A Fuzzy Based Service Quality and Performance Evaluation Model: A Case Study in Hostel Mess

Thesis submitted in partial fulfillment of the requirements for the Degree of

Bachelor of Technology (B. Tech.)

In

Mechanical Engineering

By

PRAKASH SHAH
Roll No. 109ME0538

Under the Guidance of

Prof. SAURAV DATTA

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008, INDIA

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008, INDIA

Certificate of Approval

This is to certify that the thesis entitled **A Fuzzy Based Service Quality and Performance Evaluation Model: A Case Study in Hostel Mess submitted** by ***Sri Prakash Shah*** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology*** in ***Mechanical Engineering*** at **National Institute of Technology**, **NIT Rourkela**, and this work has not been submitted elsewhere before for any other academic degree/diploma.

Dr. Saurav Datta

Assistant Professor
Department of Mechanical Engineering
National Institute of Technology, Rourkela

Rourkela-769008

Date:

Acknowledgement

I would like to express my deep sense of gratitude and indebtedness to ***Dr. Saurav Datta****, Assistant Professor, Department of Mechanical Engineering, NIT Rourkela, my supervisor, whose invaluable encouragement, suggestions, and support leads to make successful completion of the thesis work. His meticulous guidance at each phase of this thesis has inspired and helped me innumerable ways. I am feeling felicitous in deep of my heart to work under such a young, dynamic, intelligent professor and his excellence of supervision.*

I would also like to show my sincere thanks to ***Prof. K. P. Maity****, Professor and Head of the Department, Mechanical Engineering;* ***Prof. S. S. Mahapatra****, Professor and* ***Prof. S. K. Patel****, Associate Professor, Department of Mechanical Engineering, NIT Rourkela, for their intellectual support and paving me with their precious comments and creative ideas. I am indebted to all of them.*

Last, but not the least, I offer my regards and thanks to all of those, whose names have not been explicitly mentioned, yet, have supported me in any respect during the completion of this report.

Prakash Shah

Abstract

Customer service satisfaction has become a major concern of modern service industry competition. Accurate evaluation of customer service satisfaction is the basis to improve the service quality. Since there is a causal relationship between customer satisfaction and service quality and services literature and studies have shown that service quality is an antecedent of customer satisfaction, the present work seeks to find out the service dimensions of service quality, which lead to higher levels of customer satisfaction. This paper constructs the service quality evaluation system of a hostel mess of National Institute of Technology, Rourkela, India, based on the customer's (students of the hostel) point of view, and put forward the questionnaire of service quality in mess services in hostel, and set up the evaluating overall service quality and performance extent. Apart from estimating overall service quality performance extent index, the present study has been extended to identify ill-performing areas which require future improvement. A fuzzy based service quality and performance appraisement module has been reported in this work.

Keywords: Customer service satisfaction; mess services in hostel; overall service quality and performance extent

Contents

1. State of Art

Customer service satisfaction has become a vital issue of modern service industry competition. Accurate evaluation of customer service satisfaction is a base to improve the service quality. This project aims to construct the service quality evaluation system of hotel mess based on the customer's (students') point of view, and put forward the questionnaire of service quality in hotel mess, and set up the evaluating customer satisfaction by Fuzzy Logic method.

The purpose of this study is to determine mess service quality. The aims are to: (a) assess customers' expectations and perceptions, (b) establish the significance of difference between perceived and expected service quality, (c) identify the number of dimensions for expectations and perceptions scales of fuzzy model, (d) test the reliability of the applied fuzzy model.

Andaleeb and Conway (2006) determined the factors that explain customer satisfaction in the full service restaurant industry. Secondary research and qualitative interviews were used to build the model of customer satisfaction. A structured questionnaire was employed to gather data and test the model. Sampling involved a random selection of addresses from the telephone book and was supplemented by respondents selected on the basis of judgment sampling. Factor analysis and multiple regressions were used to test the model. The regression model suggested that customer satisfaction was influenced most by responsiveness of the frontline employees, followed by price and food quality (in that order). Physical design and appearance of the restaurant did not have a significant effect.

