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Finding critical criteria of evaluating electronic service quality of Internet banking using fuzzy multiple-criteria decision making

Yi-Chung Hu*, Pen-Che Liao

Department of Business Administration, Chung Yuan Christian University, Chung-Li 32023, Taiwan, ROC

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A B S T R A C T

Internet banking provides users diverse financial service through the Internet. Under the environment of drastic competition, in order to make customers proceed with transactions on the web site, Internet banking not only should provide complete functions of operations but also advance their electronic service quality. The electronic service quality evaluation for Internet banking can be treated as a multiple-criteria decision making (MCDM) problem. As for evaluating the electronic service quality, since the traditional Likert scale cannot deal with uncertain assessments according to human intuition for the service quality evaluation, fuzzy numbers are employed to measure decision-makers' subjective preferences. This paper treats the given hierarchical network with the fuzzy MCDM as a feed-forward neural network and aims to develop a genetic-algorithm-based method to automatically determine degrees of importance of respective criteria. Then, critical criteria for evaluating service quality can be easily identified. In the empirical study, five domestic banks belonging to financial holding companies in Taiwan are selected to find critical criteria. The findings provide useful information to Internet banks for improving the electronic service quality.

1. Introduction

With the rapid growth of electronic commerce, Internet banking provides efficient channels for delivering innovative financial services for each bank [13]. Customers can receive financial services and perform transactions on the Internet through the web site of a bank during off-office hours and from anywhere where Internet access is available. In Taiwan, the Citibank first established its Internet banking in 1995. Subsequently, since the Ministry of Finance of Taiwan announced the code of conduct of network banking for opening the establishment of Internet banking on 1999, other banks in Taiwan have begun investing in Internet banking to significantly strengthen competitiveness and growth. Facing the environment of drastic competition, it would be beneficial for a business to make customers proceed with transactions on the web site. It is known that service quality has played an important role for decision making [23,24], especially in the electronic commerce [25], and the improvement of service quality can enhance customer satisfaction, loyalty, and retention [20]. In order to enhance the capability of competition, Internet banking services should realize which criteria are determinants for evaluating electronic service quality, and then advances the performance on these critical criteria.

Additionally, since electronic service quality evaluation can be treated as a multiple-criteria decision making (MCDM) problem, which can be modeled by a hierarchical structure consisting of an objective, diverse aspects and attributes, it is reasonable to describe this decision problem by an appropriate hierarchical network which can clearly demonstrate the relationship between different decision levels. When evaluating service quality through questionnaires, the traditional Likert scale has been the main way [3,22]. However, this scale cannot deal with the cognitive uncertainty among the linguistic values such as "disagree", "fair", and "disagree". Relative to the Likert scale, uncertain and imprecise data can be represented by fuzzy numbers in many practical circumstances [6].

By fuzzy MCDM, this paper aims to optimally determine the degrees of importance of respective criteria with respect to the evaluation of the service quality of Internet banking using the data of attributes' performance values and the overall evaluation of objective. The hierarchical network is the skeleton constructed by integrating the instrument developed by [18], aspects used to evaluate the service quality of web sites as well as the practical consideration. To deal with cognitive uncertainty, each respondent is asked to assign the fuzzy numbers to different natural representations, such as "fair" and "agree". Furthermore, respondents evaluate subjectively Internet banking services they received through questionnaire. For this, a genetic-algorithm-based (GA-based) learning method is designed to determine automatically the degrees of

* Corresponding author. Tel.: +886 3 2655130.
E-mail address: ychu@cycu.edu.tw (Y.-C. Hu).

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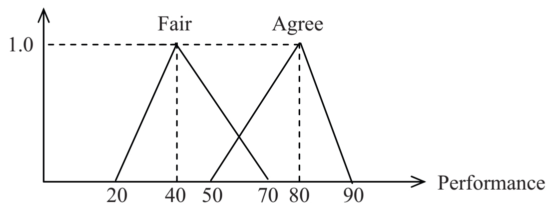

Fig. 1. Triangular fuzzy numbers.

importance by minimizing the squared error between the actual and desired outputs of individual patterns. Then, the critical criteria can be further identified by inspecting the relative importance.

