Expert Systems with Applications 37 (2010) 8387–8394

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Aviatic innovation system construction using a hybrid fuzzy MCDM model

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ARTICLE INFO

Keywords:
Fuzzy analytic hierarchical process (FAHP)
VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)
Aviatic innovation system (AIS)

ABSTRACT

Due to the occurrence of several recent threats, such as, from an international perspective, SARS, the 9/11 terrorist attack, increases in the price of oil, depressions in the economy, and, from a domestic perspective, increasing interaction with China, joining the WTO, low railway prices, and high-speed rail development, resulting in passenger rate dropping drastically, an increasing number of Taiwanese airlines have been facing deficits or closing down in recent years. Therefore, long-term strategies for gaining a competitive advantage are now starting to focus on innovation rather than cost reduction. Although attention to the importance of innovation is rising, there are few studies today that provide airlines with a clear and precise way to successfully conduct innovation operations. The aim of this study is to solve this dilemma by constructing a novel aviatic innovation system (AIS). In this paper, a hybrid fuzzy multiple criteria decision-making (MCDM) model based on a fuzzy analytical hierarchical process (FAHP) and a VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) is adopted to complete the construction of the AIS. The value of the AIS is to provide Taiwanese airlines with innovation-oriented techniques for future strategy development. We believe that the AIS can contribute to the survival of Taiwanese airlines in the near future.

1. Introduction

Due to the recent occurrence of several threats, such as, from an international perspective, SARS, the 9/11 territorial attack, increasing oil prices, economic depression, and, from a domestic perspective, increasing interaction with China, joining the WTO, low railway prices, and, especially, high-speed rail development, many airlines in Taiwan are now facing deficits; some of the airlines even closed in late 2008. Since Taiwan is an island, the nation's interactions and trade with foreign countries are highly reliant on marine transit and airlift (Civil Aeronautics Administration, 2009). In comparison to marine transit, airlifting plays a critical role in determining efficiency. Therefore, airline operational performance and market share will certainly be crucial factors in improving the Taiwanese economy. Helping Taiwanese airlines regain their market share and improve their operational performance in today's difficult global environment has become a pressing issue that must be addressed with urgency.

According to the indications of the Civil Aeronautics Administration (CAA), safety, service, and satisfaction (the 3S's) are the main directions of future development for Taiwanese airlines (Civil Aeronautics Administration, 2009). Although recent research efforts regarding safety (Liou, Tzeng, & Chang, 2007), service (Chen & Wu, 2009; Liou & Tzeng, 2007; Lu & Ling, 2008; Sim, Koh, & Shetty, 2006; Tiernan, Rhoades, & Waguespack, 2008), and satisfaction (Gkritza, Niemeier, & Mannering, 2006; Lopez-Bonilla & Lopez-Bonilla, 2008; Lu & Ling, 2008) are numerous, forming a comprehensive evaluation system by combining these research results is rare. In addition, according to the Central News Agency (CNA), Taiwan entered the "innovation economy stage" in 2009, and constructing this type of comprehensive system of various innovation views has become necessary. However, such a system has not been proposed by any current studies.

In order to construct a useful system to solve the problems listed above, a fuzzy analytic hierarchical process (FAHP) is used to evaluate the measurement criteria for innovation performance. A VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) is utilized to find the best innovation-oriented strategy creation (orientation). In this paper, we combine the fuzzy AHP and the VIKOR approach to construct an aviatic innovation system (AIS).

A literature overview for innovation is discussed in Section 2 of this paper and a criterion for innovation measurement is discussed in Section 3. In Section 4, the airline industry in Taiwan is introduced. An airline innovation measurement is discussed in Section 5. A hybrid approach is proposed in Section 6. Empirical research findings are presented in Section 7 and conclusions are posed in the last section.

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doi:10.1016/j.eswa.2010.05.043

2. Innovation

Since innovation is a new concept with increasing importance, the definitions of innovation vary from one study to another (Chen & Chen, 2007; Wolfe, 1994). Among these studies, we found that innovation is frequently defined as adopting unique ideas, and changing them into practical products or procedures (Robbins, 2005) or introducing a significant change in markets or society by introducing something useful (Mang, 2000). Innovation has also been defined as a product that is new to a business unit, a new process or attribute of the organization (Bantel & Jackson, 1998; Damanpour, 1996; Kimberly, 1981; O'Sullivan, 2000; Ordaz, Lara, & Cabrera, 2005; Tushman & Nadler, 1986; Yen & Chang, 2005), or identifying and using opportunities to create new products, services, or work practices (Subramaniam & Youndt, 2005). Moreover, innovation represents a key factor in the success of an organization (Daft, 2004; Farina & Kelly, 1983; Krause, 2004).