Chow et al. (2007) reported an empirical assessment of service quality in restaurant operations. The authors proposed and tested a conceptual model of service quality using structural equation modeling. Using data from a sample of 284 customers from two large full-service restaurants in southern China, the authors investigated the relationships of service quality, customer satisfaction, and frequency of patronage. The results supported the significant links between service quality and customer satisfaction, service quality and repeat patronage, but not customer satisfaction and repeat patronage. The study provided important insights into service quality and customer satisfaction in the field of restaurant operations.

Ko and Har (2008) highlighted an exploratory study of customer satisfaction of fine dining restaurants in Singapore. Since there was a causal relationship between customer satisfaction and service quality and services literature and studies were shown that service quality was an antecedent of customer satisfaction, this paper seek to find out the service dimensions of service quality, which lead to higher levels of customer satisfaction. This study suggested that the service dimensions of assurance, empathy and tangibles were the most important to customers' evaluation of service quality, and thus, might have a positive influence customer satisfaction. The service aspects of each of these dimensions were discussed and recommendations were made for restaurateurs to improve their service to ensure higher levels of customer satisfaction.

Xue et al. (2008) constructed the service quality evaluation system of fast food industry based on the customer's point of view, and put forward the questionnaire of service quality in Fast Food Restaurant (FFR), and set up the evaluating customer satisfaction by TOPSIS method Based on an investigation on customers in China and US, and evaluated customer satisfaction of 4 FFRs in China and 8 FFRs in US, and then sort. Through the evaluation and analysis of result of China and US, this paper analyzed the core competence of fast food industry and the main factors that influence competence, which could provide evidence for further enhancing enterprise competitiveness.

Markovic et al. (2010) determined restaurant service quality. The aims were to: (a) assess customers' expectations and perceptions, (b) establish the significance of difference between perceived and expected service quality, (c) identify the number of dimensions for expectations and perceptions scales of modified DINESERV model, (d) test the reliability of the applied DINESERV model. The empirical research was conducted using primary data. In order to meet survey goals, descriptive, bivariate and multivariate (exploratory factor analysis and reliability analysis) statistical analyses were conducted.

The empirical results showed that expectations scores were higher than perceptions scores, which indicated low level of service quality. Furthermore, this study identified seven factors that best explain customers' expectations and two factors that best explain customers' perceptions regarding restaurant service. The results of this study would help management identify the strengths and weaknesses of service quality and implement an effective strategy to meet the customers' expectations.

Shi and Wang (2011) studied evaluation method of service quality of restaurant. Based on SERVQUAL, Evaluation system for restaurant was established. And empirical study was done for a restaurant in Mianyang, china. Service quality of the restaurant was evaluated by the restaurant's service quality evaluation method based on SERVQUAL. Then according to current service quality level of the restaurant, quality improvement method was discussed.

Khattab et al. (2011) studied was to measure hotels' service quality performance from the customer perspective. To do so, a performance-only measurement scale (SERVPERF) was administered to customers stayed in three, four and five star hotels in Aqaba and Petra. Although the importance of service quality and service quality measurement was recognized, there was limited research that addressed the structure and antecedents of the concept for the hotel industry. The clarification of the dimensions was important for managers in the hotel industry as it identifies the bundles of service attributes consumers find important. The results of the study demonstrated that SERVPERF seemed as a reliable and valid tool to measure service quality in the hotel industry. The instrument consists of five dimensions, namely "tangibles", "responsiveness", "empathy", "assurance" and "reliability". Hotel customers are expecting more improved services from the hotels in all service quality dimensions. However, hotel customers have the lowest perception scores on empathy and tangibles. In the light of the results, possible managerial implications were discussed and future research subjects are recommended.

