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Ranking of Service Quality using Intuitionistic Fuzzy Weighted Entropy: A Case of Vehicle Insurance Companies

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Abstract - The importance of service quality ranking is apparent with increasingly demand to meet customer needs in highly competitive service related industry. However, service quality ranking is not always straightforward as the criteria in ranking processes and customer perceptions toward services are intangible measures. This paper presents a ranking for service quality of four vehicle insurance companies using intuitionistic fuzzy weighted entropy. The intuitionistic fuzzy weighted entropy is useful to represent the decision information in the process of decision making since it was characterized by degrees of membership, degrees of non-membership and hesitation degrees. The crisp survey results were collected via questionnaires from customers of the selected vehicle insurance companies and analysed using the intuitionistic fuzzy weight entropy. It is found that BS Insurance is the first in ranking thereby the best company in service quality out of the four companies. These ranking results would be useful for insurance companies in upgrading their service quality and eventually able to fulfil customers' needs.

Keywords - Intuitionistic fuzzy sets; intuitionistic fuzzy weight averaging operator; intuitionistic fuzzy weighted entropy; service quality.

1. Introduction

In marketing theory, service quality and customers' satisfaction are two different concepts since gaps are always exist between customers' expectation and services they perceived. Customers' satisfaction is commonly influenced by the quality of interpersonal communication between the customers and the service providers. Many researchers emphasized that the four most important service quality characteristics are assurance, empathy, reliability and responsiveness. Assurance is usually related to trustworthy, knowledgeable and competent to solve customers' problem. Empathy refers to caring, attention and well communication with customers when providing services. Reliability is frequently described as the ability of service provider to fulfil promises in a timely manner and provide guarantee for the services performed. Responsiveness is defined by Johnston [1] as the willingness of service providers to offer service quickly and accurately. More efforts have been made by service providers to emphasise on these four important characteristics in delivering services. They believe that customers' perception will be enhanced and eventually increase customers' satisfaction.

The service sector, or known as tertiary sector, plays vital role in Malaysia's economy. One of the markets in service sector is vehicle insurance market. Nowadays, the insurance market has intense competition in maintaining leading positions while supporting economic and social development. Hence, a well understanding of business performance for insurance companies is vital in order to maintain their market position and improvement. In other words, the quality of services offered by vehicle insurance companies may impact on the earned profit. Most of the customers are lack of latest information and new services from companies while they are expecting to get the best insure policy. Thus, customers do need professional guidance and suggestions about insurance from service providers such as the sum insured and the amount of claimable insurance if they involved in an accident. Meanwhile, customers are preferred to focus on companies which provide more benefits and better insurance policies instead of comparing them through the quotations.

Many scholars are keen on measuring service quality by developing various methods in order to improve the service quality and strengthen customers' loyalty. One of the widely used instruments in measuring service quality is SERVQUAL model which proposed by Parasuraman et *al.* [2] in 1985. The dimensions surveyed are tangibility, reliability, responsiveness, assurance and empathy. In 2008, Ahmad and Sungip [3] carried out an assessment on service quality in Malaysia insurance industry using SERVQUAL measure. They found that reliability has the highest gap between customers' perception and expectation. Besides, there is a study conducted by Tsai et *al.* [4] examined the performance of property-liability insurance companies in Taiwan by combining Analytic Network Process (ANP) and TOPSIS concepts. The study used Modified Delphi Method to examine the influence of property-liability insurance on out norms and then the evaluation weights are determined by ANP. Although researchers have dedicated a lot of attentions to service quality using different methods, there are still lacks of application of intuitionistic fuzzy set in measuring service quality.

Intuitionistic fuzzy set (IFS) is a tool used in solving the uncertainty and fuzziness in multiple criteria decision making with the membership and non-membership functions. Applications of IFS have been carried out in many different fields such like medical diagnosis, pattern recognition, drug selection and microelectronic fault

analysis. Throughout recent years, many researchers have shown more and more interest in IFS theory and its application in decision making. Chen [5] conducted a comparative study of score functions in multiple criteria decision analysis based on intuitionistic fuzzy sets. The relationship between the results yielded by different score functions was examined by the average Spearman correlation coefficients and contradiction rates.

Likewise, Vlachos and Sergiadis [6] performed the concepts of discrimination information and cross-entropy in the intuitionistic fuzzy setting and the De Luca-Termini entropy is obtained for IFS. Xu [7], Xu and Yager [8] found some aggregation operators such as the intuitionistic fuzzy weighted operator and intuitionistic fuzzy geometric operator to aggregate intuitionistic fuzzy information. Besides, the axiomatic requirements of intuitionistic fuzzy entropy measure have been identified by Szmidt and Kacprzyk [9] and they suggested a non-probabilistic-type entropy measure for IFS based on the ratio of intuitionistic fuzzy cardinalities.