3. Criteria for innovation measurement

Numerous studies have indicated that organizations that cannot continue to innovate often fail quickly (Daft, 2004; Krause, 2004). Because of this, innovation measurement criteria are becoming important. Table 1 presents innovation performance evaluations involving numerous complex factors, incorporating the most common innovation criteria among different industries (Chen & Chen, 2008).

In our study, we mainly focus on innovation orientation in regard to service. However, the method for measuring service quality is not well defined owing to its very nature (Stanley & Wisner, 2002). Therefore, it makes the construction of the aviatic innovation system (AIS) more complicated in practice. To overcome this dilemma, the criteria in Table 1 are proposed, with an emphasis on the 3S's indicated by the Civil Aeronautics Administration (CAA). Twenty senior aero background experts, including nine anonymous members working for airlines and eleven senior faculties in Taiwanese universities, as well as 46 customers who have been taking flights as their main transportation for business or leisure for over fifteen years, were consulted to construct our original aviatic innovation system (AIS).

Table 1
Criteria for innovation. Source: Chen and Chen (2008).

Innovation criteria	References
Patent	Griliches (1990), Hall, Jaffe, and Trajtenberg (2000), Toivanen, Stoneman, and Bosworth (2002)
R&D expenses	Griliches (1990), Hall (1999), Boswoth and Rogers (2001)
Number of new ideas	Damanpour (1996), Van Buren (2000)
Number of new products	Tushman and Nadler (1986), Damanpour (1996), Toivanen et al. (2002), Schoenecker and Swanson (2002), Ordaz et al. (2005)
Number of new designs	Van Buren (2000), Hall and Bagchi-Sen (2002)
New market and customer development	Dzinkowski (2000), Chen and Chen (2008)
Innovative culture	Dzinkowski (2000), Van Buren (2000)
Number of R&D workers	Guthrie and Petty (2000)
Innovative references product	Acs, Anselin, and Varga (2001)
Copyright and brand	Bosworth and Rogers (2001)
Royalties income	Guthrie and Petty (2000), Van Buren (2000)
Outer tech connections	Gambardella and Torrisi (2000)
New services	Subramaniam and Youndt (2005)
New work practices	Subramaniam and Youndt (2005)
New processes	O'Sullivan (2000), Ordaz et al. (2005)

4. The airline industry in Taiwan

Initially, there were only four airlines in Taiwan. It was not until the Ministry of Transportation and Communications introduced the policy of "open sky" in 1987 that the airline market grew drastically; more specifically, nine airlines including Taiwan's original four, started to compete with each other within seven years after the policy of "open sky" was introduced. Most of the airlines adopted more runs for scheduled flights and decreased ticket prices, allowing customers to enjoy good ticket prices and services.

However, although the number of airlines increased owing to the policy of "open sky" and the number of customers rose, each passenger's load factor dropped relatively and made airlines' operations difficult.

In the initial period after the policy of "open sky" was activated, domestic air routes for the number of runs of scheduled flights increased from 76,000 in 1987 to 286,000 in 1997 (a total growth rate of 273%). Additionally, the passenger load factor also increased from about three million in 1987 to almost twenty million in 1997; moreover, the growth rate for it was up 20% from 1990 to 1996. Nevertheless, since 1997, it has been continually decreasing. Notably, in 2002, it dropped to the 58% of the peak in 1997. All of above reveals the difficulties that Taiwanese airlines have faced in the past ten years. It has even made the original nine airlines decrease to only four (not the original four airlines).

Owing to the recent occurrence of several threats, such as, from an international perspective, SARS, the 9/11 terrorist attack, oil price increases, and economic depression, and, from a domestic perspective, the interaction with China, joining the WTO, low railway prices, and, especially, high-speed rail transportation, Taiwanese airlines have to compete with each other and other transportation systems, both domestically and internationally. Notably, in 2008, Far Eastern Airline, once a well-known airline in Taiwan, finally went out of business due to financial hardship, while other airlines faced less scheduled flights. We argue that it is no longer a good long-term strategy to decrease ticket prices; innovation is the key to success (Daft, 2004; Krause, 2004). The aim of this study is to provide today's airlines with a clear and precise way to innovate by constructing a novel aviatic innovation system (AIS). We believe the AIS can contribute to the survival of Taiwanese airlines in the near future.