Mola and Jusoh (2011) examined and measured the quality of services provided by hoteliers in Penang (Malaysia). Empirical research was used to determine guests' expectations and perceptions of the quality of service, and a comprehensive scale adopted from "SERVQUAL" was empirically evaluated for its usefulness in the Penang hotel industry. The findings of this research based on the mean differences between expectation and perception of hotels' guests represented positive and negative numerical scores. Two items reported positive scores, while the remaining items scores negative values which was the result of shortfalls in offering service quality and the guests' perceived value of the services less than their expectations based on measured variables. The paper findings might help Penang hoteliers to improve their service quality to fulfill shortcomings.

Min and Min (2011) measured the service performances of fast-food restaurant franchises in the USA and identified salient factors influencing the service performances of fast-food restaurants over time. This paper developed a set of benchmarks that helped fast-food restaurants to monitor their service-delivery process, to identify relative weaknesses, and to take corrective actions for continuous service improvements using analytic hierarchy process and competitive gap analysis.

This study revealed that a service attribute considered most important to the fast-food restaurant customers' impressions of service quality is taste of food. Also, the authors found a pattern of the correlation between the overall level of customer satisfaction with the fast-food restaurant and its word-of-mouth reputation. Furthermore, they discovered that the customers tended to be more favorable to easily accessible and national fast-food restaurant franchises than less accessible, relatively new, and regional counterparts.

Haghighi et al. (2012) investigated the factors affecting customer loyalty in the restaurant industry. Data was collected using questionnaire distributed in 10 randomly selected branches of Boof Chain Restaurant in Tehran. In each branch, 40 customers were selected for the study. Ultimately, the research sample consisted of 268 customers. Structured equation modeling was used for data analysis and hypothesis testing. The obtained results showed that food quality, service quality, restaurant environment, and perception of price fairness had a positive impact on customer satisfaction, but the impact of restaurant location on customer satisfaction was not confirmed. Also, food quality, service quality, and perception of price fairness had a positive effect on customer trust. The results showed that food quality seemed the most important factor affecting customer satisfaction and trust in Boof Chain Restaurants. Customer satisfaction had a positive impact on customer loyalty, but the effect of customer trust on customer loyalty was not confirmed.

Ali et al. (2012) examined the factors and sub-factors within the sector-specific measurement scale that was known as model of service quality based on 342 responds gathered by the online questionnaire method. These factors were listed and determined as highlighted in the literature. The study defined the influencing factors for the food retail industry of Turkey, which contributed to appropriate for the future strategies of the sector.

Nicolaides (2012) made an empirical assessment of customers' perceptions and expectations of service to measure service quality in three restaurants in a casino complex in Gauteng Province in South Africa. The research helped to assess the levels of customer satisfaction with service provision in three restaurants and identified factors that contributed to customer satisfaction and dissatisfaction; It also determined the current status of service and compared and ranked three restaurants service provision. Another importance was the aiding in the establishment of customer service standards for the restaurants concerned. The tipping of waitrons was also used as an indicator of customer satisfaction with service provision in general. A three-column SERVQUAL instrument was used together with part of the Fishbein model. The study was able to firstly determine and analyze service gaps that exist in the service delivery procedure to measure service quality as well as general customer satisfaction and secondly, to evaluate customers' attitudes towards the service measure attributes of similar restaurants in the same location. The findings offer implications to improve service quality in restaurant business in general.

Yoo (2012) attempted to investigate the customers' perceptions of restaurant cleanliness. Understanding what customers consider when they evaluate a restaurant's cleanliness could be beneficial for hospitality managers who could use the information to increase their restaurant's quality and to satisfy their customers. In addition, this study was conducted with two different cultural groups of customers: Westerners and Asians. Understanding how different cultures perceive restaurant cleanliness could help hospitality managers who plan to expand their business in the global market.

