

## Interval-valued Intuitionistic Fuzzy Weighted Entropy in Evaluation of Service Quality

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### ABSTRACT

The importance of measuring service quality perceived by customers is an issue since the service quality is a key to success in service oriented industry. The estimation of service quality should be carried out with suitable measurement scales according to the types of service provided. To the best of authors' knowledge, there have been little discussion about the applications of interval-valued intuitionistic fuzzy sets- based evaluation in measuring service quality. This paper proposes an evaluation for service quality of five vehicle insurance companies using interval-valued intuitionistic fuzzy entropy measure. Linguistic data were collected from customers using a questionnaire. An averaged interval-valued intuitionistic fuzzy number is used to construct decision matrix. Interval-valued intuitionistic fuzzy weighted averaging operator is used to aggregate the interval-valued intuitionistic fuzzy numbers for alternatives. It is found that PCF Insurance was evaluated as the best vehicle insurance company in providing service quality to customers.

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## 1 INTRODUCTION

The increasing competition in service industry has impacted on the closer approach of marketers in providing better products and services. Moreover, service quality and customer satisfaction are key drivers of performance in order to acquire more new customers while retaining existing customers. As mentioned by Herbet et al.[1], today's service industries employers are keen on looking new ways of operating and exploring in greater depth on how to improve service quality in order to strive towards higher levels of customer satisfaction. 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.

Service quality is one of the most important elements in evaluation of organizational performance especially in customer oriented business. Service quality has several definitions depending on different market segments. It is generally first defined by Lewis and Booms [2] as it is a measure of how well a delivered service matches the customers' expectations. However, Gronroos [3] 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. Furthermore, Bitner et al. [4] pointed out

that across various services, consumer satisfaction is frequently influenced by the quality of the interpersonal interaction between the customer and the contact employee. 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.

There are many methods carried out by researchers in measuring service quality in order to improve the service quality of all customer oriented business. One of the widely used instruments in measuring service quality is SERVQUAL model which proposed by Parasuraman *et al.* [5] in 1985. The dimensions surveyed are tangibility, reliability, responsiveness, assurance and empathy. Later, Ahmad and Sungip [6] 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.* [7] 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. On the other hand, there was a survey conducted by Firdaus [8] 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.

In this growing competitive market nowadays, service quality has become more and more important for survival especially rural tourism such as farm tourism. Rozman *et al.* [9] carried out a multi-criteria model based on the qualitative multi-criteria modeling methodology named DEX to assess the service quality of seven tourist farms. As a result, they presented the service quality assessments for individual farm and the potential improvements for farms through analysis and visualization. Recently, Erdil and Yildiz [10] measured service quality and they conducted a comparative analysis in the passenger carriage of airline industry. They gathered data via questionnaires and then compared the estimation of service quality using two scales which are the weighted SERVPERF scale and the weighted SERVQUAL scale. In their research, they found that the weighted SERVPERF scale has explained perceived service quality more than the weighted SERVQUAL scale.

Although researchers have dedicated a lot of attentions to service quality using different methods, there are still lacks of application of interval-valued intuitionistic fuzzy set (IVIFS) in measuring service quality. To the best of authors' knowledge, there have been not much of progress in the study of IVIFS in different perspective and its applications in solving problems except data analysis, pattern recognition and multi-criteria decision making (MCDM). Lately, there are many researchers has presented some distance measures [11], similarity measures [12] and correlation measures [13] of IVIFS, but, there is still lack of useful information entropy measures of IVIFS for the applications in real life especially in measuring service quality. Therefore, this paper is carried out to measure the service quality of vehicle insurance companies using interval-valued intuitionistic fuzzy entropy measure and utilize the IIFWA operator to aggregate the interval-valued intuitionistic fuzzy information corresponding to each alternative. This paper proceeds as follows. Section 2 elucidates the definitions of intuitionistic fuzzy sets and its affiliates. Sections 3 summarises the computational steps of interval-valued intuitionistic fuzzy entropy. A case study of service quality of insurance companies is presented in Section 4. Conclusion is made as the last section of the paper.

