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A non-additive model for evaluating airline service quality

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Abstract

This study develops a non-additive model for evaluating and improving the service quality of airlines and compares its results with the conventional additive method. Service quality is a composite of various attributes and many in a system have inter-dependent characteristics that may not be correctly evaluated using conventional additive measures. A fuzzy integral is thus proposed. Factor analysis is initially used to extract some independent common-factors and fuzzy integral used to integrate the performance ratings of inter-dependent attributes in each common-factor. For the analytic hierarchy process a pair-wise comparative approach is adopted to determine the relative weights linking each independent common-factor. Finally, Grey relation analysis and simple additive weight method are used to find airline service quality. A study of international airlines is conducted for verification. Safety and reliability emerge as the critical factors of service quality.

Keywords: Airline service quality; Analytic hierarchy process; Factor analysis; Fuzzy integral; Grey relation analysis

1. Introduction

Providing a high-quality service to passengers is important for many airlines because it retains customer patronage and market-share and, ultimately, profitability (Morash and Ozment, 1994). Though price is increasingly used as the primary way to attract customers; some airlines are looking more to service quality to get a competitive edge to distinguish their product because competitors are relatively efficient in responding to price changes (Jones and Sasser, 1995). These airlines' competitive advantage lies in their service quality as perceived by customers (Chang and Yeh, 2002). The services provided by airlines are not complex as, for example, those inherent in like high-tech products, but they are made up of a diverse mix of intangibles (Mazanec, 1995). Service quality is a composite of various interactions between customers and airlines, with employees seeking to influence customers' perceptions and the image of the carriers (Gursoy et al., 2005).

Service quality can be defined as a consumer's overall impression of the efficiency of the organization and its services (Park et al., 2004) or as a chain of services in which the entire service delivery is divided into a series of processes (Chen and Chang, 2005). But whatever the definition used, the attributes for service quality are still a matter of debate and depend on context and the wide range of perceptions individuals have toward airline attributes. It is thus difficult for people to describe and assess service quality.

Although service quality can be one of the key factors in attracting and retaining loyal customers, airlines often find it difficult to offer appropriate service attributes. The Airline Quality Rating Report, 2005, indicated that air travel service has declined and airline companies have failed to deliver their self-policed promise to do better in the customer-service area (Gursoy et al., 2005).

Most of the work done on service quality has assumed the attributes of service quality are independent. However, intuitively it would seem that many of attributes have some degree of inter-dependence which is not properly evaluated

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using conventional additive measures. The objective here is to construct a model that considers such inter-dependent characteristics between attributes. It allows a decision-maker's preference regarding customers' assessments of attribute weights and performance ratings to be incorporated into the evaluation process. The non-additive results are also compared with those obtained using conventional method.

The model uses factor analysis to extract some independent common-factors based on various attributes. A fuzzy integral is applied to integrate the performance ratings of attributes in each common-factor. Then the analytic hierarchy process (AHP), a pair-wise comparative approach, determines the relative weights between each common-factor. Finally, the Grey relation analysis and SAW with additive measure is conducted to find the airline service quality. Also, an empirical example is illustrated to show the feasibility of the proposed model. The results can show the strength and weakness of airlines and compare to their competitors. Also, it can improve the gaps between the real performance valve and the desired/aspiration level in each attribute for satisfying the customers' needs.

2. Evaluating airline service quality

A number of studies have addressed service quality issues. The mainstream research has been based on the notion that quality of service is perceived and evaluated by customers (Gronroos, 1990). The most widely used customer-perceived service quality model is that developed by Parasuraman et al. (1985) that uses 10 determinants of service quality: reliability, responsiveness, competence, assurance, courtesy of personnel, communications, credibility or trustworthiness of the organization, security or protection from risk, understanding of customer's needs, and tangibles or physical elements attesting to the nature of the service. Gronroos (1993) suggested that measuring customer experiences of service quality is a theoretically valid way of measuring perceived quality. This also simplifies the process of data collection and analysis using questionnaires.

Suzuki et al.'s (2001) model represented the relationship between service quality and market-share. They find that empirically, the relationship is characterized by a non-smooth curve. Tsaur et al. (2002) proposed a five-dimensional measurement of service quality that includes tangibility, reliability, responsiveness, assurance, and empathy. Each dimension includes two to four attributes. It is assumed that each attribute is independent and they used analytical hierarchical processes to obtain the attribute weight and TOPSIS in ranking the airlines. They concluded that the attributes of most importance are courtesy, safety, and comfort. Chang and Yeh (2002) used fuzzy multi-criteria analysis modeling to formulate the service quality of airlines. Due to the heterogeneity, intangibility, and inseparability of service quality, fuzzy set theory was used to describe the ambiguity between the criteria weight and performance ratings of each airline. They looked at 15 attributes to measure the quality of service and found that the most important factor is flight safety. (This is possibly because of the poor safety record in Taiwan that can cause customer concern.) Their approach is particularly applicable to major routes between cities pairs that are served by several airlines.