The results of this study indicated that the items of restroom personal hygiene, restroom appearance and server' behavior all had a positive relationship with customers' restaurant quality evaluations. The level of importance of restaurant cleanliness dimensions was found to be similar between the Western and Asian samples. The server's behavior, restroom appearance and signage were found to be the most important dimensions for both groups. However, restroom personal hygiene was found to be the only dimension ranked differently by the two groups in the study. Westerners weighed the restroom personal hygiene as more important than did Asian respondents. Asian groups were found to have higher expectations for overall restaurant cleanliness dimensions than Western groups.

2. Fuzzy Preliminaries

To deal with vagueness in human thought, Zadeh (1965) first introduced the fuzzy set theory, which has the capability to represent/manipulate data and information possessing based on nonstatistical uncertainties. Moreover fuzzy set theory has been designed to mathematically represent uncertainty and vagueness and to provide formalized tools for dealing with the imprecision inherent to decision making problems. Some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Zadeh (1975), Buckley (1985), Negi (1989), Kaufmann and Gupta (1991).The basic definitions and notations below will be used throughout this paper until otherwise stated.

2.1 Definitions of fuzzy sets:

Definition 1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element x in X a real number in the interval $[0,1]$. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$ **(Kaufmann and Gupta, 1991)**.

Definition 2. A fuzzy set $\tilde{A}$ in a universe of discourse X is convex if and only if

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min\left(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\right) \tag{1}$$

For all x_1, x_2 in X and all $\lambda \in [0,1]$, where $\min$ denotes the minimum operator (Klir and Yuan, 1995).

Definition 3. The height of a fuzzy set is the largest membership grade attained by any element in that set. A fuzzy set $\tilde{A}$ in the universe of discourse X is called normalized when the height of $\tilde{A}$ is equal to 1 (Klir and Yuan, 1995).

2.2 Definitions of fuzzy numbers:

Definition 1. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal. Fig. 1 shows a fuzzy number $\tilde{n}$ in the universe of discourse X that conforms to this definition (Kaufmann and Gupta, 1991).

Definition 2. The α -cut of fuzzy number $\tilde{n}$ is defined as:

$$\tilde{n}^{\alpha} = \{x_i : \mu_{\tilde{n}}(x_i) \geq \alpha, x_i \in X\}, \tag{2}$$

Here, $\alpha \in [0,1]$

The symbol $\tilde{n}^{\alpha}$ represents a non-empty bounded interval contained in X, which can be denoted by $\tilde{n}^{\alpha} = [n_l^{\alpha}, n_u^{\alpha}]$, n_l^{α} and n_u^{α} are the lower and upper bounds of the closed interval, respectively (Kaufmann and Gupta, 1991; Zimmermann, 1991). For a fuzzy number $\tilde{n}$, if $n_l^{\alpha} > 0$ and $n_u^{\alpha} \leq 1$ for all $\alpha \in [0,1]$, then $\tilde{n}$ is called a standardized (normalized) positive fuzzy number (Negi, 1989).

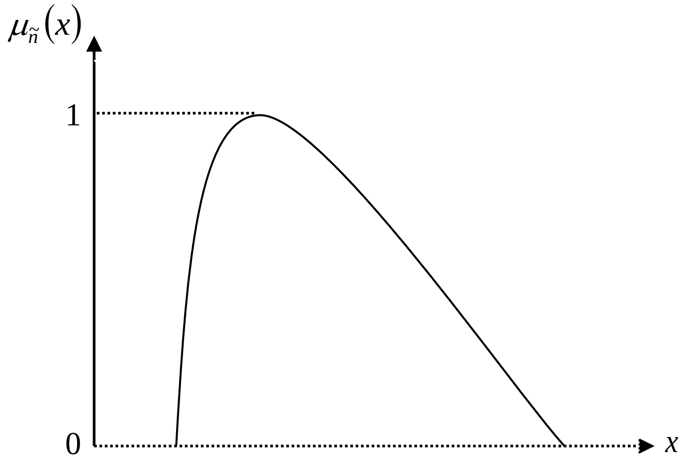

Fig. 1. A fuzzy number $\tilde{n}$

Definition 3. Suppose, a positive triangular fuzzy number (PTFN) is $\tilde{A}$ and that can be defined as (a,b,c) shown in Fig. 2. The membership function $\mu_{\tilde{n}}(x)$ is defined as:

$$\mu_{\tilde{A}}(x)=\begin{cases}(x-a)/(b-a), & if\ a \le x \le b,\\ (c-x)/(c-b), & if\ b \le x \le c,\\ 0, & otherwise,\end{cases} \quad (3)$$