5. Airline innovation measurements

Airline innovation measurements not only involve a stream of complex factors, but must also take the strategies of several different airline companies into account. Innovation criteria may be formulated with cost-reduction and low-pricing goals in mind; nonetheless, these criteria may be incomprehensive in representing all innovation measurements and unsuitable as a long-term strategy.

According to the Civil Aeronautics Administration (CAA), future airline strategies will improve operational performance by focusing on the "3S's": safety, service, and satisfaction. We have developed airline innovation measurement dimensions and criteria based on the 3S's proposed by the CAA, (see Table 1) and suggestions from twenty experts including nine anonymous members working at airlines, eleven senior faculties with aero professional background in universities, and 46 customers making flights as their main transportation for business or trip above 15 years. Finally, the study constructs an original aviatic innovative system that incorporates five innovation-oriented strategy-making types, which were produced after consultation with nine anonymous senior aero background experts and confirmed by 32 customers who took flights as their main transportation for business or pleasure trips over 20 years.

6. A hybrid fuzzy MCDM model

6.1. Fuzzy analytic hierarchical process (FAHP)

6.1.1. Fuzzy set theory

Fuzzy set theory was developed in 1965, when Professor L.A. Zadeh attempted to solve fuzzy phenomenon problems that existed in the real world, such as uncertain, incomplete, non-specific, and fuzzy situations. The fuzzy set theory has an advantage over the traditional set theory when describing set concepts in the human language. It can show unspecific and fuzzy characteristics in a language format in the evaluation, and it uses a membership function concept to represent a field that permits situations such as "incompletely belong to" and "incompletely not belong to."

6.1.2. Fuzzy number

We order the Universe of Discourse such that U is the whole target we discuss, and each target in the Universe of Discourse is called an element. Fuzzy $\widetilde{A}$, which on U stated that random $x \to U$, appointing a real number $\mu_{\widetilde{A}}(x) \to [0,1]$. We call anything above that level of *x under A*.

The universe of real numbers R is a triangular fuzzy number (TFN) $\widetilde{A}$, which means $x \in R$, appointing $\mu_{\widetilde{A}}(x) \in [0,1]$, and

$$\mu_i(x) = \begin{cases} (x-L)/(M-L), & L \leqslant x \leqslant M \\ (U-x)/(U-M), & M \leqslant x \leqslant U \\ 0, & otherwise \end{cases}$$

The triangular fuzzy number above can be shown as $\widetilde{A} = (L, M, U)$, where L and U represent fuzzy probabilities between the lower and upper boundaries of evaluation information, as shown in Fig. 1. Assume two fuzzy numbers $\widetilde{A}_1 = (L_1, M_1, U_1)$ and $\widetilde{A}_2 = (L_2, M_2, U_2)$, then

(1) $\widetilde{A}_1 \oplus \widetilde{A}_2 = (L_1, M_1, U_1) \oplus (L_2, M_2, U_2)$
$= (L_1 + L_2, M_1 + M_2, U_1 + U_2)$
(2) $\widetilde{A}_1 \otimes \widetilde{A}_2 = (L_1, M_1, U_1) \otimes (L_2, M_2, U_2)$
$= (L_1 L_2, M_1 M_2, U_1 U_2),\ L_i > 0,\ M_i > 0,\ U_i > 0$
(3) $\widetilde{A}_1 - \widetilde{A}_2 = (L_1, M_1, U_1) - (L_2, M_2, U_2)$
$= (L_1 - L_2, M_1 - M_2, U_1 - U_2)$
(4) $\widetilde{A}_1 \div \widetilde{A}_2 = (L_1, M_1, U_1) \div (L_2, M_2, U_2)$
$= (L_1/U_2, M_1/M_2, U_1/L_2),\ L_i > 0,\ M_i > 0,\ U_i > 0$
$\widetilde{A}_1^{-1} = (L_1, M_1, U_1)^{-1} = (1/U_1, 1/M_1, 1/L_1), L_i > 0, M_i > 0, U_i > 0$

6.1.3. Fuzzy linguistic variable

The fuzzy linguistic variable is a variable that reflects the different levels of human language. Its value represents the range between natural and artificial language. When precisely reflecting the value or meaning of a linguistic variable, there must be an appropriate way to change its value. Variables in a human word or sentence can be divided into numerous linguistic criteria, such as equally important, moderately important, strongly important, very strongly important, and extremely important (as shown in Fig. 2, with definitions and descriptions shown in Table 2). For the purpose of the present study, a 5-point scale was used to represent the values of equally important, moderately important, strongly important, very strongly important, and extremely important.