The objective of this study is to measure the service quality of vehicle insurance companies by using intuitionistic fuzzy entropy measure, De Luca-Termini entropy. In addition, we also rank all the performance of vehicle insurance companies according to score values by applying intuitionistic fuzzy weighted averaging operator. The result of a numerical example is then presented. Furthermore, the recommendations for future research are discussed in conclusions.

2. Preliminaries

Intuitionistic fuzzy sets was first introduced by Atanassov [10, 11] and it give a measure of non-membership and membership of the set, with the sum of the measures less than or equal to one. Let X be an ordinary finite non-empty set. An IFS A in a universe X is defined as the following:

$$\mathrm{A} = \{x, \mu(x), \gamma(x) : x \in X\} \tag{1}$$

where $\mu : X \to [0,1]$ and $\gamma : X \to [0,1]$ such that $0 \le \mu(x) + \gamma(x) \le 1$ for all $x \in X$. The numbers of $\mu(x)$ and $\gamma(x)$ denote the membership degree and non-membership degree of the element x in A respectively. For every IFS A $\in$ X, the value of

$$\pi(x) = 1 - \mu(x) - \gamma(x) \tag{2}$$

represents the consistency degree or called as the intuitionistic fuzzy index of the element x in the IFS A where $\mu(x) + \gamma(x) < 1$ and $0 \le \pi(x) \le 1$ for all x. As stated by Hersh [12], it is generally appropriate to calculate the consistency, $\pi(x)$ first before the value of $\mu(x)$ and $\gamma(x)$. It will be easier if information on the consistency is first expressed as linguistic variable and then convert the linguistic value to numerical value for $\pi(x)$, using the scale in Table 1 which shows that a high degree of consistency corresponds to a low value of $\pi(x)$.

Table 1. Membership grades for consistency degree.

Consistency	$\pi(x)$
No or very low consistency	0.8 – 1
Low consistency	0.6 – 0.8
Moderate consistency	0.4 – 0.6
High consistency	0.2 – 0.4
Very high or total consistency	0 – 0.2

According to Chen and Tan [13], the score function s of x is defined as

$$s(x) = \mu(x) - \gamma(x) \tag{3}$$

where $s(x) \in [-1,1]$. The IFS A becomes greater when the value of $\mu(x)$ become bigger and $\gamma(x)$ gets smaller which impacts on the deviation between $\mu(x)$ and $\gamma(x)$ gets greater. An accuracy function h defined by Hong and Choi [14] to estimate the degree of accuracy of the intuitionistic fuzzy value as

$$h(x) = \mu(x) + \gamma(x) \tag{4}$$

where $h(x) \in [0,1]$. The higher degree of accuracy of the degree of membership of the IFS A then it will resulted in the bigger value of $h(x)$. Let $a_1 = (\mu_1, \gamma_1), a_2 = (\mu_2, \gamma_2)$ be two intuitionistic fuzzy values. Thus,

i. if $s(a_1) < s(a_2)$, then $a_1 < a_2$;

ii. if $s(a_1) = s(a_2)$, then :

if $h(a_1) < h(a_2)$, then $a_1 < a_2$; and

if $h(a_1) = h(a_2)$, then $a_1 = a_2$.

Wu and Zhang [15] stated that the intuitionistic fuzzy weighted averaging operator is defined as

$$IFWA_{\omega}(a_1, a_2, .., a_n) = (1 - \prod_{i=1}^{n} (1 - \mu_i)^{\omega_i}, \prod_{i=1}^{n} \gamma_i^{\omega_i}) \tag{5}$$

when a_i is a collection of intuitionistic fuzzy values where ω_i is the weight of a_i, $\omega_i \in [0,1]$ and the sum of weights is equal to one. Let $L = \{(\alpha, \beta) : \alpha, \beta \in [0,1], \alpha + \beta \le 1\}$ be the set of all intuitionistic fuzzy values, and ε be a real-valued function $\varepsilon : L \to [0,1]$ then functional

$$E(A) = \frac{1}{n} \sum_{i=1}^{n} \varepsilon(a_i) \tag{6}$$

is an entropy measure for IFS. A measure of fuzziness often used and cited in the literature is the entropy first mentioned by Zadeh [16].