Gilbert and Wong (2003) developed a 26-attribute model incorporating reliability, assurance, facilities, employees, flight patterns, customization, and responsiveness dimensions to measure and compare the differences in passengers' expectations of the desired airline's service quality. Their findings show passengers consistently ranking assurance as the most important service dimension. Chen and Chang (2005) examined airline service quality from a process perspective by first examining the gap between passengers' service expectations and the actual service received and then the gaps associated with passenger service expectations and perceptions of these expectations by frontline managers and employees. Importance–performance analysis was then used to construct service attribute evaluation maps to identify areas for improvement. They found that gaps did exist and passengers were most interested in the responsiveness and assurance dimensions from airline frontline staff. Gursoy et al. (2005) considered 15 attributes of service quality when looking at 10 major US airlines using canonical correspondence analysis. They established a positioning map using the data in the US Department of Transportation's Air Travel Consumer Report.

Although there has been progress in evaluating the service quality of airlines, most of the work has assumed the attributes of service quality are independent. To circumvent this assumption the fuzzy integral can be used that allow flexibility in the assumptions of dependency in the AHP.

3. Constructing the fuzzy integral model for service quality of airlines

The conventional multi-criteria decision-making evaluation is based on the assumption that each attribute is independent with the evaluation of multiple attributes executed by simply weighting the relative importance and performance of each. The integrated performance of each alternative is measured by adding the product of weighting and performance for each attribute. In the real world there is some degree of inter-dependent characteristics between attributes. Therefore, partitioning the type of fuzzy integral has to be applied on these related attributes to regroup a new hierarchy system and then apply the fuzzy integral proposed by Sugeno (1974) and Sugeno and Kwon (1995). The fuzzy integral combines the efficient value of those related attributes and develops a new combining performance value.

The evaluation procedure adopted here is seen in Fig. 1. Factor analysis is initially used to extract independent

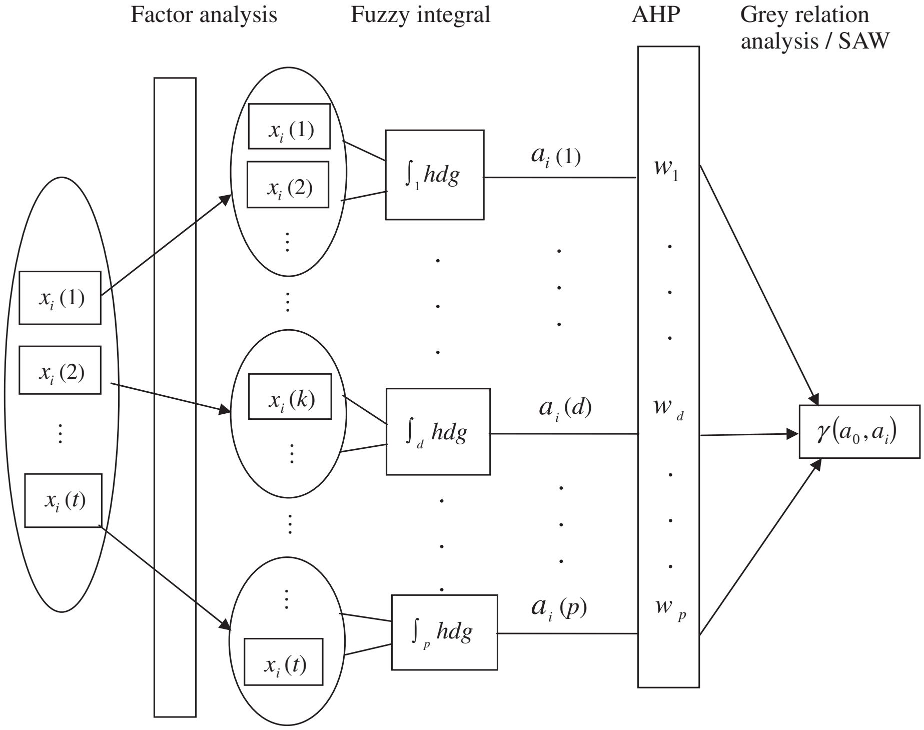

Fig. 1. Evaluation procedures.

common-factors based on considered t attributes. Second, the fuzzy integral is used to evaluate the integrated performance of attributes in each common-factor. The AHP, a pair-wise comparative approach, is deployed to determine the relative weights between each common-factor. Finally, Grey relation analysis and SAW method with additive measure are conducted to find the airline service quality.

