method, at the next round once the consensus conditions cannot be satisfied at the latest investigation results. The analysis results will be appended into the next questionnaire for the reference to respondents. These kinds of information include the results of all respondents, of ITF, and of respondent's self. As the requirement of the study, the analysis contents must contain the final decision results for all respondents, members of ITF, and respondents of non-ITF.

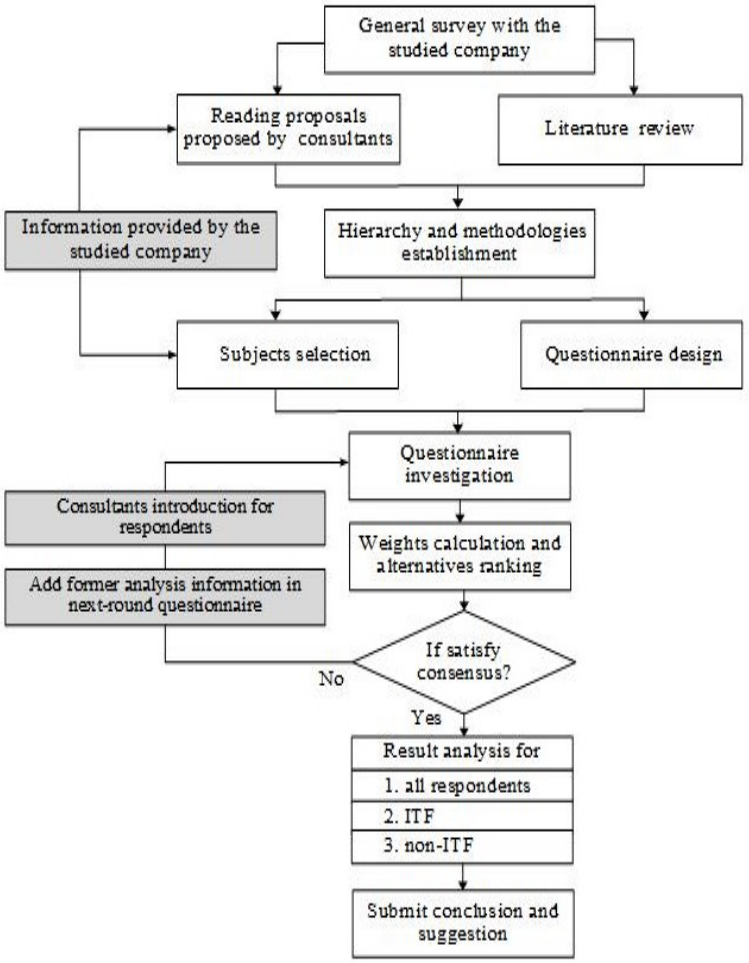


Fig. 1. Steps of the proposed Delphi-AHP Model

**Analysis Hierarchy Framework**

We proposed an evaluate hierarchy framework as shown in Figure 2 after referring to the original framework submitted by the ITF of the studied company. The proposed framework consists of 4 hierarchies, i.e., goal, criteria, sub-criteria and alternative. The ultimate goal of the analysis model is to evaluate an appropriate system consultant for the studied airline. All factors are categorized into 3 criteria of consultant's business information, capabilities and proposals. Meanwhile, 13 sub-criteria are attributed for each criteria, respectively. In total, 4 system consultants to be evaluated are provided by the ITF. The related information about these 4 companies performed on every sub-criteria has been collected by the ITF.