Let ε be a function defined on L with range [0,1] and we get

$$\varepsilon(a_i) = \pi_i - (\ln 2)^{-1} \bullet \left[\mu_i \ln\left(\frac{\mu_i}{(\mu_i + \gamma_i)} \right) + \gamma_i \ln\left(\frac{\gamma_i}{(\mu_i + \gamma_i)} \right) \right] \tag{7}$$

The entropy measure is used to describe the degree of fuzziness and intuitionism. The larger value of entropy will be resulted in the higher hesitancy in the judgement of decision maker.

3. Related research

In customer oriented business, service quality is one of the most important elements in evaluation of organizational performance. Service quality has several

definitions depending on different market segments. It is generally first defined by Lewis and Booms [17] as it is a measure of how well a delivered service matches the customers' expectations. However, Gronroos [18] stated that customer perceived service quality is the difference between customer expected service quality and the service quality they experienced. Customers will not satisfy when their perceptions are higher than the services perceived although the service providers understand the needs of customers. Clearly, one's experience of a service does impact on the assessment of its quality. Thus, it is necessary to listen to customers and respond to their complaints or comments in order to improve the service quality.

Grove et *al.* [19] described that viewing services as theatre is a theoretical outline in the services literature by many scholars. In their major study, they demonstrated the theatrical aspects of front stage service workers and they believed Stanislavsky's system of actor development gives significant changes for training service personnel. They claimed that successful performance is depends on carrying out one's role with credibility and proficiency. A survey conducted by Firdaus [20] examined the relative efficiency of three measuring instruments of service quality namely Higher Education Performance (HEdPERF), service performance (SERVPERF) and the moderating scale of HEdPERF-SERVPERF. He identified the strength and weakness of each instrument in terms of unidimensionally, reliability, validity and explained the variance of service quality. He concluded that the modified HEdPERF scale is the best in higher education service settings. He also suggested that the dimension access is the most important determinant of service quality in higher education.

Chang and Yeh [21] conducted a survey analysis of service quality for domestic airlines using fuzzy multi criteria analysis to formulate the evaluation problem. Their study helped airlines to understand better customers views related to airline competitors and the evaluation of their service quality. Toloie et *al.* [22] assessed quality of insurance companies using multiple criteria decision making which utilizing analytic hierarchy process (AHP) in gaining weights of criteria and TOPSIS in ranking the results. Pair wise comparison is used in the AHP method and they found out the company at the first ranking has less market share than the second ranked company. This means that larger market share does not equivalent to better service quality which satisfy customers' perception.

4. Case study of insurance services quality

The evaluation of service quality normally involves a set of n alternatives, A_i (i = 1, 2,…, n). The alternatives in this case are several vehicle insurance companies. The quality of services provided by these alternatives are evaluated by their customers which represented by a set of m criteria C_j (j= 1, 2,…, m). A modified survey questionnaire from Toloie et *al.* (2011) is used to estimate the quality levels of services perceived by customers. Four selected vehicle insurance companies are BS Insurance (A_1), LPC Insurance (A_2), KRN Insurance (A_3) and UAG Insurance (A_4). The indexes of the questionnaires consist of four evaluation criteria which are confidence (C_1), responsiveness (C_2), reliability (C_3) and tangibles (C_4). Table 2 shows the assessment criterion for vehicle insurance service quality.

Table 2. Assessment criterion for evaluate the vehicle insurance companies' service quality. (Source: Adapted from Toloie et al. [22])

Objective	Index
Confidence (C_1)	• Capability of staff in solving customers' problems. (C_{11}) • Appropriate services offers by staff.(C_{12}) • Good communication skills of staff.(C_{13}) • Enthusiasm of staff in correcting faults.(C_{14})
Responsiveness (C_2)	• Proper speed of responding and dealing with customers on peak hours.(C_{21}) • Offering latest information and new services to customers.(C_{22}) • Offering guidance and suggestions to customers according to their needs.(C_{23}) • Establishing easy links between customers and division directors.(C_{24})
Reliability (C_3)	• Professional knowledge to answer questions of customers.(C_{31}) • Trustworthy, confidant, and honest staff.(C_{32}) • Understandable and able to answer customers clearly.(C_{33})
Tangibles (C_4)	• Friendly environment to customers. (C_{41}) • Strategic signboard to guide customers.(C_{42}) • Convenient access to company branches.(C_{43}) • Simple and easy understanding of forms. (C_{44})

In order to rank the performance of vehicle insurance companies' service quality, the five steps of computations are proposed.