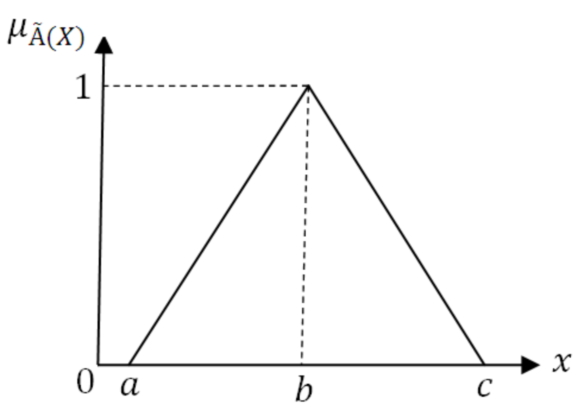

Fig. 2. A triangular fuzzy number $\tilde{A}$

Based on extension principle, the fuzzy sum $\oplus$ and fuzzy subtraction Θ of any two triangular fuzzy numbers are also triangular fuzzy numbers; but the multiplication $\otimes$ of any two triangular fuzzy numbers is only approximate triangular fuzzy number (Zadeh, 1975). Let's have a two positive triangular fuzzy numbers, such as $\tilde{A}_1 = (a_1, b_1, c_1)$, and $\tilde{A}_2 = (a_2, b_2, c_2)$, and a positive real number $r = (r, r, r)$, some algebraic operations can be expressed as follows:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \quad (4)$$

$$\tilde{A}_1 \Theta \tilde{A}_2 = (a_1 - a_2, b_1 - b_2, c_1 - c_2), (5)\ \tilde{A}_1 \otimes \tilde{A}_2 = (a_1 a_2, b_1 b_2, c_1 c_2), \quad (6)$$

$$r \otimes \tilde{A}_1 = (ra_1, rb_1, rc_1), \quad (7)$$

$$\tilde{A}_1 \varnothing \tilde{A}_2 = (a_1/c_2, b_1/b_2, c_1/a_2), \quad (8)$$

The operations of $\vee$ (max) and $\wedge$ (min) are defined as:

$$\tilde{A}_1 (\vee) \tilde{A}_2 = (a_1 \vee a_2, b_1 \vee b_2, c_1 \vee c_2), \quad (9)$$

$$\tilde{A}_1 (\wedge) \tilde{A}_2 = (a_1 \wedge a_2, b_1 \wedge b_2, c_1 \wedge c_2), \quad (10)$$

Here, $r > 0$, and $a_1, b_1, c_1 > 0$,

Also the crisp value of triangular fuzzy number set $\tilde{A}_1$ can be determined by defuzzification which locates the Best Non-fuzzy Performance (BNP) value. Thus, the BNP values of fuzzy number are calculated by using the center of area (COA) method as follows: (Moeinzadeh and Hajfathaliha, 2010)

$$\text{BNP}_i = \frac{[(c-a)+(b-a)]}{3} + a, \qquad \forall_i, \quad (11)$$

Definition 4. A matrix $\tilde{\mathbf{D}}$ is called a fuzzy matrix if at least one element is a fuzzy number (Buckley, 1985).