3.1. The λ fuzzy measure and fuzzy integral

Let g_λ be a λ fuzzy measure which is defined on a power set $P(x)$, for the finite set $X = \{x_1, x_2, ..., x_n\}$. The fuzzy measure has the following property:

$$\forall A, B \in P(X), \quad A \cap B = \phi,$$

$$g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B) \quad \text{for } -1 < \lambda < \infty. \tag{1}$$

The density of the fuzzy measure $g_i = g_\lambda(\{x_i\})$ can be formulated as

$$\begin{aligned} g_\lambda(\{x_1, x_2, \ldots, x_n\}) &= \sum_{i=1}^{n} g_i + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n} g_{i_1} g_{i_2} \\ &\quad + \cdots + \lambda^{n-1} g_1 g_2, \ldots, g_n \\ &= \frac{1}{\lambda} \left| \prod_{i=1}^{n} (1 + \lambda g_i) - 1 \right| \\ &\quad \text{for } -1 < \lambda < \infty. \end{aligned} \tag{2}$$

Based on these properties, one of the three following situations will be sustained for a specific case with two attributes, x_1 and x_2.

(a) If $\lambda > 0$, then $g_\lambda(A \cup B) > g_\lambda(A) + g_\lambda(B)$: this implies that x_1 and x_2 have multiplicative effect in $\{A, B\}$.
(b) If $\lambda = 0$, then $g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B)$: this implies that x_1 and x_2 have additive effect in $\{A, B\}$.
(c) If $\lambda < 0$, then $g_\lambda(A \cup B) < g_\lambda(A) + g_\lambda(B)$: this means that x_1 and x_2 have substitutive effect in $\{A, B\}$.

Let h be a measurable set function defined on the fuzzy measurable space, and supposing that $h(x_1) \geqslant h(x_2) \geqslant \cdots \geqslant h(x_n)$, then the fuzzy integral of fuzzy measure $g(\cdot)$ with respect to $h(\cdot)$ can be defined as Eq. (3) (Ishii and Sugeno, 1985) and shown in Fig. 2:

$$\begin{aligned} \int h \, \mathrm{d}g &= h(x_n) g(H_n) + [h(x_{n-1}) - h(x_n)] g(H_{n-1}) \\ &\quad + \cdots + [h(x_1) - h(x_2)] g(H_1) \\ &= h(x_n)[g(H_n) - g(H_{n-1})] + h(x_{n-1})[g(H_{n-1}) \\ &\quad - g(H_{n-2})] + \cdots + h(x_1) g(H_1), \end{aligned} \tag{3}$$

where $H_1 = \{x_1\}$, $H_2 = \{x_1, x_2\}, \ldots, H_n = \{x_1, x_2, \ldots, x_n\} = X$.

The fuzzy integral is the Choquet integral. Using the fuzzy integral to formulate the original data, not only can fewer and more representative factors be extracted to describe the system, but the interactions between attributes can be considered. The various common-factors that are extracted from factor analysis can be reasonably processed

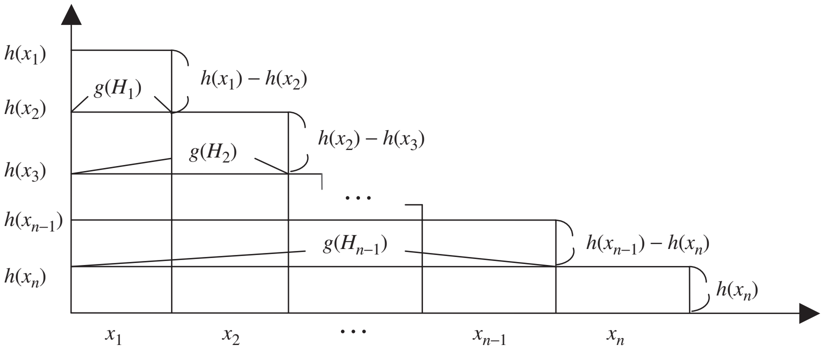

Fig. 2. Concept of fuzzy integral.

by a conventional additive measure, such as Grey relational analysis and SAW method. Here we used $\int h\,\mathrm{d}g = a_i(d)$ as the integrated performance value of the common-factor C_d at alternative i.

3.2. Grey relational analysis

Grey theory was developed by Deng (1982) to study the relation degree among various attributes in an MCDM problem. It is useful mathematically when dealing with a system with limited information. In comparison with the conventional methods that require larger samples, Grey relational analysis possesses advantages (Deng, 1982; Shi, 1990): it involves simple calculations; it requires smaller samples; a typical distribution of samples is not needed; the quantified outcomes from the Grey relational grade do not result in contradictory conclusions to qualitative analysis; and the Grey relational grade model is a transfer functional model that is effective in dealing with discrete data.