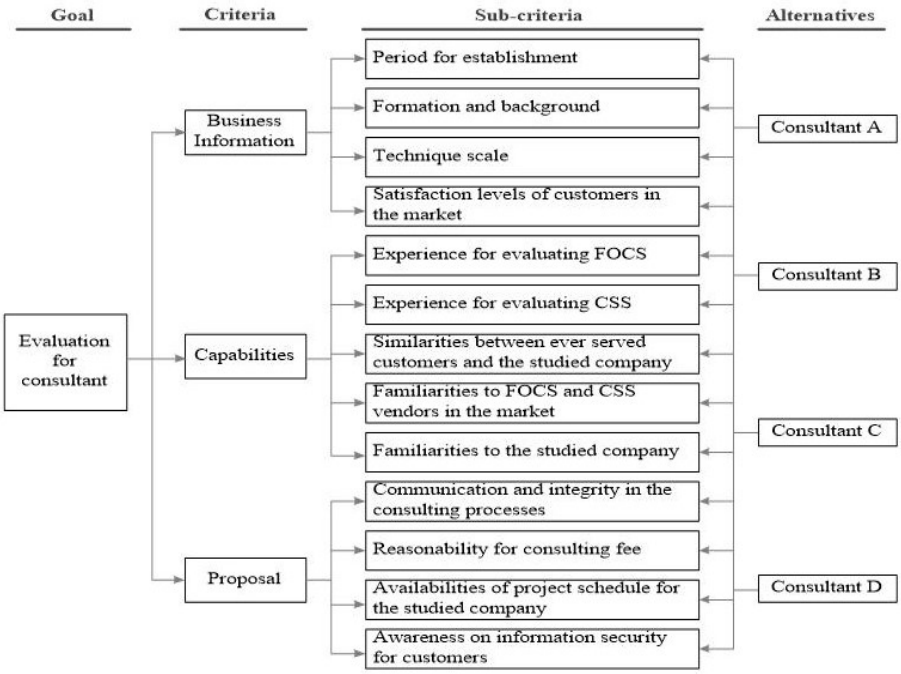


Fig. 2. The Framework for Evaluation System Consultants

The attribution and definition for sub-criteria are described as the following:

**Business Information**

- Period for establishment: Means when the consultant was established.
- Formation and background: includes consultant's background for its enterprise group and company's organization and scale.
- Technique scale: Includes consultant's human resources, capabilities to collect information, remittance process and request acknowledged by industries.
- Satisfaction levels of customers in the market: means the reputation and the satisfaction levels reflected by those customers which have ever been served.

**Capabilities**

- Experience for evaluating FOCS: means the number of served companies for selecting flight operation control system.
- Experience for evaluating CSS: means the number of served companies for selecting crew scheduling system.
- Similarities between ever served customers and the studied company: means the similarities of operation scales and business models between ever served companies and the studied airline.
- Familiarities to FOCS and CSS vendors in the market: includes the numbers of available FOCS and CSS vendors in the consultant's database.
- Familiarities to the studied company: includes the cooperation experience between consultant and the studied company.

**Proposal**

- Communication and integrity in the consulting processes: Means the communication pattern between customers and the consultant and the integrity of interview contents.
- Reasonability for consulting fee: means the reasonability of consulting fee quotation in comparing with its competence and the consulting processes.
- Availabilities of project schedule for the studied company: Means the availabilities of consulting duration and processes for the studied airline.
- Awareness on information security for customers: means the possibilities that consultant can protect the confidential information of studied company from disclosure. The alternatives for 4 consultants to be evaluated had different experience in consulting operation system vendors for well-known airlines. Three of them ever had the cooperated experience on other systems with the studied company. For the confidential reason, the information will be disclosed partly only for the evaluated candidate in the Section 4.

**Questionnaire Design**

When implementing a traditional AHP, each responded questionnaire should be proved that it meets the consistent standard for every hierarchy. In this case, inexperienced participants may feel difficult in pair-wise comparisons to assess the whole priorities between involved elements and result in inconsistency. Then, it will lead to a tedious research duration. For ensuring the consistency and lessening inconvenience to respondents, this study designed a questionnaire of RPC [9, 10] to assess the transitivity of preference for consecutive elements.

The questionnaire collects experts' opinions with Saaty's 9-point scale for listed involved elements. The panel of experts were asked to assess the priority between criteria or alternatives, then to assess the relative weights for two consecutive ranks. The 9-point scale includes the importance from 1 to 9, where 1 means equally important, 3 for moderately important, 5 for strongly important, 7 for very strongly important, 9 for extremely important, and 2, 4, 6, 8 for intermediate value. The relative performance for 4 alternatives on every sub-criteria uses the same scales. The questionnaires after second round investigation additionally provide the results of pair-wise comparisons of all respondents, of ITF members, and respondent's self in the previous round.