## 2 PRELIMINARIES

In this section, definitions about interval-valued intuitionistic fuzzy sets (IVIFS) are briefly reviewed.

### 2.1. Interval-valued intuitionistic fuzzy sets [14]

Let  $M [0,1]$  be the set of all closed subintervals of the interval  $[0,1]$ . Let  $X$  be an ordinary finite non-empty set. An interval-valued intuitionistic fuzzy set (IVIFS) in a universe  $X$  is defined by  $A = \{x, \mu_A(x), \gamma_A(x) : x \in X\}$ , where  $\mu_A : X \rightarrow M[0,1], \gamma_A : X \rightarrow M[0,1]$  with the condition  $0 < \sup \mu_A(x) + \sup \gamma_A(x) \leq 1$ . The intervals  $\mu_A(x)$  and  $\gamma_A(x)$  denote the membership degree and non-membership degree of the element  $x$  in  $A$  respectively. Then, for each  $x \in X, \mu_A(x)$  and  $\gamma_A(x)$  are closed intervals whose  $\mu_{AL}(x), \mu_{AU}(x)$  and  $\gamma_{AL}(x), \gamma_{AU}(x)$  represented lower and upper end points respectively.

Hence, in the condition where  $0 < \mu_{AU}(x) + \gamma_{AU}(x) \leq 1, \mu_{AL}(x) \geq 0, \gamma_{AL}(x) \geq 0$ , A is denoted by  $A = \left\{ \left\langle x, [\mu_{AL}(x), \mu_{AU}(x)], [\gamma_{AL}(x), \gamma_{AU}(x)] \right\rangle \mid x \in X \right\}$ . The interval-valued intuitionistic index of  $x$  in A or so called as hesitancy degree, denoted by  $\pi_A(x)$  and abbreviated by  $[\pi_{AL}(x), \pi_{AU}(x)]$  can be calculated using the formula

$$\begin{aligned} \pi_A(x) &= 1 - \mu_A(x) - \gamma_A(x) \\ &= [1 - \mu_{AU}(x) - \gamma_{AU}(x), 1 - \mu_{AL}(x) - \gamma_{AL}(x)] \end{aligned} \quad (1)$$

For every two IVIFS,  $A = \left\{ \left\langle x, [\mu_{AL}(x), \mu_{AU}(x)], [\gamma_{AL}(x), \gamma_{AU}(x)] \right\rangle \mid x \in X \right\}$  and  $B = \left\{ \left\langle x, [\mu_{BL}(x), \mu_{BU}(x)], [\gamma_{BL}(x), \gamma_{BU}(x)] \right\rangle \mid x \in X \right\}$ , the relations and operations are as follows:

- i.  $A \subset B$  if and only if  $\mu_{AL}(x) \leq \mu_{BL}(x), \mu_{AU}(x) \leq \mu_{BU}(x)$  and  $\gamma_{AL}(x) \geq \gamma_{BL}(x), \gamma_{AU}(x) \geq \gamma_{BU}(x), \forall x \in X$ ;
- ii.  $A = B$  if and only if  $A \subset B$  and  $B \subset A$ ;
- iii.  $A^c = \left\{ \left\langle x, [\gamma_{AL}(x), \gamma_{AU}(x)], [\mu_{AL}(x), \mu_{AU}(x)] \right\rangle \mid x \in X \right\}$ .