Grey relational grade satisfies four axioms. We let $A = \{a_\sigma | \sigma = 0, 1, \ldots, m \in N\}$ be an alternative set of the Grey relation, $a_0 \in A$ the referential sequence, $a_i \in A$ $(i = 1, 2, \ldots, m)$ the comparative sequence; $a_0(d)$ and $a_i(d)$ $(d = 1, 2, ..., p)$ represent the data at dth common-factor for a_0 and a_i, respectively. $a_i(d)$ is the integrated performance value of common factor C_d at alternative i after the original data $x_i(k)$ have been processed by factor analysis and fuzzy integral.

If the Grey relational coefficient in $a_i(d)$ corresponding to $a_0(d)$ is $\gamma(a_0(d), a_i(d))$, then the Grey relational grade in a_i corresponding to a_0, $\gamma(a_0, a_i)$, must satisfy the following:

(a) Norm interval
$0 < \gamma(a_0, a_i) \leqslant 1, \ \forall i,$
$\gamma(a_0, a_i) = 1$ iff $a_0 = a_i$,
$\gamma(a_0, a_i) = 0$ iff $a_0, a_i \in \phi$; where ϕ is an empty set.
(b) Duality symmetric
$x, y \in X \Rightarrow \gamma(x, y) = \gamma(x, y)$ iff $X = \{x, y\}$.
(c) Wholeness
$$\gamma(a_0, a_i) \underset{often}{\neq} \gamma(a_i, a_0) \text{ iff } X = \{x_i | i = 0, 1, 2, \ldots, n\}, n < 2.$$
(d) Approachability
$\gamma(a_0(d), a_i(d))$ decreasing along with $|a_0(d) - a_i(d)|$ increasing.

If we let the common-factor d be the X-axis and $a_i(d)$ be the Y-axis, the m+1 lines from a_0 to a_m sequences can be drawn. The relation degree among the various comparative and referential sequences can be determined by degree of similarity between the lines. Based on the geometry in conjunction with the axioms, the requirements and quantified model of Grey relational grade can be identified (Tzeng et al., 2002).

Let $a_i(d)$ be the integrated performance value of common-factor C_d at alternative i. According to the four axioms and the premise of independency among $a_i(d)$, the additive Grey relational coefficient in a_i corresponding to a_0, $\gamma(a_0(d), a_i(d))$, can be derived from Eq. (4) (Deng, 1989)

$$\gamma(a_0(d), a_i(d)) = \frac{\min_i \min_d |a_0(d) - a_i(d)| + \zeta \max_i \max_d |a_0(d) - a_i(d)|}{|a_0(d) - a_i(d)| + \zeta \max_i \max_d |a_0(d) - a_i(d)|}, \tag{4}$$

where $\zeta \in [0, 1]$ is the distinguished coefficient and represents the significance of $\max_i \max_d |a_0(d) - a_i(d)|$, whose value is generally set at $\zeta = 0.5$ (Guo, 1985).

Therefore, the Grey relational grade in a_i corresponding to the best alternative a_0, $\gamma(a_0,a_i)$ can be obtained by Eq. (5) (Shi, 1990):

$$\gamma(a_0, a_i) = \sum_{d=1}^{p} w_d(a_0(d), a_i(d)), \tag{5}$$

where w_d is obtained using AHP methods and denotes the normalized weights of independent common-factors C_d and $\sum_{d=1}^{p} \omega_d = 1$, and $d = 1, 2, \ldots, p$.

4. An empirical example

Traffic has grown and competition among airlines is increasing after deregulation. To acquire and retain customers many airlines seek to provide superior service quality to satisfy customer needs. Although many analysis techniques for service quality have been developed for airlines to understand their competitive position with other competitors, most of them assume that the attributes are independent and the simple additive model was used. Here we provide a non-additive measure of the partitioning fuzzy integral multi-criteria assessment model. The model evaluates the performance for individual criterion of six international airlines serving Taiwan. To preserve confidentiality, the six airlines are referenced as A1, A2, A3, A4, A5, and A6. The A5 and A6 are from North America while the others are from the Asia Pacific region.

To reflect an airline's service quality as perceived by customers there are a manageable number of distinct attributes. Previous work using SERVQUAL (Parasuraman et al., 1993; Cunningham et al., 2002; Lam and Zhang, 1999; Park et al., 2004) is used to define these combined with supplementary sources (Gursoy et al., 2005; Park et al., 2004; Tsaur et al., 2002) and information obtained from five airline industry experts. This allows the multi-criteria assessment to include: seating comfort (C1), in-flight entertainment service (C2), meal service (C3), on-time performance (C4), safety record (C5), promptness and accuracy of baggage delivery (C6), convenient flight schedule (C7), appearance of employees (C8), service efficiency of airline personnel (C9), frequent flyer programs (FFPs) (C10), customer complaints handling (C11), and language skill of airline personnel (C12).