In the given hierarchical network, the weighted average method (WAM) can be employed to derive the performance values of the objective and each aspect of Internet banking, since the WAM can yield extremely close approximations to "true" value functions [27] (i.e., synthetic evaluations). The hierarchical decision network, which is commonly not fully connected, is similar to a feed-forward neural network. In the implementation, each criterion in the hierarchical network can be treated as a neuron. Furthermore, the WAM serves as an activation function for each neuron.

The rest of this paper is organized as follows. The hierarchical network with fuzzy MCDM is presented in Section 2 in detail. Section 3 describes the proposed GA-based learning method to determine the degrees of importance of respective criteria. In Section 4, five domestic banks belonging to financial holding companies in Taiwan are selected to identify the critical criteria for evaluating the electronic service quality for Internet banking. From the findings, Internet banks can pay more attention on customer needs so as to strengthen competitiveness. This paper is concluded in Section 5.

2. Fuzzy-MCDM-based hierarchical decision

In this section, the characteristics of the fuzzy number for dealing with the cognitive uncertainty are described in Section 2.1. Section 2.2 demonstrates the way of deriving the performance values for the aspects and the objective by operating triangular fuzzy numbers.

2.1. Deal with cognitive uncertainty

The traditional 5-point Likert scale assumes that the differences between the successive categories are equal [19] and cannot deal with the cognitive uncertainty. For instance, the ratings of 1, 2, 3, 4 and 5 may be set to "strongly disagree", "disagree", "fair", "agree" and "strongly agree", respectively. In other words, "fair" is transformed to the same scale point for each respondent, although each respondent has her or his subjective thinking for different natural representations. However, the cognitive uncertainty among these natural representations of preference should be taken into account. In other words, it is reasonable for each respondent to subjectively express her or his own measurements for different natural representations.

A linguistic variable is a variable with linguistic words or sentences in a natural language [31]. The performance can be treated as a linguistic variable defined in the closed interval [0,100], whereas a set of the above-mentioned five linguistic values, {strongly disagree, disagree, fair, agree, strongly agree}, is called a term set, denoted by *T*(preference), with respect to the performance. Each linguistic value can be represented by the triangular fuzzy number, which is a fuzzy set in the universe of discourse that is both convex and normal [31]. As depicted in Fig. 1, instead of assigning a scale point to a linguistic value, "fair" and "agree" can be represented as triangular fuzzy numbers (20, 40, 70) and (50, 80, 90), respectively. It can be seen that two intervals of scale points (i.e., [20, 70], [50, 90]) have an intersection (i.e., [50, 70]). Furthermore, there exist scale points whose membership degrees in different linguistic values cannot be zero. For instance, the membership degrees of scale points in [50, 70] in both "dissatisfied" and "fair" are not zero. Each respondent can be asked to assign a triangular fuzzy number to each of the above linguistic values in the questionnaire.

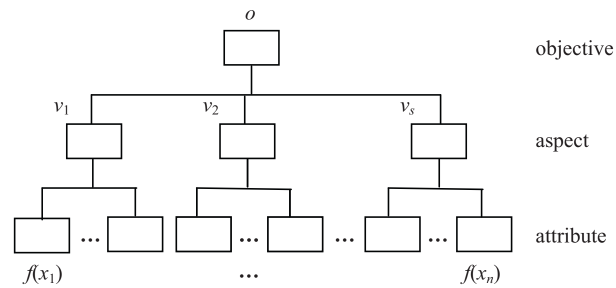

Fig. 2. A hierarchical network with notations of inputs and outputs.

2.2. Computing performance values

A hierarchical structure or network is usually employed to model a decision problem. In general, a hierarchical network decomposes from the top element (i.e., objective) to a more specific attribute until a level of manageable decision criteria is met. As depicted in Fig. 2, the hierarchical network is composed of three decision levels including the objective, the aspects, and the attributes. Furthermore, the objective and the *s* aspect nodes can perform the widely used WAM. It is possible that no attributes are beneath an aspect.