## 2.2. Score function [15]

In 2007, Xu defined the score function under interval-valued intuitionistic environment. He mentioned that the greater value of score value, the greater is the interval-valued intuitionistic fuzzy sets (IVIFS). Then, the alternatives are ranked according to the score function. The score function is applied to compare the grades of the IVIFS. Hence, the alternative with the largest value of score is the best alternative for customers. Let an interval-valued intuitionistic fuzzy number denoted by  $A = [\mu_{AL}(x), \mu_{AU}(x)], [\gamma_{AL}(x), \gamma_{AU}(x)]$ . The score function,  $S$ , is given by

$$s(A) = \frac{1}{2} (\mu_{AL}(x) - \gamma_{AL}(x) + \mu_{AU}(x) - \gamma_{AU}(x)). \quad (2)$$

## 2.3. Intuitionistic fuzzy sets entropy

Intuitionistic entropy is used to measure the degree of fuzziness or intuitionism of a set. For an IFS A, Wang et al. [16] defined entropy formula by

$$E(A) = \frac{1}{n} \sum_{i=1}^n \frac{\min\{\mu_A(x_i), \gamma_A(x_i)\} + \pi_A(x_i)}{\max\{\mu_A(x_i), \gamma_A(x_i)\} + \pi_A(x_i)}. \quad (3)$$

Wei et al. [17] transformed the fuzzy entropy formula for a vague set to an entropy formula for an IFS A by

$$E(A) = \frac{1}{n} \sum_{i=1}^n \frac{1 - |\mu_A(x_i) - \gamma_A(x_i)| + \pi_A(x_i)}{1 + |\mu_A(x_i) - \gamma_A(x_i)| + \pi_A(x_i)}. \quad (4)$$

From the studies conducted by Atanssov [14], Deschrijver and Kerre [18], it is worthwhile to mention that IVIFS theory extended IFS theory and it is mathematically equivalent to IFS theory. Therefore, Wei et al. [17] mentioned that for each  $A \in \text{IVIFS}(X)$ ,  $E(A)$  is defined by

$$E(A) = \frac{1}{n} \sum_{i=1}^n \frac{2 - |\mu_{AL}(x_i) - \gamma_{AL}(x_i)| - |\mu_{AU}(x_i) - \gamma_{AU}(x_i)| + \pi_{AL}(x_i) + \pi_{AU}(x_i)}{2 + |\mu_{AL}(x_i) - \gamma_{AL}(x_i)| + |\mu_{AU}(x_i) - \gamma_{AU}(x_i)| + \pi_{AL}(x_i) + \pi_{AU}(x_i)}. \quad (5)$$

In MCDM problems, the hesitancy degree of the intuitionistic set are preferred to be as small as possible to get more stable results. Meanwhile, the bigger value of entropy gives the smaller weight to each corresponding criteria.

## 2.4. Subjective weighting vector [19]

Let  $w = (w_1, w_2, \dots, w_n)$  be a subjective weighting vector of decision makers, with the condition of  $w_i > 0, \sum_{i=1}^n w_i = 1, i = 1, 2, \dots, n$ . Then the weight vector can be calculated by

$$w_i = \frac{1 - E(A)}{\sum_{i=1}^n (1 - E(A))}, i = 1, 2, \dots, n$$

(6)

### 2.5. Interval-valued intuitionistic fuzzy weighted averaging operator (IIFWA) [20]

Let  $A_i = ([\mu_{A_iL}, \mu_{A_iU}], [\gamma_{A_iL}, \gamma_{A_iU}]), (i = 1, 2, \dots, n) \in IVIFS(X)$ . The interval-valued intuitionistic fuzzy weighted averaging operator (IIFWA) is denoted by

$$IIFWA_w(A_1, A_2, \dots, A_n) = \sum_{i=1}^n w_i A_i = \left[ \left[ 1 - \prod_{i=1}^n (1 - \mu_{A_iL}(x_i))^{w_i}, 1 - \prod_{i=1}^n (1 - \mu_{A_iU}(x_i))^{w_i} \right], \left[ \prod_{i=1}^n \gamma_{A_iL}^{w_i}(x_i), \prod_{i=1}^n \gamma_{A_iU}^{w_i}(x_i) \right] \right]$$

(7)

where  $w = (w_1, w_2, \dots, w_n)$  is the weight of  $A_i, i = 1, 2, \dots, n$  and  $\sum_{i=1}^n w_i = 1$ . It is used to aggregate the interval-valued intuitionistic fuzzy information corresponding to each alternative towards the final ranking.