Based on these attributes a survey using questionnaires was conducted at Taoyuan International Airport for a period of 2 weeks. The result was 408 usable replies from economic class passengers who had flown designated airlines within the previous year. Only one class of service was selected to provide a reasonably homogeneous sample. Passengers were asked to rate their satisfaction levels against the various attributes on an 11-point scale ranging from 10 (extremely high) to 0 (extremely low) (Chang and Yeh, 2002). The data were then analyzed to extract common-factors. The attributes within the common-factors can be calculated by fuzzy integral to get an integrated performance. With independence among the common-factors they can be analyzed by the additive measure.

Principle component analysis isolated six common-factors as shown in Table 1 being 24.4%, 19.3%, 15.8%, 9.7%, 7.4%, and 7.3%, respectively. The variance explained is as much as 83.9%. There are three common-factors with more than a single attribute meaning these attributes in the common-factor have inter-dependent relationships. After the axis is rotated, four attributes, C8, C9, C11, and C12, have a higher loading factor in common-factor 1 that we rename 'employees' service'. Attributes C1, C2, and C3 form a new common-factor—'on-board service'. The C5 and C6 are then combined as 'safety and reliability'—Fig. 3.

Using these results, the re-constructed assessment hierarchy system is shown in Fig. 4. Three common-factors are found that are interrelated between attributes; fuzzy measures can be used to obtain the integrated performance. A survey of 18 senior managers of travel agents was used to estimate the fuzzy integral λ values that range from -1 to positive infinity, and represent the properties of substitution or multiplicative effects between attributes. There are substitution effects between on-board service, and employees' service and a multiplicative effect among safety and reliability. The λ values and the fuzzy measure $g(\cdot)$ are shown in Table 2. Using $g(\cdot)$ and Eq. (3), the

Table 1
Factor analysis results after varimax rotated

Common-factors	Influential parameters (relations)	Common-factors						Communality
		1	2	3	4	5	6	h^2
1. Employees' service	1. Appearance of employees	0.743	0.124	0.101	0.408	0.215	0.113	0.804
	2. Service efficiency of airline personnel	0.713	0.289	0.325	0.270	0.0	0.0	0.782
	3. Customers complaints handling	0.759	0.343	0.240	0.0	0.0	0.171	0.790
	4. Language skill of employees	0.827	0.114	0.175	0.0	0.234	0.133	0.803
2. Safety and reliability	1. Safety record	0.198	0.186	0.870	0.0	0.180	0.121	0.880
	2. Promptness and accuracy of baggage delivery	0.293	0.218	0.784	0.256	0.121	0.111	0.841
3. On-board service	1. Comfort and clearness of seat	0.165	0.771	0.118	0.0	0.256	0.345	0.821
	2. In-flight entertainment service	0.237	0.785	0.168	0.117	0.124	0.271	0.803
	3. Meal service	0.232	0.789	0.266	0.268	0.0	−0.214	0.869
4. Schedule	Take-off, arriving, and transferring time	0.291	0.224	0.219	0.801	0.183	0.198	0.896
5. On-time performance	On-time performance	0.358	0.193	0.312	0.214	0.785	0.0	0.926
6. FFP	Free ticket and upgrading	0.353	0.296	0.246	0.266	0.0	0.712	0.850
Eigenvalue		2.922	2.320	1.896	1.159	0.890	0.879	—
Variance interpreted (%)		24.35	19.33	15.80	9.66	7.42	7.32	—
Accumulated variance (%)		24.35	43.69	59.49	69.14	76.56	83.89	—

Note: Extraction method—principle component analysis. Rotated method—varimax with Kaiser normalization.