In Fig. 2, v_j $(1 \le j \le s)$ and o denote the performance values of the jth aspect and the objective, respectively. Let X denote a finite set of $\{x_1, x_2, \ldots, x_n\}$ and f be a nonnegative real-valued measurable function defined on X such that f: $X \to T$(preference). Here, $f(x_i)$ represents the observation or perceived value of attribute x_i $(1 \le i \le n)$. In practice, $f(x_i)$ is a triangular fuzzy number obtained by assigning a linguistic value (e.g., "satisfied") to x_i. Let (x_{il}, x_{ic}, x_{iu}) denote $f(x_i)$, where $0 \le x_{il} \le x_{ic} \le x_{iu} \le 100$. Then, v_j is defined as

$$\begin{aligned} v_j &= \sum_{i=1}^{n} w_{ij}^{(a)} f(x_i) \\ &= \sum_{i=1}^{n} (w_{ij}^{(a)} x_{il}, w_{ij}^{(a)} x_{ic}, w_{ij}^{(a)} x_{ir}) \\ &= \left(\sum_{i=1}^{n} w_{ij}^{(a)} x_{il}, \sum_{i=1}^{n} w_{ij}^{(a)} x_{ic}, \sum_{i=1}^{n} w_{ij}^{(a)} x_{iu} \right) \end{aligned} \quad (1)$$

where $w_{ij}^{(a)}$ denotes the degree of importance of x_i with respect to the jth aspect denoted by a_j $(1 \le j \le s)$, and

$$\sum_{i=1}^{n} w_{ij}^{(a)} = 1 \quad (2)$$

$w_{ij}^{(a)}$ is the local weight of x_i under a_j. If there is no connection between x_i and a_j, then $w_{ij}^{(a)}$ is specified as 0 so as to express that x_i is not taken into account for a_j. When $f(x_1), f(x_2), \ldots, f(x_n)$ with respect to an alternative are presented to the network, v_j's are obtained for respective aspects. Let (v_{jl}, v_{jc}, v_{ju}) denote v_j, the synthetic performance value (i.e., o) can be obtained via v_j's as follows:

$$o = \sum_{j=1}^{s} w_j^{(o)} v_j = \left(\sum_{i=1}^{n} w_j^{(o)} v_{jl}, \sum_{i=1}^{n} w_j^{(o)} v_{jc}, \sum_{i=1}^{n} w_j^{(o)} v_{ju} \right) \tag{3}$$

where $w_j^{(o)}$ denotes the degree of importance of v_j with respect to the objective, and

$$\sum_{i=1}^{n} w_j^{(o)} = 1 \tag{4}$$

It is obvious that v_j and the actual output o are triangular fuzzy numbers. The global weight of x_i, denoted by w_i^g, for the objective is computed as

$$w_i^g = \frac{w_j^{(o)} w_{ij}^{(a)}}{\sum_{j=1}^{s} \sum_{i=1}^{n} w_j^{(o)} w_{ij}^{(a)}} \tag{5}$$

Then, the sum of the global weights of all attributes is equal to 1.

$$\sum_{i=1}^{n} w_i^g = 1 \tag{6}$$

To measure the system performance, o can be converted to a non-fuzzy value using the defuzzification, which can convert a fuzzy number into a crisp real number. Defuzzification is to locate the best non-fuzzy performance (BNP) value. Let (o_l, o_c, o_u) denote v_j, the widely used center-of-area (COA) [11] is employed to convert o into the corresponding BNP value, BNP_o:

$$\mathrm{BNP}_o = \frac{(o_u - o_l) + (o_c - o_l)}{3} + o_l \tag{7}$$

From the viewpoint of the feed-forward neural network, the layer consisting of aspects can be treated as the hidden layer. $w_{ij}^{(a)}$ is the connection weight in the link between the ith input (i.e., x_i) and the jth hidden ((i.e., a_j) neurons, and $w_j^{(o)}$ is the connection weight in the link between the jth hidden and the output neurons.

3. Genetic-algorithm-based learning method

This section demonstrates the genetic-algorithm-based method for determining degrees of importance of respective aspects and attributes. Data for training the hierarchical network are described in Section 3.1. Section 3.2 demonstrates the formulation of optimization problems. The coding scheme and genetic operations are described in detail in Section 3.3. Finally, the proposed GA-based learning method for determining connection weights in the given hierarchical network is presented.