**Converging Conditions for Consensus**

The standards of evaluating consensus must be preset to determine the stop point in multi-round questionnaire surveys when using the Delphi method. Common ways to evaluate if the consensus has been converged include mode, median, mean, interquartile range (IQR) and standard deviation. IQR is popular than others in the previous studies using Delphi method. IQR is a measure of dispersion tendency that is defined as one-half of the interquartile range, which is the difference between the $25^{th}$ and $75^{th}$ percentile in a frequency distribution. High consensus is defined as the questionnaire items received as an IQR$\leq$ 0.6. When 0.6<IQR$\leq$ 1, consensus is defined as moderate consensus, and then IQR>1 as low consensus [13, 14]. The converging conditions for reaching consensus are defined as the following two measures:

- IQRs for upper triangle pair-wise comparison elements in the criteria tier (3 items in total) must all be high consensus.
- IQRs for upper triangle pair-wise comparison elements in the sub-criteria tier (22 items in total) and the alternative tier (78 items in total) must have 85% items receiving moderate or high consensus.

**RESULTS**

**Investigation Processes**

In the first round investigation, the panel of respondents consists of 23 members in the studied company who are familiar with either FOCS or CSS. 23 questionnaires were distributed and 100% returned and effected. However, the IQR for pair-wise comparison of 3 criteria received was moderate that has not satisfied the converging conditions of consensus yet. Therefore, a second-round investigation was required. In the second round, 26 questionnaires were distributed to original respondents and 3 additional members of ITF with 96% returned and effected. Both of the converging standards to measure the consensus were satisfied as shown in table 1. Thus, the investigation stopped here.

TABLE 1
CONSENSUS EVALUATION IN THE INVESTIGATION

| Consensus | Criteria | Sub-criteria | Alternative |
|---|---|---|---|
| 1st round distributed 23 questionnaires with 100% effective rate | | | |
| High Consensus | 0 | 22 | 78 |
| Moderate Consensus | 3 | 0 | 0 |
| Low Consensus | 0 | 0 | 0 |
| 2nd round distributed 26 questionnaires with 96% effective rate | | | |
| High Consensus | 3 | 22 | 77 |
| Moderate Consensus | 0 | 0 | 0 |
| Low Consensus | 0 | 0 | 1 |
| Total | 3 | 22 | 78 |

**Evaluation Results for Criteria and Sub-criteria**

Accord to the operation principles of the RPC, the geometric averages for three different groups, i.e., all respondents, ITF, and non-ITF, are calculated for the final pair-comparison matrices. The vectors of relative weights for criteria and sub-criteria can, then, be obtained as shown in table 2.

TABLE 2
WEIGHTS AND RANKS OF SUB-CRITERIA FOR THREE GROUPS

| Criteria | Sub-criteria | Weight | Rank |
|---|---|---|---|
| | Results of All Respondents | | |
| Business Information (0.1906) | Period for establishment | 0.0418 | 12 |
| | Formation and background | 0.0392 | 13 |
| | Technique scale | 0.0553 | 10 |
| | Satisfaction levels of customers in the market | 0.0543 | 11 |
| Capabilities (0.5248) | Experience for evaluating FOCS | 0.1047 | 4 |
| | Experience for evaluating CSS | 0.0952 | 5 |
| | Similarities between ever served customers and the studied company | 0.1053 | 3 |
| | Familiarities to FOCS and CSS vendors in the market | 0.1129 | 1 |
| | Familiarities to the studied company | 0.1067 | 2 |
| Proposal (0.2847) | Communication and integrity in the consulting processes | 0.0796 | 7 |
| | Reasonability for consulting fee | 0.0631 | 8 |
| | Availabilities of project schedule for the studied company | 0.0800 | 6 |
| | Awareness on information security for customers | 0.0620 | 9 |
| | Results of ITF | | |
| Business Information (0.1808) | Period for establishment | 0.0393 | 12 |
| | Formation and background | 0.0339 | 13 |
| | Technique scale | 0.0506 | 11 |
| | Satisfaction levels of customers in the market | 0.0570 | 9 |
| Capabilities (0.5667) | C21 Experience for evaluating FOCS | 0.1095 | 4 |
| | Experience for evaluating CSS | 0.1036 | 5 |
| | Similarities between ever served customers and the studied company | 0.1101 | 3 |
| | Familiarities to FOCS and CSS vendors in the market | 0.1244 | 1 |
| | Familiarities to the studied company | 0.1190 | 2 |
| Proposal (0.2525) | Communication and integrity in the consulting processes | 0.0669 | 7 |
| | Reasonability for consulting fee | 0.0581 | 8 |
| | Availabilities of project schedule for the studied company | 0.0753 | 6 |
| | Awareness on information security for customers | 0.0521 | 10 |
| | Results of non-ITF | | |
| Business Information (0.1934) | Period for establishment | 0.0424 | 12 |
| | Formation and background | 0.0410 | 13 |
| | Technique scale | 0.0567 | 10 |
| | Satisfaction levels of customers in the market | 0.0534 | 11 |
| Capabilities (0.5114) | C21 Experience for evaluating FOCS | 0.1031 | 3 |
| | Experience for evaluating CSS | 0.0925 | 5 |
| | Similarities between ever served customers and the studied company | 0.1036 | 2 |
| | amiliarities to FOCS and CSS vendors in the market | 0.1093 | 1 |
| | Familiarities to the studied company | 0.1029 | 4 |
| Proposal (0.2952) | Communication and integrity in the consulting processes | 0.0839 | 6 |
| | Reasonability for consulting fee | 0.0646 | 9 |
| | Availabilities of project schedule for the studied company | 0.0813 | 7 |
| | Awareness on information security for customers | 0.0654 | 8 |