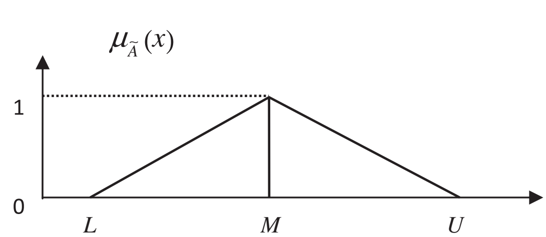

Fig. 1. Triangular fuzzy number.

6.1.4. Calculation steps of FAHP

The four-step procedure in this approach is given as follows:

- Step 1: Comparing the performance score:
  Assuming K experts, we precede to decision making on P alternatives with n criteria.
- Step 2: Construct fuzzy comparison matrix:
  We use a triangular fuzzy number to represent the meaning of questionnaires and to construct positive reciprocal matrixes.
- Step 3: Examine the consistency of fuzzy matrix $\widetilde{A}_i$:
  Assume $A = [a_{ij}]$ is a positive reciprocal matrix and $\widetilde{A} = [\tilde{a}_{ij}]$ is a fuzzy positive reciprocal matrix. If $A = [a_{ij}]$ is consistent, $\widetilde{A} = [\tilde{a}_{ij}]$ will also be consistent.
- Step 4: Calculate the fuzzy evaluation of number $\tilde{r}_i$:

  $$\tilde{r}_i = [\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{in}]^{1/n}$$

- Step 5: Calculate the fuzzy weight $\widetilde{W}_i$:

  $$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_i \oplus \cdots \oplus \tilde{r}_m)^{-1}$$

- Step 6: De-fuzzy

This study finds the best crisp, or non-fuzzy value, in accordance with the Center of Area (COA or Center Index, CI), which was developed by Teng and Tzeng (1993); we calculate clear weights for each index. The calculation method is as follows:

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i, \quad \forall i$$

6.2. Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

The VIKOR method was developed by Opricovic and Tzeng (2004). This method is based on the compromise programming of multi-criterion decision making (MCDM). We assume that each

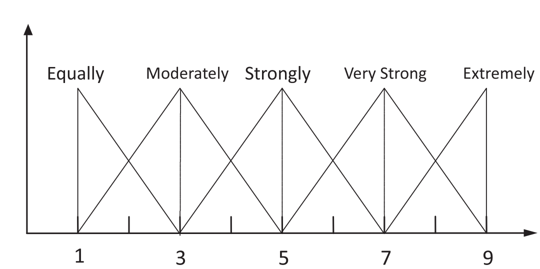

Fig. 2. Fuzzy membership function for linguistic values for attributes.

Table 2
Definition and membership function of fuzzy numbers.

Fuzzy number	Linguistic variable	Triangular fuzzy number
$\tilde{9}$	Extremely important/preferred	(7, 9, 9)
$\tilde{7}$	Very strongly important/ preferred	(5, 7, 9)
$\tilde{5}$	Strongly important/preferred	(3, 5, 7)
$\tilde{3}$	Moderately important/preferred	(1, 3, 5)
$\tilde{1}$	Equally important/preferred	(1, 1, 3)

alternative is evaluated according to separate criterion functions; the compromise ranking can be utilized by comparing the measure of closeness to the ideal alternative (Tzeng, Lin, & Opricovic, 2005). The multi-criterion measure for compromise ranking is developed from the L_p-*metric* and used as an aggregating function in a compromise programming method (Zeleny, 1982). The numerous J alternatives are represented as $a_1, a_2, \ldots, a_J$. For alternative a_j, the rating of the ith aspect is denoted by f_{ij}, i.e., f_{ij} is the value of ith criterion function for the alternative a_j; and n is the number of criteria (Tzeng et al., 2005). The VIKOR method development started with the form of L_p-*metric* as follows (Opricovic & Tzeng, 2004):

$$L_{p,j} = \left\{ \sum_{i=1}^{n} [w_i (f_i^* - f_{ij})/(f_i^* - f_i^-)]^p \right\}^{1/p} \quad 1 \leqslant p \leqslant \infty; \quad j = 1, 2, \ldots, J.$$

In the VIKOR method, L_{1j} (represented S_j as the following) and $L_{\infty j}$ (represented R_j as the following) are used to formulate ranking measurements. The solution gained by $\min_j S_j$ has maximum group utility, and the solution gained by $\min_j R_j$ has mixed individual regret of the "opponent". The compromise solution F^c is a solution that is the closest to the ideal, F^*, where compromise means an agreement established by mutual concessions, which is shown in Fig. 3 by $\Delta f_1 = f_1^* - f_1^c$ and $\Delta f_2 = f_2^* - f_2^c$ (Opricovic & Tzeng, 2004).