3.1. Data description

In the implementation, the performance values of individual attributes and the overall evaluation for an Internet bank can be subjectively assigned by m users. Thus, m fuzzy input-output patterns can be employed to find the unknown values of $w_{ij}^{(a)}$ and $w_j^{(o)}$ parameters. The questionnaire data from m users for an Internet bank are reorganized as follows:

Attribute				Overall evaluation
x_1	x_2	...	x_n	
f_{11}	f_{12}	...	f_{1n}	d_1
f_{21}	f_{22}	...	f_{2n}	d_2
...	...	...	...	...
f_{m1}	f_{m2}	...	f_{mn}	d_m

where f_{ij} and d_i denote the fuzzy performance value of x_j and the corresponding overall evaluation, respectively, given by the ith respondent. f_{ij} is a fuzzy number and is relative to the measurable function $f^{(i)}$ $(1 \le i \le m)$.

$$f^{(i)}(x_j) = f_{ij} \tag{8}$$

d_i can be regarded as the desired output for the ith input-output pattern. The above data are employed to train the given hierarchical network. Then, the degrees of respective aspects and attributes can be obtained from the connection weights.

3.2. Problem formulation

Let S denote a set of parameters including the values of $w_{ij}^{(a)}$ and $w_j^{(o)}$ for the given hierarchical network. The problem of determining $w_{ij}^{(a)}$ and $w_j^{(o)}$ is formulated as the following single-objective optimization problem:

$$\text{Minimize}\, e(S) \tag{9}$$

where $e(S)$ is the root-mean-square error obtained by S. Assume that o_i is the actual output (i.e., a fuzzy number) corresponding to an n-dimensional non-fuzzy input vector $(f_{i1}, f_{i2}, \ldots, f_{in})$ for the given hierarchical network. Without loss of generality, $e(S)$ is defined as

$$e(S) = \sqrt{\frac{\sum_{i=1}^{m} (\mathrm{BNP}_{d_i} - \mathrm{BNP}_{o_i})^2}{m}} \tag{10}$$

where BNP_{d_i} and BNP_{o_i} denote the defuzzified values of d_i and o_i, respectively. The single-objective GA, which is a general-purpose optimization technique, can be applied to this problem by formulating the fitness function as

$$f(S) = \frac{1}{1 + e(S)} \tag{11}$$

where $f(S)$ is the fitness value of S. The fitness value of a set of connection weights is updated at each generation for the GA. Thus, the aim of the GA is to find a set of parameters S by minimizing the root-mean-square error.

3.3. Genetic operations

Let N_{pop} and N_{con} denote the population size and the total number of generations, respectively. Each parameter is coded as a binary string. In an initial population, a population containing N_{pop} strings is generated, and each bit in the string is randomly assigned as either 1 or 0, with the probability of 0.5. When the fitness of each chromosome in the current population is obtained, the genetic operators including selection, crossover and mutation [4,14,16] are employed to determine the newly generated N_{pop} strings in the next population.

In order to generate new strings in the next population, the tournament selection is taken into account. Two strings are randomly selected from the current population, and the one with the maximum fitness can be placed on the mating pool. This process can be repeated N_{pop} times until there are N_{pop} strings in the mating pool. In other words, $1/2N_{pop}$ pairs of chromosomes can be randomly selected from the current population.

Subsequently, crossover and mutation are applied to a selected parent to reproduce children by altering the chromosomal makeup of two parents. In practice, the one-point crossover operation with the crossover probability Pr_c is used for exchanging partial information between two substrings in the selected pair of strings, and two newly generated strings are generated to replace their parent strings. That is, each crossover point in a substring is chosen randomly. The mutation operation with the mutation probability Pr_m is performed on each bit of strings generated by the crossover operation.

3.4. Algorithm implementation

The aim of GA-based learning method is to determine connection weights for a given hierarchical network by minimizing the root-mean-square error. The proposed algorithm is written in the following:

Algorithm: A hierarchical decision network learning algorithm
Input: a. A hierarchical network for a decision problem;
b. Population size: N_{pop};
c. Total number of generations: N_{con};
d. Number of elite chromosomes: N_{del};
e. Crossover rate: Pr_c;
f. Mutation rate: Pr_m;
g. A set of training patterns.
Output: A trained hierarchical decision network
Method
Step 1. Initialization
Generate N_{pop} binary strings for the initial generation at random. Set 0 to t.
Step 2. Compute fitness values
Compute the fitness value of each string in the current population.
Step 3. Termination test
The total number of generations is used as the stopping condition. If the stopping condition is not satisfied, then continue to the next step. That is, the genetic operations are iterated again to generate the new strings in the next population.
Step 4. Generate new strings
Generate N_{pop} new strings from the current population using selection, crossover and mutation.
Step 5. Perform elitist strategy
N_{del} strings are randomly removed from the newly generated N_{pop} strings. Then, add N_{del} best strings in the current population to form the next one. Set $(t+1)$ to t and go to Step 2.