## 3. MCDM BASED ON INTERVAL-VALUED INTUITIONISTIC FUZZY WEIGHTED ENTROPY

There is a study conducted by Wu and Zhang [21] in presenting the concept of intuitionistic fuzzy weighted entropy for intuitionistic fuzzy MCDM problems. They mentioned that MCDM problems are defined on a set of alternatives, and the decision maker has to determine the best alternative according to the evaluation criteria. In their study, they constructed a weight identification model based on intuitionistic fuzzy weighted entropy and computed the optimal weight vector of criteria by linear programming in their decision procedures.

In order to rank the performance of vehicle insurance companies' service quality, the decision procedures in [21] are modified into the procedures based on interval-valued intuitionistic fuzzy weighted entropy. The weight vector of criteria is obtained by means of the interval-valued intuitionistic fuzzy weighted entropy measure. The entropy measure is used to describe the fuzziness and intuitionism degree of an interval-valued intuitionistic fuzzy set. Thus, an approach to interval-valued intuitionistic fuzzy MCDM based on interval-valued intuitionistic fuzzy weighted entropy are presented as follows.

**Step 1.** Construct the interval-valued intuitionistic fuzzy decision matrix  $D = (d_{ij})_{m \times n}$ , where

$$d_{ij} = ([\mu_{A_iL}(x_j), \mu_{A_iU}(x_j)], [\gamma_{A_iL}(x_j), \gamma_{A_iU}(x_j)]) \text{ by the evaluation of the alternatives.}$$

**Step 2.** Utilize Eq. (5) to derive the entropy values corresponding to the criteria  $C_j (j = 1, 2, \dots, n)$ .

**Step 3.** Utilize Eq. (6) to calculate the weight vector  $w = (w_1, w_2, \dots, w_n)$  of the criteria.

**Step 4.** Aggregate the evaluation of the alternatives by  $IIFWA_w$  operator in Eq. (7) and get the synthetic evaluation  $a_i$ .

**Step 5.** Utilize Eq. (2) to determine the scores  $s(a_i) (i = 1, 2, \dots, m)$  of the alternatives.

**Step 6.** Rank the alternatives  $A_i (i = 1, 2, \dots, m)$  and then select the most desirable one(s).

## 4. A CASE OF SERVICES QUALITY EVALUATION

The evaluation of service quality normally involves a set of  $m$  alternatives,  $A_i (i = 1, 2, \dots, m)$ . 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  $n$  criteria  $C_j (j = 1, 2, \dots, n)$ . A survey questionnaire is used to estimate the quality levels of services perceived by customers. Five selected vehicle insurance companies are BS Insurance ( $A_1$ ), LPC Insurance ( $A_2$ ), KRN Insurance ( $A_3$ ), UAG Insurance ( $A_4$ ) and PCF Insurance ( $A_5$ ). The questionnaires consist of six evaluation criteria which are confidence ( $C_1$ ), responsiveness ( $C_2$ ), reliability ( $C_3$ ), Assurance ( $C_4$ ), Empathy ( $C_5$ ) and tangibles ( $C_6$ ). Table 1 shows the assessment criterion for vehicle insurance service quality.

**Table 1.** Assessment Criterion for Evaluate Vehicle Insurance Companies' Service Quality. (Adapted from Parasuraman et al. [22])