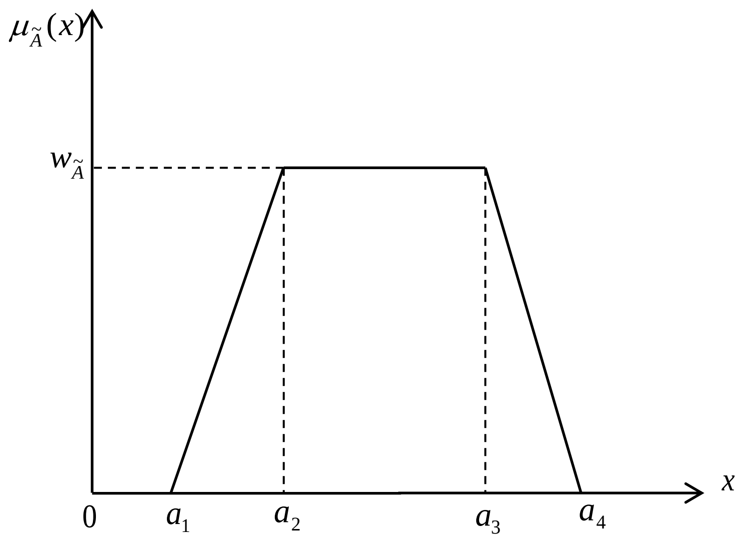

Fig. 3 Trapezoidal fuzzy number $\tilde{A}$

2.3 Linguistic variable:

Definition 1. A linguistic variable is the variable whose values are not expressed in numbers but words or sentences in a natural or artificial language (Zadeh, 1975). The concept of a linguistic variable is very useful in dealing with situations, which are too complex or not well-defined to be reasonably described in conventional quantitative expressions (Zimmermann, 1991). For example, 'weight' is a linguistic variable whose values are 'very low', 'low', 'medium', 'high', 'very high', etc. Fuzzy numbers can also represent these linguistic values.

2.4 The concept of generalized trapezoidal fuzzy numbers

By the definition given by (Chen, 1985), a generalized trapezoidal fuzzy number can be defined as $\tilde{A} = (a_1, a_2, a_3, a_4; w_{\tilde{A}})$, as shown in Fig. 3.

and the membership function $\mu_{\tilde{A}}(x): R \to [0,1]$ is defined as follows:

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-a_1}{a_2-a_1}\times w_{\tilde{A}}, & x\in(a_1,a_2)\\ w_{\tilde{A}}, & x\in(a_2,a_3)\\ \dfrac{x-a_4}{a_3-a_4}\times w_{\tilde{A}}, & x\in(a_3,a_4)\\ 0, & x\in(-\infty,a_1)\cup(a_4,\infty)\end{cases} \tag{12}$$

Here, $a_1 \le a_2 \le a_3 \le a_4$ and $w_{\tilde{A}} \in [0,1]$

The elements of the generalized trapezoidal fuzzy numbers $x \in R$ are real numbers, and its membership function $\mu_{\tilde{A}}(x)$ is the regularly and continuous convex function, it shows that the membership degree to the fuzzy sets. If $-1 \le a_1 \le a_2 \le a_3 \le a_4 \le 1$, then $\tilde{A}$ is called the normalized trapezoidal fuzzy number. Especially, if $w_{\tilde{A}} = 1$, then $\tilde{A}$ is called trapezoidal fuzzy number (a_1, a_2, a_3, a_4); if $a_1 < a_2 = a_3 < a_4$, then $\tilde{A}$ is reduced to a triangular fuzzy number. If $a_1 = a_2 = a_3 = a_4$, then $\tilde{A}$ is reduced to a real number.