4. Empirical study

4.1. Survey

From 2001, the financial holding companies, combining the bank, the stock and the assurance, in Taiwan have been established in response to the global financial trend and in support of government's fiscal reform policy, with the aims to achieve the economy of scale, advance credit rating, optimize operating synergy and strengthen business competitiveness in the world. To increase the market share, each financial holding company in Taiwan has paid more attention to Internet banking services. In view of the development trend of the financial holding in Taiwan, five domestic Internet banks belonging to financial holding companies are selected to identify the critical criteria for evaluating the electronic service quality of Internet banking. According to the report conducted by academics and professional institutions in Taiwan, these five financial holding companies has gained respectable rating in terms of financial performance, operational quality, capital adequacy and strategic performance (FOCAS) in 2007.

Five financial holding companies help us send out questionnaires to the customers who have used Internet banking services. In the end, 264 valid questionnaires are collected. The demographic statistics indicate that 93.19% are at their age of 20–35 and 91.67% received at least college education. The high ratio of age 20-35 indicates that the people of this age are the primary population of Internet access in Taiwan.

Table 1
Aspects for evaluating electronic service quality of Internet banking.

Aspect	Definition
Efficiency	The ease and speed of accessing and using the site
System availability	The correct technical functioning of the site
Responsiveness	Effective handling of problems and returns to customers
Compensation	Compensates customers for questionable transactions
Contact	The availability of assistance through telephone number or available channels
Tangibility	The site has neat pages and provide complete information and functions
Privacy	The site is safe and protects customer information
Reliability	The service promises and accuracy of information
Reputation	The physical bank is well-known and has good reputation
Continue improvement	Continue improvement on each service
Personalization	Provide customized services or satisfy customers' specific needs
Benefit	Attract customers to visit the site through available channels (e.g., e-mail, advertisement)

4.2. Constructing hierarchical network

The electronic service quality can be defined as the extent to which a web site facilitates efficient and effective shopping, purchasing and delivery [28,29]. Previously, Parasuraman et al. [17] proposed five aspects, including tangibility, reliability, responsiveness, assurance and empathy, in the SERVQUAL instrument for evaluating service quality for the banks and the stockbrokers. The SERVQUAL instrument could not be directly employed to evaluate the electronic service quality [12].

Previously, Parasuraman et al. [18] developed the e-core service quality scale (E-S-QUAL) and the e-recovery service quality scale (E-RecS-QUAL) for measuring the electronic service quality. The former scale includes efficiency, system availability, fulfillment, and privacy, while the latter scale includes responsiveness, compensation, and contact. Both scales demonstrate good psychometric properties based on findings according to findings from a variety of reliability and validity tests [18]. Jun and Cai [7] identified 17 dimensions of evaluating the service quality for Internet banking, which can be classified into three broad categories: customer service quality, banking service product quality, and online systems quality. Since the aspects developed by [18] are relatively complete for evaluating electronic service quality and useful for this study, the hierarchical network for evaluating electronic service quality of Internet banking is mainly constructed according to an integration of the scales developed by [18].

The fulfillment dimension of the E-S-QUAL is defined as "the extent to which the site's promises of order delivery and item availability are fulfilled" the fulfillment is crucial for evaluating the service quality of online retailers [9]. Relative to online retailers, the fulfillment is withdrawn because the fulfillment is not appropriate for evaluating the service quality of Internet banking. In addition to E-S-QUAL and E-RecS-QUAL, according to the characteristic of Internet banking, the other aspects developed by Jun and Cai [7] are also taken into account. These aspects include reliability and continuous improvement. Moreover, both tangibility [21] and personalization [26], which are used to evaluate the service quality of web sites, are considered to be appropriate. Meziane and Kasiran [15] also shown that, to increase consumers' trust towards an electronic commerce website, a website can be expected to provide personal information to them. We further consulted 3 bank managers in the above-mentioned financial holding companies to judge the appropriateness of evaluation aspects and the attributes under each aspect. As a result, in addition to the above ten aspects, reputation and benefit are suggested by these managers. The confirmative aspects and their definitions are as displayed in Table 1. It can be seen that, usefulness, ease of use, security, convenience and responsiveness which can significantly explain the variation in customer interactions with e-banking services [13] are incorporated into the hierarchy. The aspects and attributes established for the hierarchical network are summarized as follows:

Aspect	Attribute
Efficiency (c_1)	Fast access to the Internet bank (c_{11}), Link to other pages easily (c_{12}), Loading pages fast (c_{13}), Finding the needs easily (c_{14}), Simple procedure of application for services (c_{15}), Easy to use (c_{16}), Completing a transaction or an inquiry quickly(c_{17})
System availability (c_2)	System stability (c_{21}), Pages do not freeze during a transaction (c_{22}), The Internet bank is always available (c_{23})
Responsiveness (c_3)	Providing notification quickly when a transaction is completed (c_{31}), Solving customers' problems promptly (c_{32}), Courtesy (c_{33}), Emphasizing services for completed transactions (c_{34}), Providing notification and help promptly for an incomplete transaction (c_{35}), Repairing a breakdown on the web site quickly (c_{36})
Compensation (c_4)	
Contact (c_5)	
Tangibility (c_6)	Getting information available from each item (c_{61}), Clear and understandable information (c_{62}), Providing complete information (c_{63}), Updating news and information timely (c_{64}), Visually appealing (c_{65}), Complete searching functionalities on information (c_{66}), Providing functions on financial services (e.g., credit transfer) (c_{67}), Providing diverse financial products (e.g., assurance, loan, futures) (c_{68})
Privacy (c_7)	Safe transactions (c_{71}), Protecting customers' information (c_{72})
Reliability (c_8)	Providing accurate transaction data (c_{81}), Providing accurate financial information (c_{82}), Specialized bank personnel (c_{83})
Reputation (c_9)	Good reputation (c_{91}), Many customers have made good appraisal (c_{92})
Continuous improvement (c_{10})	System functions and operations (c_{101}), Attitude and capability for solving problems (c_{102}), Contents of financial goods (c_{103})
Personalization (c_{11})	
Benefit (c_{12})	

Since the decision hierarchy is carefully constructed by consulting experts, the questionnaire designed by such a decision hierarchy should have certain content validity. As for the reliability of the questionnaire, the Cronbach's alpha is usually served as a tool of measurement. To compute the Cronbach's alpha for each aspect, the fuzzy performance value of each attribute can be converted to a non-fuzzy value by the defuzzification mentioned above. The results are shown as follows:

Aspect	Cronbach alpha
Efficiency	0.921
System availability	0.856
Responsiveness	0.915
Tangibility	0.925
Privacy	0.799
Reliability	0.843
Reputation	0.842
Continuous improvement	0.906

The higher the Cronbach's alpha, the more stable the questionnaire. Usually, an acceptable value of the Cronbach's alpha is higher than 0.7 [2]. It is clear that the Cronbach's alpha for each aspect is higher than 0.7.

Table 2
Average degrees of importance of aspects and attributes.

Aspect	Attribute
Efficiency (0.138)	c_{11} (0.349), c_{12} (0.112), c_{13} (0.059), c_{14} (0.076), c_{15} (0.219), c_{16} (0.105), c_{17} (0.080)
System availability (0.034)	c_{21} (0.317), c_{22} (0.157), c_{23} (0.526)
Responsiveness (0.080)	c_{31} (0.144), c_{32} (0.188), c_{33} (0.288), c_{34} (0.033), c_{35} (0.091), c_{36} (0.256)
Compensation (0.001)	
Contact (0.105)	
Tangibility (0.129)	c_{61} (0.267), c_{62} (0.064), c_{63} (0.089), c_{64} (0.151), c_{65} (0.046), c_{66} (0.217), c_{67} (0.037), c_{68} (0.129)
Privacy (0.084)	c_{71} (0.576), c_{72} (0.424)
Reliability (0.136)	c_{81} (0.298), c_{82} (0.036), c_{83} (0.666)
Reputation (0.087)	c_{91} (0.145), c_{92} (0.855)
Continue improvement (0.130)	c_{101} (0.420), c_{102} (0.270), c_{103} (0.310)
Personalization (0.001)	
Benefit (0.075)	

$Pr_c = 0.95$ and $Pr_m = 0.01$: Since a Pr_c with a larger value allows the exploration of more of the solution space, a larger Pr_c is usually taken into account. Furthermore, in order not to generate excessive perturbation, Pr_m should be specified as a lower value.