Objective	Index
Confidence ( $C_1$ )	• Capability of staff in solving customers' problems. ( $C_{11}$ )
	• Appropriate services offers by staffs. ( $C_{12}$ )
	• Good communication skills of staffs. ( $C_{13}$ )
	• 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 ( $C_3$ )	• Providing services to customers as promised. ( $C_{31}$ )
	• Trustworthy, confident, and honest staffs. ( $C_{32}$ )
	• Understandable and able to answer customers clearly. ( $C_{33}$ )
Assurance ( $C_4$ )	• Professional knowledge to answer questions of customers. ( $C_{41}$ )
	• Making customers feel safe in their transactions of any deal. ( $C_{42}$ )
	• Staffs are consistently courteous. ( $C_{43}$ )
Empathy ( $C_5$ )	• Giving customers individual attention by staffs. ( $C_{51}$ )
	• Having the customers' best interest at heart. ( $C_{52}$ )
	• Providing services during convenient business hours. ( $C_{53}$ )
Tangibles ( $C_6$ )	• Modern equipment and friendly environment to customers. ( $C_{61}$ )
	• Strategic signboard to guide customers and convenient access to company branches. ( $C_{62}$ )
	• Simple and easy understanding of forms. ( $C_{63}$ )
	• Staffs have neat and professional appearance. ( $C_{64}$ )

The evaluation is made according to the following steps.

**Step 1:** Construct the interval-valued intuitionistic fuzzy decision matrix  $D = (d_{ij})_{5 \times 6}$ , where

$d_{ij} = ([\mu_{AL}(x), \mu_{AU}(x)], [\gamma_{AL}(x), \gamma_{AU}(x)])$  by the evaluation of the alternatives.

The intuitionistic fuzzy values decision matrix of vehicle insurance companies is made up according to the six evaluating criteria ( $C_1, C_2, C_3, C_4, C_5, C_6$ ) and each criteria consists of sub-criteria as shown in Table 1. Customers are invited to evaluate the services of five selected vehicle insurance companies based on the sub-criteria as aforementioned. The rating by customers for each sub-criteria is then averaged to get the values for main criteria. By integrating the preference value of customers over five selected vehicle insurance companies according to six evaluation criteria, the intuitionistic fuzzy decision matrix of alternatives is obtained as in Table 2.

**Table 2.** The Interval-valued Intuitionistic Fuzzy Values Decision Matrix of Vehicle Insurance Companies.

	$C_1$	$C_2$	$C_3$
$A_1$	([0.4, 0.5], [0.2, 0.3])	([0.6, 0.8], [0.1, 0.2])	([0.4, 0.5], [0.2, 0.4])
$A_2$	([0.5, 0.7], [0.1, 0.2])	([0.3, 0.8], [0.1, 0.3])	([0.3, 0.4], [0.4, 0.6])
$A_3$	([0.2, 0.3], [0.6, 0.7])	([0.4, 0.5], [0.3, 0.4])	([0.7, 0.8], [0.1, 0.2])
$A_4$	([0.5, 0.6], [0.1, 0.2])	([0.3, 0.4], [0.2, 0.3])	([0.5, 0.8], [0.1, 0.2])
$A_5$	([0.4, 0.5], [0.3, 0.4])	([0.8, 0.9], [0.0, 0.1])	([0.6, 0.8], [0.1, 0.2])
	$C_4$	$C_5$	$C_6$
$A_1$	([0.8, 0.9], [0.1, 0.1])	([0.2, 0.6], [0.2, 0.3])	([0.5, 0.7], [0.1, 0.2])
$A_2$	([0.8, 0.9], [0.0, 0.1])	([0.2, 0.5], [0.3, 0.4])	([0.1, 0.2], [0.4, 0.5])
$A_3$	([0.2, 0.5], [0.1, 0.2])	([0.7, 0.8], [0.0, 0.1])	([0.5, 0.6], [0.2, 0.4])
$A_4$	([0.6, 0.7], [0.1, 0.2])	([0.3, 0.4], [0.3, 0.4])	([0.1, 0.2], [0.7, 0.8])
$A_5$	([0.8, 0.9], [0.0, 0.1])	([0.7, 0.8], [0.1, 0.2])	([0.5, 0.6], [0.1, 0.2])