Step 1: Construct decision matrix.
The intuitionistic fuzzy values decision matrix of vehicle insurance companies is made up according to the four evaluating criteria (C_1, C_2, C_3, $C4$). Customers are invited to evaluate the services of four selected vehicle insurance companies. By integrating the preference value results of twenty customers to four selected vehicle insurance companies according to four evaluation criteria, the intuitionistic fuzzy decision matrix of alternatives is obtained as in Table 3.

Table 3. The intuitionistic fuzzy values decision matrix of selected vehicle insurance companies.

	A_1	A_2	A_3	A_4
C_1	(0.449,0.370)	(0.719,0.188)	(0.546,0.192)	(0.520,0.337)
C_2	(0.565,0.162)	(0.630,0.232)	(0.727,0.182)	(0.630,0.100)
C_3	(0.705,0.232)	(0.448,0.378)	(0.641,0.322)	(0.539,0.271)
C_4	(0.730,0.170)	(0.557,0.160)	(0.399,0.200)	(0.679,0.188)

Step 2: Construct the entropy measure of intuitionistic fuzzy values.

By using the equation (7), De Luca-Termini entropy of the intuitionistic fuzzy values is resulted in the decision matrix as below.

$$\mathrm{D} = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_4 \end{array} \\ \begin{bmatrix} 0.994 & 0.761 & 0.872 & 0.972 \\ 0.829 & 0.862 & 0.748 & 0.691 \\ 0.820 & 0.996 & 0.922 & 0.935 \\ 0.729 & 0.832 & 0.951 & 0.787 \end{bmatrix} \end{array}$$

Step 3: Obtain weight vector of criteria.
The principle of minimum entropy value is utilized using $\min E_\omega = \sum_{j=1}^{m}\sum_{i=1}^{n} \omega_i \varepsilon(d_{ij})$, the value of weight vector for the evaluated criteria is obtained as $\min E_\omega = 3.599\omega_1 + 3.130\omega_2 + 3.673\omega_3 + 3.299\omega_4$ such that $0.0 \le \omega_1 \le 0.3, 0.1 \le \omega_2 \le 0.2, 0.2 \le \omega_3 \le 0.5,$ and $0.1 \le \omega_4 \le 0.3$ in the condition where $\omega_1 + \omega_2 + \omega_3 + \omega_4 = 1$. This problem can be solved using linear programming manually calculation and the results obtained are $\omega_1 = 0.3, \omega_2 = 0.2, \omega_3 = 0.2, \omega_4 = 0.3.$

Step 4: Obtain score function.
By applying $IFWA_\omega$ operator (equation (5)), the collection of intuitionistic fuzzy values, $a_i = (\mu_i, \gamma_i)$ where $i = 1, 2, ..., n$, is obtained as

$$a_1 = (0.626, 0.226),$$
$$a_2 = (0.610, 0.215),$$
$$a_3 = (0.574, 0.213),$$
$$a_4 = (0.599, 0.212).$$

Using equation (3), the score $s(a_j), (j = 1, 2, 3, 4)$ is obtained as:

$$s(a_1) = 0.400$$
$$s(a_2) = 0.395$$
$$s(a_3) = 0.361$$
$$s(a_4) = 0.387$$

Step 5: Final ranking.
By comparing the score values, the alternatives are ranked from the highest to lowest. Therefore, one can see that the optimal ranking order of the alternatives is given by $A_1 > A_2 > A_4 > A_3$. Therefore, the alternative A_1 is the best choice. In other words, the highest ranking of service quality goes to the company BS Insurance.

4. Conclusions

In this paper, intuitionistic fuzzy De Luca-Termini weighted entropy measure and intuitionistic fuzzy weighted averaging operator have been used to rank the service quality of vehicle insurance companies. As an extension of intuitionistic fuzzy entropy, the intuitionistic fuzzy weighted entropy is the weighted sum of the entropies of intuitionistic fuzzy values, where every intuitionistic fuzzy value was given a non-zero weight. The result from the vehicle insurance companies' case study shows that the company BS Insurance is the highest ranking in service quality. It implicates that the company BS Insurance is the first choice of customers when they decide to purchase vehicle insurance. Furthermore, the gap between customers' perception and customers' satisfaction for BS Insurance is the smallest among those four vehicle insurance companies. From the findings, it shows that the intuitionistic fuzzy set is a suitable tool to solve the uncertainty and fuzziness in the multiple criteria decision making problem by considering the membership function, non-membership function and hesitation degree. Thus far, there are many entropy measures that have been applied intuitionistic fuzzy environments in many real life applications. It would be suggested that in future, there are new possibilities to develop a new entropy measure for distinct interval-valued intuitionistic fuzzy sets.

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