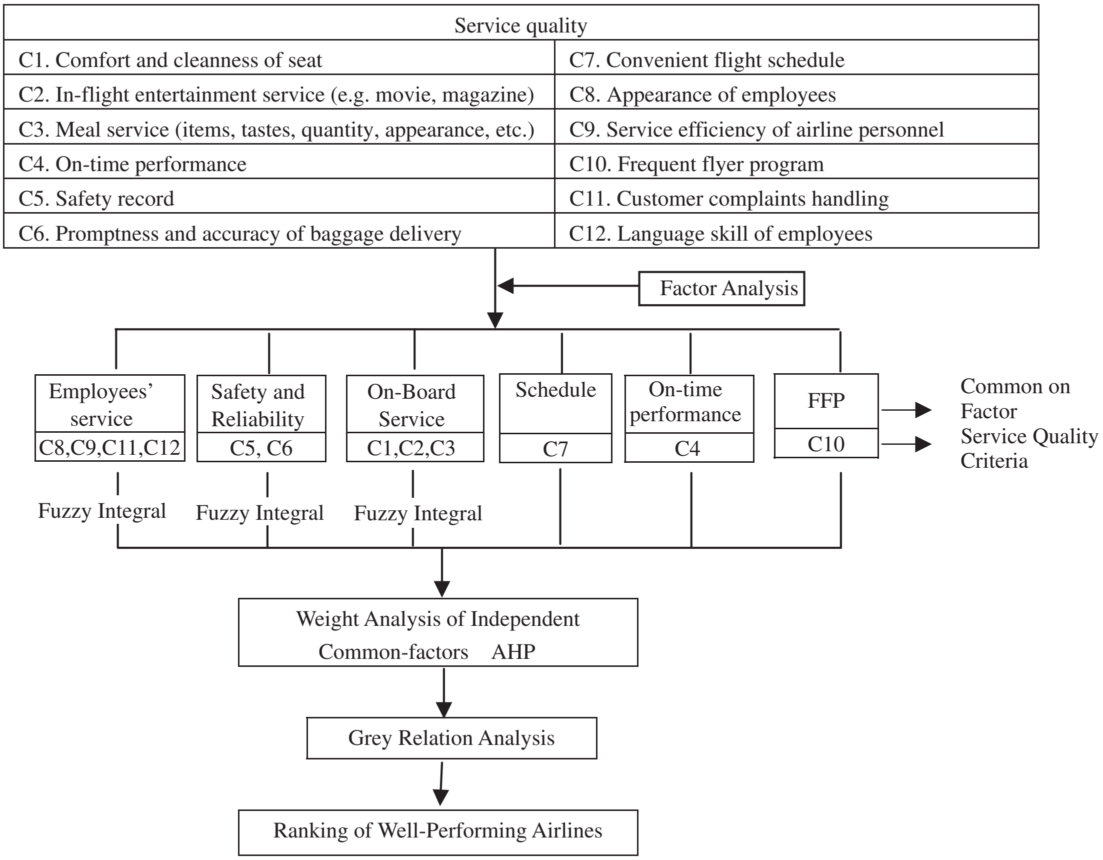

Fig. 3. Analysis flow.

integrated performance of airlines for independent common-factors are can be calculated—Table 3. The relative weights for each independent common-factor obtained from the travel agents are estimated by the analytical hierarchy process (Saaty, 1977, 1980).

Six independent common-factors are derived from the factor analysis—three that include more than one attribute are subjected to a fuzzy integral to obtain their integrated performance. Since they are mutually independent between common-factors, we apply the additive aggregated method to conduct the grade of Grey relation. The Grey relational coefficients $\gamma(a_0(d), a_i(d))$ $(i, d = 1, 2, \ldots, 6)$ are calculated using Eq. (4) where i is the airline and d is the common-factor. The corresponding referential sequence $a_0(d)$ and distinguished coefficient ζ are set equal to 1 and 0.5, respectively. Finally, the grade of Grey relation $\gamma(a_0,a_i)$ is estimated using Eq. (5) with the relative weight between common-factors. The $\gamma(a_0,a_i)$ represents the grade of Grey relation ith airline correspondence to ideal airline a_0. From the grade of Grey related to the ideal airline we can then rank the other airlines.

5. Discussions

Table 3 shows the relative weight of the six elements of service quality obtained from AHP. Safety and reliability contribute one-third of service quality with employees' service also playing an important role. This reflects that most of the air travelers are still concerned with face-to-face interaction with the airlines. In contrast, FFPs seem to have little attraction for customers. The fuzzy measure of Table 2 suggests that customers' complaint handling is the most important attribute of the employees' services included. Though shorter seat pitch can increase the capacity of each flight, it degrades the on-board service drastically. Finally, safety records dominate customers' responses regarding service quality.

Using the non-additive model, the final grade of Grey relation and average performance values from SAW method for each airline is seen in Table 4. If we take $A \succ B$ to mean A outranks B, then the ranking of service quality attributes for the surveyed airlines are: $A6 \succ A4 \succ A5 \succ A3 \succ A2 \succ A1$. The airlines can crudely be divided into groups, a leading group A6, a very competitive group A4 and A5, a competitive group A2 and A3, and a lagging group A1. The leading airline A6 has good performance in most aspects of service while A1 gets poor grade in many areas. Though A6 is in the leading position, it could still improve its board services. In the very competitive group, A4 and A5 have similar performance levels although if A4 could rearrange its schedule or A5 be more focused on its safety and reliability they could