**Step 2:** Utilize Eq. (5) to derive the entropy values corresponding to the criteria  $C_j$  ( $j= 1, 2, \dots, n$ ). The entropy values for each criteria is calculated as

$$E(C_1) = \frac{1}{5} \left[ \left( \frac{2 - |0.4 - 0.2| - |0.5 - 0.3| + 0.2 + 0.4}{2 + |0.4 - 0.2| + |0.5 - 0.3| + 0.2 + 0.4} \right) + \left( \frac{2 - |0.5 - 0.1| - |0.7 - 0.2| + 0.1 + 0.4}{2 + |0.5 - 0.1| + |0.7 - 0.2| + 0.1 + 0.4} \right) \right. \\ \left. + \left( \frac{2 - |0.2 - 0.6| - |0.3 - 0.7| + 0.2}{2 + |0.2 - 0.6| + |0.3 - 0.7| + 0.2} \right) + \left( \frac{2 - |0.5 - 0.1| - |0.6 - 0.2| + 0.2 + 0.4}{2 + |0.5 - 0.1| + |0.6 - 0.2| + 0.2 + 0.4} \right) \right. \\ \left. + \left( \frac{2 - |0.4 - 0.3| - |0.5 - 0.4| + 0.1 + 0.3}{2 + |0.4 - 0.3| + |0.5 - 0.4| + 0.1 + 0.3} \right) \right] \\ = 0.6092$$

Using the same entropy formula as calculated for  $C_1$ , the entropy values are also calculated for other criteria.

Hence,

$$E(C_2) = 0.5514$$

$$E(C_3) = 0.5195$$

$$E(C_4) = 0.3318$$

$$E(C_5) = 0.6429$$

$$E(C_6) = 0.5168$$

**Step 3:** Utilize Eq. (6) to calculate the weight vector  $w = (w_1, w_2, \dots, w_n)$  of the criteria. As mentioned above, the bigger value of entropy gives the smaller weight to the corresponding criteria. The results obtained are given.

$$w_1 = \frac{1 - 0.6092}{\left[ (1 - 0.6092) + (1 - 0.5514) + (1 - 0.5195) + (1 - 0.3318) + (1 - 0.6429) + (1 - 0.5168) \right]} \\ = 0.1382$$

Applying the formula as calculated for  $w_1$ , the weight vectors are also calculated for other criteria. Hence,

$$w_2 = 0.1586$$

$$w_3 = 0.1699$$

$$w_4 = 0.2363$$

$$w_5 = 0.1263$$

$$w_6 = 0.1708$$

**Step 4:** Aggregate the evaluation of the alternatives by  $IIFWA_w$  operator in Eq. (7) and get the synthetic evaluation  $a_i$ . Then, the collection of interval-valued intuitionistic fuzzy values,  $a_i = [\mu_{A_L}, \mu_{A_U}], [\gamma_{A_L}, \gamma_{A_U}]$  where  $i = 1, 2, \dots, m$  is obtained as

$$a_1 = \left( \left[ \left( 1 - \left( 0.6^{0.1382} \times 0.4^{0.1586} \times 0.6^{0.1699} \times 0.2^{0.2363} \times 0.8^{0.1263} \times 0.5^{0.1708} \right) \right), \right. \right. \\ \left. \left[ 1 - \left( 0.5^{0.1382} \times 0.2^{0.1586} \times 0.5^{0.1699} \times 0.1^{0.2363} \times 0.4^{0.1263} \times 0.3^{0.1708} \right) \right] \right), \\ \left( \left[ \left( 0.2^{0.1382} \times 0.1^{0.1586} \times 0.2^{0.1699} \times 0.1^{0.2363} \times 0.2^{0.1263} \times 0.1^{0.1708} \right) \right), \right. \\ \left. \left[ \left( 0.3^{0.1382} \times 0.2^{0.1586} \times 0.4^{0.1699} \times 0.1^{0.2363} \times 0.3^{0.1263} \times 0.2^{0.1708} \right) \right] \right) \\ = ([0.5637, 0.7367], [0.1351, 0.2126]) \\ a_2 = ([0.4724, 0.6922], [0, 0.2785]) \\ a_3 = ([0.4725, 0.6157], [0, 0.2737]) \\ a_4 = ([0.4229, 0.5803], [0.1788, 0.2949]) \\ a_5 = ([0.6777, 0.8057], [0, 0.1674])$$