The five VIKOR calculation steps are shown as follows (Opricovic & Tzeng, 2004; Opricovic & Tzeng, 2007; Tzeng et al., 2005):

- Step 1: Find the best f_i^* and the worst f_i^- values for all criterion functions $i = 1, 2, \ldots, n$. If the ith function represents a benefit, then:

  $$f_i^* = \max_j f_{ij}, \quad f_i^- = \min_j f_{ij}$$

- Step 2: Calculate the values S_j and R_j; $j = 1, 2, \ldots, J$ by the equations $S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij})/(f_i^* - f_i^-)$ and $R_j = \max_i [w_i (f_i^* - f_{ij})/(f_i^* - f_i^-)]$, where w_i are the weights of criteria, expressing their relative importances.
- Step 3: Calculate the values Q_j; $j = 1, 2, \ldots, J$, by the relations

  $$Q_i = v(S_j - S^*)/(S^- - S^*) + (1 - v)(R_j - R^*)/(R^- - R^*),$$
  $$S^* = \min_j S_j, \quad S^- = \max_j S_j$$
  $$R^* = \min_j R_j, \quad R^- = \max_j R_j$$

  and v is introduced as the weight of the strategy of maximum group utility; here $v = 0.5$.
- Step 4: Rank alternatives in decreasing order, sorted by the values S, R and Q. The results are three ranking lists.
- Step 5: We propose a compromise solution, the alternative (d), which is best ranked by the measure Q (min) if it satisfies the following two conditions:
- $Q(a'') - Q(a') \geqslant DQ$, which is called acceptable advantage, where a'' is the alternative with the second position in the ranking list by $DQ = 1/(J - 1)$; J is the number of alternatives.

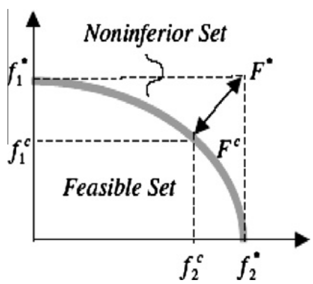

Fig. 3. Ideal and compromise solutions.

- Acceptable stability in decision making: alternative d must also be the best ranked by S or/and R. This solution is stable in a decision-making process, which could be: "voting by majority rule" (when $v > 0{:}5$ is needed), or "by consensus" $v \approx 0{:}5$, or "with veto" ($v < 0{:}5$). Here, v is the weight of the decision-making strategy with the maximum group utility.

If these two conditions are not fully satisfied, then a set of compromise solutions is proposed:

1. Alternatives a' and a'' if only Condition 2 is not satisfied, or
2. Alternatives a' and a'', ..., $a^{(M)}$ if Condition 1 is not satisfied; $a^{(M)}$ is determined by the relation $Q(a^{(M)}) - Q(a') < DQ$ for max$M$.

The best alternative ranked by Q is the one with the minimum value of Q. The main ranking result is the compromise ranking list of alternatives and the compromise solution with the advantage rate (Tzeng, Teng, & Chen, 2002).

Ranking by utilizing the VIKOR method needs to be performed with different values of criteria weights, and must analyze the impact of criteria weights on a proposed compromise solution. It determines the weight stability intervals by using the methodology cited in Opricovic (1998). The compromise solution gained with initial weights (w_i, $i = 1, \ldots, n$) will be replaced if the value of a weight is not within the stability interval. The analysis of weight stability intervals for a single criterion is utilized for all criterion functions with the given initial values of weights; by doing so, the preference stability of a gained compromise solution may be analyzed using the VIKOR program (Opricovic & Tzeng, 2004).

VIKOR is a tool that is used beneficially in MCDM in situations where the decision-maker is unstable during the beginning of the system design. In addition, decision-makers accept the obtained compromise solution because it provides maximum group utility, represented by min Q, and minimum individual regret, represented by min R (Tzeng et al., 2002).

7. An empirical study

7.1. Constructing an original aviatic innovation system (OAIS)

Constructing an aviatic innovation system (AIS) is complicated due to the numerous aspects that must be considered, such as policy, hardware and software construction, operation philosophy, and external cooperation. In addition, it is obvious that the AIS should be based on real practice. In this paper, we consulted twenty senior aero background experts, including nine anonymous members working in airlines, and 11 senior faculties with aero professional background in universities, as well as 56 customers who had taken flights as their main transportation for business or leisure for over fifteen years; the 3S's of the Civil Aeronautics Administration (CAA), and several current studies (Chen & Wu, 2009; Gkritza et al., 2006; Liou & Tzeng, 2007; Liou et al., 2007; Lopez-Bonilla & Lopez-Bonilla, 2008; Lu & Ling, 2008; Sim et al., 2006; Tiernan et al., 2008; Lu & Ling, 2008), especially the criteria in Table 1 were taken into account.