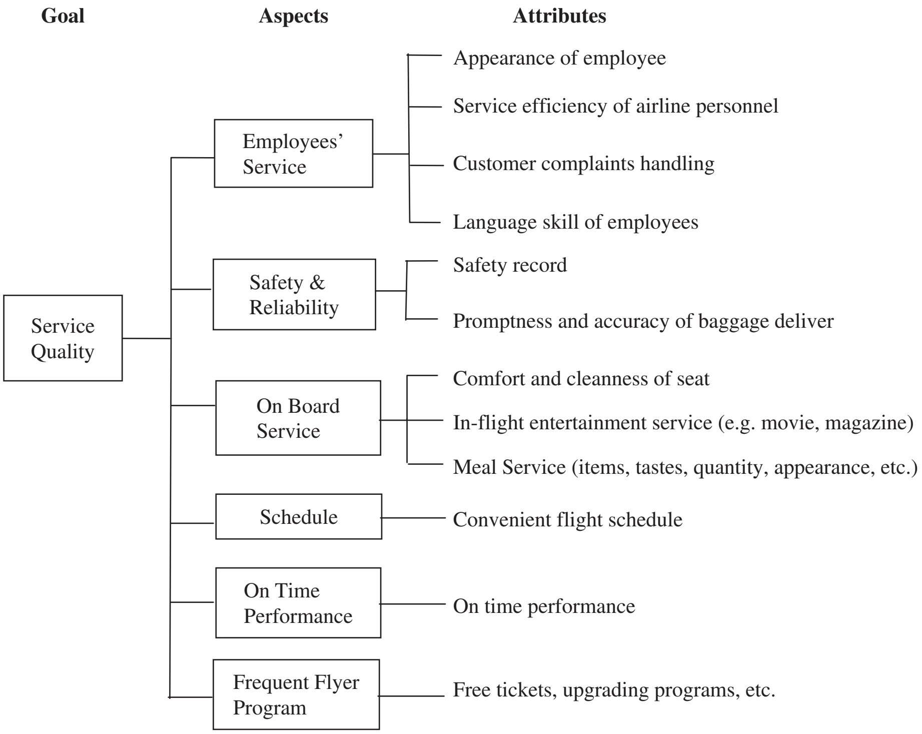

Fig. 4. Revised assessment hierarchy system.

Table 2
Fuzzy measure $g(\cdot)$ of each parameter and parameter combination

Fuzzy measure $g(\cdot)$			
Employees' service ($\lambda = -0.86$)			
$C8 = 0.33$	$\{C8, C9\} = 0.71$	$\{C8, C9, C11\} = 0.93$	$\{C8, C9, C11, C12\} = 1$
$C9 = 0.53$	$\{C8, C11\} = 0.73$	$\{C8, C9, C12\} = 0.85$	
$C11 = 0.56$	$\{C8, C12\} = 0.58$	$\{C8, C11, C12\} = 0.86$	
$C12 = 0.35$	$\{C9, C11\} = 0.83$	$\{C9, C11, C12\} = 0.93$	
	$\{C9, C12\} = 0.72$		
	$\{C11, C12\} = 0.74$		
Safety and reliability ($\lambda = 0.14$)			
$C5 = 0.60$	$\{C5, C6\} = 1$		
$C6 = 0.37$			
On-board service ($\lambda = -0.72$)			
$C1 = 0.60$	$\{C1, C2\} = 0.84$	$\{C1, C2, C3\} = 1$	
$C2 = 0.43$	$\{C1, C3\} = 0.83$		
$C3 = 0.40$	$\{C2, C3\} = 0.71$		

Table 3
Common-factor's combining assessment value from partitioning fuzzy integral

Alternative	Employees' service	Safety and reliability	On-board service	Schedule	On-time performance	FFP
	$W_1 = 0.21$	$W_2 = 0.32$	$W_3 = 0.13$	$W_4 = 0.12$	$W_5 = 0.13$	$W_6 = 0.09$
A1	7.52	6.58	6.56	7.09	7.19	6.53
A2	7.77	7.96	7.01	7.00	7.11	6.70
A3	7.88	7.64	6.63	7.64	7.25	7.21
A4	8.42	7.44	7.46	7.33	7.87	7.57
A5	7.73	8.17	6.81	7.65	7.87	7.09
A6	8.71	8.28	7.41	8.37	8.70	7.67

Table 4
Comparison between non-additive and additive results

	A1	A2	A3	A4	A5	A6
Additive						
SAW	6.83(6)	7.56(4)	7.40(5)	7.65(3)	7.67(2)	8.26(1)
Grey relation	0.44(6)	0.47(4)	0.46(5)	0.49(2)	0.49(2)	0.53(1)
Non-additive						
SAW	6.91(6)	7.45(5)	7.47(4)	7.71(2)	7.70(3)	8.27(1)
Grey relation	0.46(6)	0.50(5)	0.51(4)	0.53(2)	0.52(3)	0.59(1)

both upgrade and move to the leading position. In the competitive group, the strength of A2 is on safety and reliability and of A3 is on employee's service. It seems that FFP of A2 is, however, not recognized by its customers. The results also show that airlines A5 and A6 performance in terms of perceptions of safety and reliability was better than the other airlines possibly because of the generically good safety record of North American.