**Step 5:** Utilize Eq. (2) to determine the scores  $s(a_i)(i=1,2,\dots,m)$  of the alternatives. The scores for each alternative are resulted as below.

$$\begin{aligned} s(A_1) &= \frac{1}{2}(0.5637 - 0.1351 + 0.7367 - 0.2126) \\ &= 0.4764 \\ s(A_2) &= 0.4431 \\ s(A_3) &= 0.4073 \\ s(A_4) &= 0.2648 \\ s(A_5) &= 0.6580 \end{aligned}$$

**Step 6:** Rank the alternatives  $A_i (i = 1, 2, \dots, m)$  and then select the most desirable one(s).

By comparing the scores values, the alternatives are ranked from the highest to the lowest. Thus, the optimal ranking order of the alternatives is given by  $A_5 > A_1 > A_2 > A_4 > A_3$ . So, the most desirable alternative is  $A_5$ . In other words, the company PCF Insurance achieved the highest ranking of service quality among the five selected vehicle insurance companies.

## 5. CONCLUSIONS

Although researchers have dedicated a lot of attentions to service quality using different methods, there are still lacks of application of interval- valued intuitionistic fuzzy set (IVIFS) in measuring service quality. Hence, more applications of IVIFS in measuring service quality are encouraged to be carried out because IVIFS is a suitable tool to describe the uncertainty degree in decision information.

In this paper, interval-valued intuitionistic fuzzy entropy measure by Wei et al. [17] and IIFWA operator have been used to aggregate the interval-valued intuitionistic fuzzy values information. Then, score function defined by Xu [15] has been used to rank the service quality of vehicle insurance companies. As an extension of intuitionistic fuzzy entropy, the interval- valued intuitionistic fuzzy weighted entropy is the weighted sum of the entropies of interval- valued intuitionistic fuzzy values, where the weight of every interval- valued intuitionistic fuzzy value was greater than zero. The result from the vehicle insurance companies' case study has shown that the company PCF Insurance has achieved the highest ranking in service quality. This implicates that the company PCF Insurance is the first choice of customers when they decided to purchase vehicle insurance. This paper has provided evidence that the interval- valued intuitionistic fuzzy set is a suitable tool to solve the uncertainty and fuzziness in the multiple criteria decision making of service quality problem. It would be suggested that more entropy measures of intuitionistic fuzzy sets could be tested in diverse real life applications.

## REFERENCES

- [1] Herbert, D.; Curry, A.; Angel, L.; "Use of Quality Tools and Techniques in Services," *The Service Industries Journal*, vol.23, no.4, pp.61-80, 2003.
- [2] Lewis, R. C.; Booms, B. H.; "The Marketing Aspects of Service Quality," *Emerging Perspectives on Services Marketing*, American Marketing Association, vol., no., pp. 99-107, 1983.
- [3] Gronroos, C.; "Assessing Competitive Edge in The New Competition of The Service Economy: The Five Rules of Services," *Working Paper at First Interstate Centre for Services Marketing*, Arizona State University, vol., no.9, pp., 1998.
- [4] Bitner, M. J.; Booms, B. H.; Mohr, L. A.; "Critical Service Encounters: The Employee's View," *Journal of Marketing*, vol. 58, no. 3, pp. 95-106, 1994.
- [5] Parasuraman, A.; Zeithaml, V. A.; Berry, L. L.; "A Conceptual Model of Service Quality and Its Implications for Future Research," *Journal of Marketing*, vol. 49, no., pp. 41-50, 1985.
- [6] Ahmad, A.; Sungip, Z.; "An Assessment on Service Quality in Malaysia Insurance Industry," *Communications of the International Business Information Management Association*, vol. 1, no., pp. 13-26, 2008.
- [7] Tsai, H. Y.; Huang, B. H.; Wang, A. S.; "Combining ANP and TOPSIS Concepts for Evaluation the Performance of Property-liability Insurance Companies," *Journal of Social Sciences*, vol. 4, no., pp.56-61, 2008.
- [8] Firdaus, A.; "Measuring Service Quality in Higher Education: HEDPERF versus SERVPERF," *Journal of Marketing Practice: Applied Marketing Science*, vol. 24, no., pp. 31-47, 2006.
- [9] Rozman, C.; Potocnik, M.; Pazek, K.; Borec, A.; Majkovic, D.; Bohanec, M.; "A Multi-criteria Assessment of Tourist Farm Service Quality," *Tourism Management*, vol. 30, no., pp.629-637, 2009.
- [10] Erdil, S. T.; Yildiz, O.; "Measuring Service Quality and A Comparative Analysis in the Passenger Carriage of Airline Industry," *Procedia Social and Behavioral Sciences*, vol. 24, no., pp. 1232-1242, 2011.
- [11] Xu, Z.; "A Method Based on Distance Measure for Interval-valued Intuitionistic Fuzzy Group Decision Making," *Information Sciences*, vol. 180, no., pp. 181-190, 2010.