In addition, to indicate more precise directions for future innovation-oriented strategies, five strategies (operation professional oriented, operation differentiation oriented, reliability oriented, operation diversified oriented, and high value added oriented) were developed; this was done after consultation with nine anonymous senior aero background experts in order to get ascertain real practices and then confirmed by 32 customers who flew as their main transportation for business or leisure for over 20 years. The original aviatic innovation system was developed (Table 3) in

Table 3
Original aviatic innovation system.

System name	Extracted dimension	Extracted criteria (scoring for future innovation possibility)	Alternatives (orientations) for strategy creation
Original Aviatic Innovation System (OAIS)	Safety (D1)	Low accident rate control (C1) Pilot training status monitoring (C2) Flight crew competence examination (C3)	Operation professional oriented (A1) Operation differentiation oriented (A2)
	Service (D2)	Efficiency of solving passenger requirements and complaint (C4) Service with differentiation (C5) Diversification of ticket prices (C6)	Reliability oriented (A3)
	Satisfaction (D3)	Low flight schedule delay (C7) Compensation for service negligence (C8) Enhancement of customer relationship management (C9)	Operation diversified oriented (A4)
	Management (D4)	Operation diversification (C10) Fostering specialists by cooperating with educational institutes (C11) Full support from top managers toward organizational change (C12)	High value added oriented (A5)

Table 4
Pairwise comparison matrix and weight of measurement dimension.

Extracted Dimensions	D1			D2			D3			D4			BNP	Local weight
D1	1.000	1.000	3.000	0.719	1.000	2.158	0.558	0.858	1.809	0.517	1.204	1.904	0.759	0.247
D2	0.463	1.000	1.390	1.000	1.000	3.000	0.644	1.933	2.627	1.116	3.157	5.171	0.958	0.312
D3	0.553	1.166	1.793	0.381	0.517	1.552	1.000	1.000	3.000	7.000	9.000	9.000	1.028	0.335
D4	0.525	0.831	1.933	0.193	0.317	0.896	0.111	0.111	0.143	1.000	1.000	3.000	0.324	0.106

Table 5
Pairwise comparison matrix and weights of measurement criteria (D1).

Extracted criteria (D1)	C1			C2			C3			BNP	Local Weight	Global Weight
C1	1.000	1.000	3.000	3.436	5.484	7.361	3.323	5.348	7.361	0.214	0.710	0.175
C2	0.136	0.182	0.291	1.000	1.000	3.000	0.830	1.528	2.124	0.048	0.159	0.039
C3	0.136	0.187	0.301	0.471	0.654	1.206	1.000	1.000	3.000	0.040	0.132	0.033

Table 6
Pairwise comparison matrix and weights of measurement criteria (D2).

Extracted criteria (D2)	C4			C5			C6			BNP	Local weight	Global Weight
C4	1.000	1.000	3.000	0.163	0.245	0.517	0.200	0.333	1.000	0.053	0.142	0.044
C5	1.933	4.076	6.119	1.000	1.000	3.000	2.581	4.945	6.938	0.236	0.634	0.198
C6	1.000	3.000	5.000	0.144	0.202	0.387	1.000	1.000	3.000	0.083	0.224	0.070

Table 7
Pairwise comparison matrix and weights of measurement criteria (D3).

Extracted criteria (D3)	C7			C8			C9			BNP	Local weight	Global weight
C7	1.000	1.000	3.000	0.148	0.210	0.372	0.200	0.333	1.000	0.052	0.144	0.048
C8	2.688	4.751	6.768	1.000	1.000	3.000	0.365	0.547	0.845	0.132	0.368	0.123
C9	1.000	3.000	5.000	1.184	1.827	2.736	1.000	1.000	3.000	0.175	0.488	0.163

order to be utilized in further calculations. A questionnaire was utilized to find out from three groups with 93 experts (nine anonymous senior members of airlines, seventeen faculty members from universities, and 67 customers who took flights as their main transportation for business or leisure for over 10 years). Their scoring of measurement dimensions and criteria regarding the innovation conduction using a 5-point scale ranging from 9 (Extremely important) to 1 (Equally important) is shown in Table 2.