4.3. Parameter specifications of GA

Although the performance of the GA could be influenced by different parameter specifications, there is no best set of parameter values. In practice, according to the principles introduced in [16], the pre-specified parameter specifications for our empirical study are described in the following:

a. $N_{pop} = 100$: The most common size of population varies from 50 to 500 individuals. Hence, 100 individuals is an acceptable population size. In an initial population, each bit in a binary string is randomly assigned as either one or zero, with the probability of 0.5.
b. $N_{con} = 2000$: The stopping condition is specified according to the available computing time. Moreover, a sufficient evolution of the GA is required.
c. $N_{del} = 2$: To avoid generating much perturbation in the next generation, a small number of elite chromosomes is taken into account.
d. Substring length set to 10: The required precision for each parameter has three decimal places.

4.4. Analyze degrees of importance

Each respondent is asked to assign the triangular fuzzy numbers to different linguistic values, including strongly disagree, disagree, fair, agree, and strongly agree. Furthermore, respondents rate the overall evaluation of Internet banking and the performances on individual attributes using the above 5-point scale. Since it is not possible for a respondent to visit all Internet banks before making the evaluation, the fuzzy input-output patterns corresponding to the evaluation of each Internet bank can be aggregated to a data set separately. As a result, two data sets have at least 100 input-output patterns, and the other data sets have 50–100 input-output patterns. Subsequently, using the proposed GA-based learning method, the degrees of importance of respective aspects and attributes are determined for each Internet bank by the corresponding data set. Then, each of the aspects and attributes has five different degrees of importance because five financial holding companies are taken into account.

The average degrees of importance of respective aspects are shown in Table 2. The local weights on an average of individual attributes under the corresponding aspects are also shown. It can

Table 3
Average global weights of attributes.

Aspect	Attribute
Efficiency (0.138)	c_{11} (0.059), c_{12} (0.018), c_{13} (0.010), c_{14} (0.012), c_{15} (0.037), c_{16} (0.017), c_{17} (0.013)
System availability (0.034)	c_{21} (0.013), c_{22} (0.006), c_{23} (0.022)
Responsiveness (0.080)	c_{31} (0.015), c_{32} (0.018), c_{33} (0.028), c_{34} (0.004), c_{35} (0.009), c_{36} (0.025)
Compensation (0.001)	
Contact (0.105)	
Tangibility (0.129)	c_{61} (0.042), c_{62} (0.010), c_{63} (0.013), c_{64} (0.023), c_{65} (0.007), c_{66} (0.034), c_{67} (0.006), c_{68} (0.021)
Privacy (0.084)	c_{71} (0.059), c_{72} (0.044)
Reliability (0.136)	c_{81} (0.050), c_{82} (0.006), c_{83} (0.112)
Reputation (0.087)	c_{91} (0.016), c_{92} (0.091)
Continue improvement (0.130)	c_{101} (0.067), c_{102} (0.043), c_{103} (0.049)
Personalization (0.001)	
Benefit (0.075)	

be seen that the more concerned aspects are efficiency, reliability, continuous improvement and tangibility. These indicate in general that customers emphasize the speed of accessing the web site and that the web site is simple to use. Furthermore, it is necessary for Internet banking to provide complete and accurate information. Chu [1] and Zickefoose [30] also indicated the importance of the quality of information on the websites. Moreover, customers could not be interested in Internet banking services that are not updated or remain unchanged. Thus, innovation on Internet banking can be an important issue of concern to the financial holding companies. Besides, customers are concerned on whether Internet banks provide available contact channels or not. Internet banks should pay more attention to these four aspects to enhance the overall performance.