- [12] Ye, J.; "Multicriteria Decision-making Method Using the Dice Similarity Measure Based on the Reduct Intuitionistic Fuzzy Sets of Interval-valued Intuitionistic Fuzzy Sets," *Applied Mathematical Modelling*, doi:10.1016/j.apm.2011.11.075, 2011.
- [13] Park, D. G.; Kwun, Y. C.; Park, J. H.; Park, I. Y.; "Correlation Coefficient of Interval-valued Intuitionistic Fuzzy Sets and Its Application to Multiple Attribute Group Decision-making Problems," *Mathematics Computation Model*, vol. 50, no., pp. 1279-1293, 2009.
- [14] Atanassov, K.; Gargov, G.; "Interval-valued Intuitionistic Fuzzy Sets," *Fuzzy Sets and Systems*, vol. 31, no.3, pp. 343-349, 1989.
- [15] Xu, Z. S.; "Methods for Aggregating Interval-valued Intuitionistic Fuzzy Information and Their Application to Decision Making," *Control and Decision*, vol.22, no., pp. 215-219, 2007.
- [16] Wang, Y.; Lei, Y. J.; "A Technique for Constructing Intuitionistic Fuzzy Entropy," *Control and Decision*, vol. 22, no. 12, pp. 1390-1394, 2007.
- [17] Wei, C. P.; Wang, P.; Zhang, Y. Z.; "Entropy, Similarity Measure of Interval -valued Intuitionistic Fuzzy Sets and Their Applications," *Information Sciences*, vol. 181, no., pp. 4273- 4286, 2011.
- [18] Deschrijver, G.; Kerre, E. E.; "On the Relationship between Some Extensions of Fuzzy Set Theory," *Fuzzy Sets and Systems*, vol. 133, no., pp. 227-235, 2003.
- [19] Wei, C. P.; Tang, X. J.; "An Intuitionistic Fuzzy Group Decision-making Approach Based on Entropy and Similarity Measures," *International Journal of Information Technology & Decision Making*, vol. 10, no.6, pp. 1111-1130, 2011.
- [20] Xu, Z. S.; Chen, J.; "An Approach to Group Decision Making Based on Interval-valued Intuitionistic Judgement Matrices," *Systems Engineering – Theory and Practice*, vol. 27, no. 4, pp. 126-133, 2007.
- [21] Wu, J. Z.; Zhang, Q.; "Multicriteria Decision Making Method Based on Intuitionistic Fuzzy Weighted Entropy," *Experts Systems with Applications*, vol. 38, no., pp. 916-922, 2011.
- [22] Parasuraman, A.; Zeithaml, V. A.; Berry, L. L.; "Alternative Scales for Measuring Service Quality: A Comparative Assessment Based on Psychometric and Diagnostic Criteria," *Journal of Retailing*, vol. 70, no., pp. 201-230, 1994..

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