The priorities in criteria for three groups are the same. Capabilities are the most important criteria and have more than half of the whole weight, regardless any group. Proposal is ranked second with nearly 0.25 to 0.3 of weight values for three groups. The sub-criterion of Familiarities to FOCS and CSS vendors in the market is commonly considered most important than others. Although the ranks among second and fifth important appear different in non-ITF, they all belong to the criterion of Capabilities. To understand the studied airline is a key factor to be selected from the weight values for sub-criteria of Familiarities to the studied company and Similarities between ever served customers and the studied company.

**Evaluation Results for Consultants**

For the evaluation results of consultants, there are imperceptible differences in ranks for different groups in spite of variations in weights. Consultant D is the top priority alternative among others, followed by consultant B, consultant C and consultant A, as shown in table 3.

TABLE 3
WEIGHTS AND RANKS OF SUB-CRITERIA FOR THREE GROUPS

| Alternatives | Weight | Rank |
|---|---|---|
| All Respondents | | |
| Consultant A | 0.2277 | 4 |
| Consultant B | 0.2525 | 2 |
| Consultant C | 0.2395 | 3 |
| Consultant D | 0.2804 | 1 |
| ITF | | |
| Consultant A | 0.2175 | 4 |
| Consultant B | 0.2439 | 2 |
| Consultant C | 0.2438 | 3 |
| Consultant D | 0.2948 | 1 |
| Non-ITF | | |
| Consultant A | 0.2306 | 4 |
| Consultant B | 0.2553 | 2 |
| Consultant C | 0.2382 | 3 |
| Consultant D | 0.2759 | 1 |

Consultant D had been established about 10 years. Its team has extensive experience in consulting airlines to select many kinds of information systems including FOCS. In addition, this consultant has ever assisted the studied company for selecting system once. Consultant D provided a potential proposal this time with a 10-day schedule to finish the assessment works for the studied airline.

## CONCLUSION AND SUGGESTIONS

As the requirement of the studied airline, this study proposed a Delphi-AHP model to assist the evaluation of system consultants for introducing FOCS and CSS vendors. A systematic hierarchical framework was constructed to design the investigation questionnaires with RCP concept and calculation principles. After a two-round survey for inner experts, the most important criterion to evaluate consultants is their capabilities. The understanding of FOCS and CSS vendors and the familiarities to the studied company are considerable important. Consultant D which also has higher capability condition is the potential candidate than others.

The Delphi-AHP model and the hierarchical framework proposed in this study obtain a promising result in the topic of system consultant evaluation for airlines. They can also be applied to the similar cases for airlines and other industries with a little of modification. The concept and operation of a Delphi-AHP approach can be a valuable reference in research design for other decision making topics.

**Acknowledgement**

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