7.2. Weighting of innovation measurement criteria of OAIS

After constructing the original aviatic innovation system, the fuzzy AHP was utilized to acquire criteria weights. Local weights for the dimensions and criteria were calculated first. All the fuzzy measuring matrices were developed in the same manner. Pairwise comparison matrices and local weights were also analyzed. These pairwise comparisons were in accordance with Saaty's

Table 8
Pairwise comparison matrix and weights of measurement criteria (D4).

Extracted criteria (D4)	C10			C11			C12			BNP	Local weight	Global weight
C10	1.000	1.000	3.000	2.213	3.624	5.163	1.184	2.807	4.709	0.214	0.567	0.060
C11	0.194	0.276	0.452	1.000	1.000	3.000	0.276	0.440	1.116	0.058	0.153	0.016
C12	0.212	0.356	0.845	0.896	2.271	3.624	1.000	1.000	3.000	0.106	0.280	0.030

Table 9
Best and worst values of performance.

Alternatives (orientations)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
A1*	8	7	8	8	8	7	8	9	8	7	7	8
A2*	8	8	8	8	8	9	7	8	8	9	8	7
A3*	7	8	7	7	5	5	8	6	7	6	6	6
A4*	7	6	7	8	7	8	7	8	7	6	7	6
A5*	9	8	9	8	9	8	8	8	9	9	8	9
f_i^*	9	8	9	8	9	9	8	9	9	9	8	9
f_i^-	7	6	7	7	5	5	7	6	7	6	6	6
$f_i^* - f_i^-$	2	2	2	1	4	4	1	3	2	3	2	3

* 1. At the 10th position after the decimal point, numbers less than or equal to four are dropped, and numbers greater than four are rounded up to one.

Table 10
S_j and R_j calculation.

Alternatives (orientations)	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	S_j	R_j
A1	0.500	0.500	0.500	0.000	0.250	0.500	0.000	0.000	0.500	0.667	0.500	0.333	0.348	0.073
A2	0.500	0.000	0.500	0.000	0.250	0.000	1.000	0.333	0.500	0.000	0.000	0.667	0.344	0.079
A3	1.000	0.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	0.912	0.156
A4	1.000	1.000	1.000	0.000	0.500	0.250	1.000	0.333	1.000	1.000	0.500	1.000	0.714	0.079
A5	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.333	0.000	0.000	0.000	0.000	0.059	0.037
Weights	0.175	0.039	0.033	0.044	0.198	0.070	0.048	0.123	0.163	0.060	0.016	0.030		

Table 11
Ranking of alternatives (orientations).

Alternatives (orientations)	S_j	R_j	S_j-S^*	$R_j - R^*$	$S^- - S^*$	$R^- - R^*$	(S_j-S^*)/(S-S^*)	(R_j-R^*)/(R^--R^*)	v	Q	Ranking
A1	0.348	0.088	0.289	0.047	0.854	0.157	0.339	0.299	0.5	0.317	2
A2	0.344	0.088	0.286	0.047			0.335	0.299		0.319	3
A3	0.912	0.198	0.854	0.157			1.000	1.000		1.000	5
A4	0.714	0.175	0.655	0.134			0.767	0.854		0.810	4
A5	0.059	0.041	0.000	0.000			0.000	0.000		0.000	1

C1. $0.320 - 0.000 = 0.320 \geqq 1/(5 - 1) = 0.25$; acceptable advantage.
C2. $v \approx$ voting by consensus; acceptable stability in decision making.

Table 12
The aviatic innovation system (AIS).

Extracted dimension	Local weight	Extracted criteria	BNP	Local weight	Global weight	Prior	Alternatives (orientations)	v	Q	Ranking
Safety (D1)	0.247	C1	0.214	0.710	0.175	2	A1	0.5	0.317	2
		C2	0.048	0.159	0.039	9				
		C3	0.040	0.132	0.033	10				
Service (D2)	0.312	C4	0.053	0.142	0.044	8	A2		0.319	3
		C5	0.236	0.634	0.198	1				
		C6	0.083	0.224	0.070	5	A3		1.000	5
Satisfaction (D3)	0.335	C7	0.052	0.144	0.048	7				
		C8	0.132	0.368	0.123	4				
		C9	0.175	0.488	0.163	3	A4		0.810	4
Management (D4)	0.106	C10	0.214	0.567	0.060	6				
		C11	0.058	0.153	0.016	12	A5		0.000	1
		C12	0.106	0.280	0.030	11				

9-point scale, ranging from 1 (equally important) to 9 (extremely important) of one element over another (see Table 2). Local weights for dimensions and criteria are given in tables four through eight.