Table 4 shows the results of the conventional additive model that assumes all the attributes are mutually independent; technically the same as when $\lambda = 0$ in the fuzzy analysis. The rank of airlines for the additive model is $A6 \succ A5 \succ A4 \succ A2 \succ A3 \succ A1$ with the ordering of A2, A3, A4, and A5 changed mainly because of the substitution effects between employees' and on-board service, and multiplicative effects involving safety and reliability. It is worth mentioning that while A2 is better than A3 in the conventional additive model, when, using the non-additive model, A3 is superior to A2. The same situation emerges for the very competitive group.

6. Conclusions

Airline service quality is based largely on customers' perceptions of what services should be and how they should be delivered. The indications here are that safety records can exert a significant effect on customers' perceptions although they are still sensitive to the airline employees' attitudes. Comfort and the cleanness of seats are also essential elements of on-board service. The results of the non-additive model suggests that it may be a more effective method for looking at these issues because it considers synthetic performance. It helps airlines identify their competitive advantages relative to other competitors.

References

Chang, Y.H., Yeh, C.H., 2002. A survey analysis of service quality for domestic airlines. European Journal of Operational Research 139, 166–177.

Chen, F.Y., Chang, Y.H., 2005. Examining airline service quality from a process perspective. Journal of Air Transport Management 11, 79–87.

Cunningham, L.F., Young, C.E., Lee, M., 2002. Cross-cultural perspectives of service quality and risk in air transportation. Journal of Air Transportation 7, 3–14.

Deng, J., 1982. Control problems of Grey systems. Systems and Control Letters 5, 288–294.

Deng, J., 1989. Introduction to Grey system theory. The Journal of Grey Systems 1, 1–24.

Gilbert, D., Wong, K.C., 2003. Passenger expectations and airline services: a Hong Kong-based study. Tourism Management 24, 519–532.

Gronroos, C., 1990. Service management and marketing: managing the moments of truth in service competition. Free Press, Lexington books, Lexington, MA.

Gronroos, C., 1993. Quality comes to service. In: Scheuing, E.E., Christopher, W.F. (Eds.), The service handbook. AMACOM, New York, pp. 17–24.

Guo, H., 1985. Identification coefficient of relational grade of Grey systems. The Journal of Fuzzy Mathematics 3, 55–58.

Gursoy, D., Chen, M.H., Kim, H.Y., 2005. The US airlines relative positioning based on attributes of service quality. Tourism Management 26, 57–67.

Ishii, K., Sugeno, M., 1985. A model of human evaluation process using fuzzy measure. International Journal of Man–Machine Studies 22, 19–38.

Jones, T.O., Sasser, W.E., 1995. Why satisfied customers defect. Harvard Business Review 73, 88–99.

Lam, T., Zhang, H.Q., 1999. Service quality of travel agents: the case of travel agents in Hong Kong. Tourism Management 20, 341–349.

Mazanec, J.A., 1995. Positioning analysis with self-organization maps: an exploratory study on luxury hotels. The Cornell Hotel and Restaurant Administration Quarterly 31, 84–91.

Morash, E.A., Ozment, J., 1994. Toward management of transportation service quality. Logistics and Transportation Review 30, 115–140.

Parasuraman, A., Zeithaml, V.A., Berry, L.L., 1985. A conceptual model of service quality and its implications for future research. Journal of Marketing 49, 41–50.

Parasuraman, A., Berry, L.L., Zeithamal, V.A., 1993. More on improving service quality measurement. Journal of Retailing 69, 140–147.

Park, J.W., Robertson, R., Wu, C.L., 2004. The effect of airline service quality on passengers' behavioral intentions: a Korean case study. Journal of Air Transport Management 10, 435–439.

Saaty, T., 1977. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15, 234–281.

Saaty, T., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

Shi, K., 1990. Grey Relation Theory and Its Applications. ISUMA90.

Sugeno, M., 1974. Theory of fuzzy integral and its applications. Ph.D. Dissertation, Tokyo Institute of Technology.

Sugeno, M., Kwon, S.H., 1995. A clusterwise regression type model for subjective evaluation. Journal of Japan Society for Fuzzy Theory and Systems 7, 291–310.

Suzuki, Y., Tyworth, J.E., Novack, R.A., 2001. Airline market shear and customer service quality: a reference-dependent model. Transportation Research A 35, 773–788.

Tsaur, S.H., Chang, T.Y., Yeh, C.H., 2002. The evaluation of airline service quality by fuzzy MCDM. Tourism Management 23, 107–115.

Tzeng, G.H., Chang, J.R., Lin, J.D., Hung, C.T., 2002. Non-additive Grey relation model for the evaluation of flexible pavement condition. International Journal of Fuzzy Systems 4, 715–724.