It seems that customers have relatively less concern on compensation and personalization. It is presumed that since Internet banks usually follow common performance bonds, customers do not treat compensation as a troublesome problem. In addition, it is interesting that personalization is not of concern to customers. It is presumed that customers feel that current services, such as personal account statement, credit transfer, search for data (e.g., stock, futures) and applications for services (e.g., electronic bill), are enough for dealing with personal finance. However, individual customers need different types of information and use different types of data processing while making a purchasing decision [9,10]. In order to achieve personal Internet banking, the Internet banks should provide more useful information to a customer by analyzing the customers' behaviors on the web site. For instance, Internet banking should actively recommend other financial information or financial products when a customer read one piece of financial information or purchase one financial product. Furthermore, according to the routes of visiting web pages, Internet banking may design customized web pages to facilitate the search for data for valuable customers. It is considered that data mining techniques should be incorporated into Internet banking services, since the use of such techniques can be helpful for finding very important and potentially useful information or knowledge from databases [5].

To concretely improve the electronic service quality, it is necessary to identify critical attributes by determining the global weights of individual attributes. As shown in Table 3, the degrees of importance of attributes can be comparable with each other by computing the global weights of respective attributes. It can be seen that the attribute of the greatest concern to customers is specialized bank personnel (i.e., c_{83}). Customers are also attentive to appraisal for the Internet bank (i.e., c_{92}), continuous improvement on system functions and operations (i.e., c_{101}), fast access to the Internet bank (i.e., c_{11}), and safe transactions (i.e., c_{71}). Apparently, customers need professional service. It is noteworthy that public praise distinctly affects the overall evaluation of electronic service quality.

The finding indicates that Internet banking services on system functions and operations that remain unchanged could not be acceptable. In other words, Internet banking should keep improving searching functions and functions on financial services. Besides, customers could not bear that it takes a long time to access the web site. Zickefoose [30] pointed out that the speed of a web site is one of the fundamental factors of a successful web site. The result on safe transactions indicates that, even though Internet banks claim that they can provide completely safe mechanisms, such as SSL, for transactions, customers still concern whether a transaction is truly safe or not.

5. Discussion and conclusion

In order to strengthen competitiveness, Internet banking should pay more attention to the improvement of electronic service quality. Although the traditional Likert scale has been the main way for evaluating service quality, the Likert scale cannot deal with cognitive uncertainty arising from human thinking and perception process. Thus, this paper employs fuzzy numbers to represent uncertain performances of overall evaluation and individual attributes for an Internet bank.

Through questionnaire, each respondent can be asked to give the following data: (1) a triangular fuzzy number corresponding to each of the linguistic values; (2) the performance values of individual attributes and the overall evaluation for Internet banks which he or she visited before. Then, for each Internet bank, degrees of importance of respective aspects and attributes under the corresponding aspect can be automatically determined by the proposed genetic-algorithm-based learning method. The learning method is performed for the given hierarchical decision network. In the empirical study, five domestic Internet banks of financial holding companies with respectable FOCAS on 2007 in Taiwan are selected. The average degrees of importance of respective aspects and attributes are reported.

From the empirical results, it can be seen that, in comparison with the other aspects, those of greater concern to customers are efficiency, reliability, continuous improvement and tangibility. The degrees of importance of respective aspects provide a general view of evaluating the electronic service quality. The analytic result with respect to reliability and tangibility indicates that providing useful, relevant and accurate financial information directly on the Internet banks is important. Kaynama and Black [8] also shown that a potential customer must depend on the site's reputation to verify the accuracy of the information provided.

The global contribution from attributes towards the objective can be expressed by the global weights of individual attributes. Furthermore, the degrees of importance of attributes can be comparable with each other by computing the global weights of respective attributes. It can be seen that the attribute of the greatest concern is specialized bank personnel. Customers are also concerned about good appraisal for the Internet bank, continuous improvement on system functions and operations, fast access to the Internet bank, and safe transactions. The performances of these top five evaluation attributes can significantly affect that of the overall evaluation of an Internet bank. Thus, through the relative importance of the aspects and the attributes determined by the proposed fuzzy MCDM method, we can point out the feasible direction of improving the electronic service quality to the Internet banks. Although the critical criteria are derived from the subject perception for the electronic service quality provided by the Internet banks in Taiwan, we think that the findings can help the other Internet-only banks and traditional banks offering Internet banking service to improve their electronic service quality.

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