Global weights of criteria were then calculated using local weights of each dimension (the last column in Table 4). The global weights of each criterion are provided in the last column of Tables 5–8.

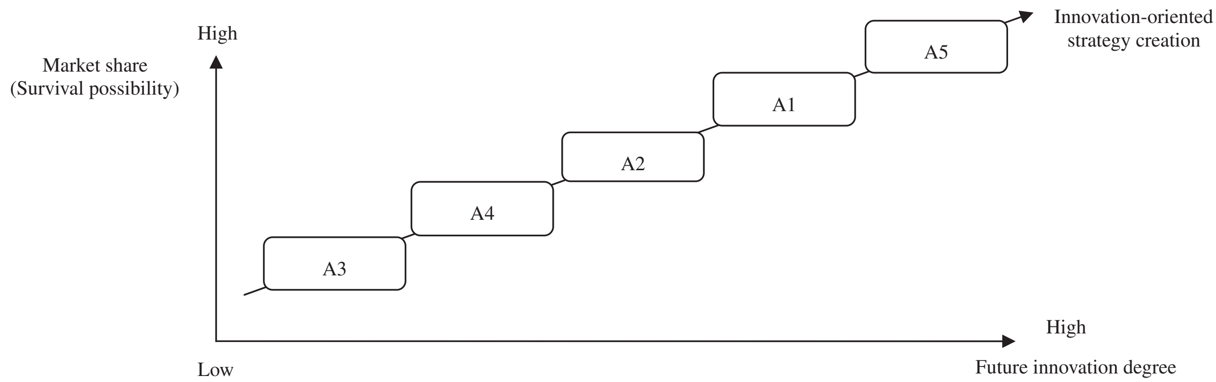

Fig. 4. Conception diagram of market share (survival possibility) and innovation degree among orientations of strategy making.

7.3. Alternative selections in OAIS and AIS construction

After obtaining the global weights of dimensions and criteria, alternatives (orientations) were ranked by applying the VIKOR method to the data in Table 9 and to the global weights in Tables 5–8. Due to the non-quantifiable nature of performances of alternatives among criteria, we utilized a scale ranging from 10 (the best) to 0 (the worst), based on the experiences of senior related background experts. First, f_i^* and f_i^- were acquired based on the best and worst values of each criteria, as shown in Table 9. Next, S_j and R_j were calculated according to equations $S_j = \sum_{i=1}^{n} w_i(f_i^* - f_{ij})/f_i^* - f_i^-$ and $R_j = \max_i[w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)]$; the results are shown in Table 10. Then, the equation $Q_j \frac{v(S_j - S^*)}{S^- - S^*} + \frac{(1-v)(R_j - R^*)}{R^- - R^*}$, with $v = 0.5$ (voting by consensus), was adopted to find Q. The results for Q's and the ranking of alternatives (orientations) are given in Table 11. Based on the above results, a novel aviatic innovation system can be constructed, shown in Table 12. In accordance with the aviatic innovation system, the fifth orientation (high value added oriented) is the optimal alternative for future innovation-oriented strategy making. That is, there is a consensus among senior experts that the fifth orientation is the most innovative manner of future strategy creation. With greater orientation preferences, the corresponding scoring criteria also increase, indicating that the more innovation-oriented strategy creation is, the more organizational resources are needed and the AIS provides alternative strategy creation orientations for different operational statuses of airlines.

In addition, based on the arguments of Daft (2004) and Krause (2004), an organization that cannot continue innovating will quickly fail. We claim that there is a strong positive correlation between market share (survival possibility) and the degree of innovation, as depicted in the conception diagram in Fig. 4. The AIS not only indicates a way for effectively conducting innovation operations but also provides useful strategy creation orientations for different operations statuses for airlines. That is, an airline cannot merely choose what strategy creation orientation it can utilize currently, but must realize what the best orientation for the future is and how best to achieve it.

8. Conclusions

Due to several recent threats, such as, from an international perspective, SARS, the 9/11 terrorist attacks, oil price increases, economic depression, and, from a domestic perspective, the interaction with China, joining the WTO and low railway prices, especially in the high-speed rail industry, an increasing number of Taiwanese airlines are facing deficits or even total business closure. As we enter the "innovation economy stage," strategies to regain market share by developing competitive advantages can no longer focus on cost-reduction, but must focus on innovation. In this paper, an aviatic innovative system (AIS) is proposed to overcome these problematic factors. The value of the AIS is to provide airlines in Taiwan with innovation-oriented techniques for future strategy creation. We therefore believe that the AIS can contribute to the survival of Taiwanese airlines in the near future.

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