Suppose that $\tilde{a} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})$ and $\tilde{b} = (b_1, b_2, b_3, b_4; w_{\tilde{b}})$ are two generalized trapezoidal fuzzy numbers, then the operational rules of the generalized trapezoidal fuzzy numbers $\tilde{a}$ and $\tilde{b}$ are shown as follows (Chen and Chen, 2009):

$$\tilde{a} \oplus \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \oplus (b_1, b_2, b_3, b_4; w_{\tilde{b}}) =$$

$$(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{13}$$

$$\tilde{a} - \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) - (b_1, b_2, b_3, b_4; w_{\tilde{b}}) =$$

$$(a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{14}$$

$$\tilde{a} \otimes \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \otimes (b_1, b_2, b_3, b_4; w_{\tilde{b}}) =$$

$$(a, b, c, d; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{15}$$

Here,

$$a = \min\left(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4\right)$$

$$b = \min\left(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3\right)$$

$$c = \max\left(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3\right)$$

$$d = \max\left(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4\right)$$

If $a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4$ are real numbers, then

$$\tilde{a} \otimes \tilde{b} = \left(a1 \times b1, a2 \times b2, a3 \times b3, a4 \times b4; \min\left(w_{\tilde{a}}, w_{\tilde{b}}\right)\right)$$

$$\tilde{a} / \tilde{b} = \left(a_1, a_2, a_3, a_4; w_{\tilde{a}}\right) \big/ \left(b_1, b_2, b_3, b_4; w_{\tilde{b}}\right)$$

$$= \left(a_1 / b_4, a_2 / b_3, a_3 / b_2, a_4 / b_1; \min\left(w_{\tilde{a}}, w_{\tilde{b}}\right)\right) \quad (16)$$

Chen and Chen (2003) proposed the concept of COG point of generalized trapezoidal fuzzy numbers, and suppose that the COG point of the generalized trapezoidal fuzzy number $\tilde{a} = \left(a_1, a_2, a_3, a_4; w_{\tilde{a}}\right)$ is $\left(x_{\tilde{a}}, y_{\tilde{a}}\right)$, then:

$$y_{\tilde{a}} = \begin{cases} \dfrac{w_{\tilde{a}} \times \left(\dfrac{a_3 - a_2}{a_4 - a_1} + 2\right)}{6}, & if\ a_1 \neq a_4 \\ \dfrac{w_{\tilde{a}}}{2}, & if\ a_1 = a_4 \end{cases} \quad (17)$$

$$x_{\tilde{a}} = \frac{y_{\tilde{a}} \times \left(a_2 + a_3\right) + \left(a_1 + a_4\right) \times \left(w_{\tilde{a}} - y_{\tilde{a}}\right)}{2 \times w_{\tilde{a}}} \quad (18)$$

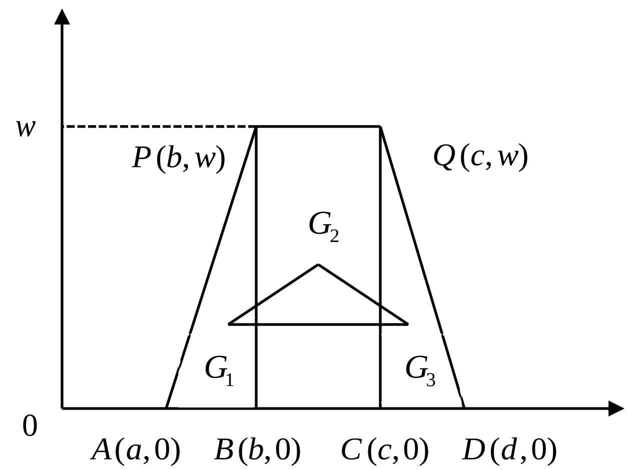

Fig. 4. Trapezoidal Fuzzy Number [Thorani et al. (2012)]

2.5 Ranking of Generalized Trapezoidal Fuzzy Numbers **[**Thorani et al. (2012)]

The centroid of a trapezoid is considered as the balancing point of the trapezoid (Fig. 4). Divide the trapezoid into three plane figures. These three plane figures are a triangle (APB), a rectangle (BPQC), and a triangle (CQD), respectively. Let the centroids of the three plane figures be G_1, G_2, and G_3 respectively. The Incenter of these Centroids G_1, G_2 and G_3 is taken as the point of reference to define the ranking of generalized trapezoidal fuzzy numbers. The reason for selecting this point as a point of reference is that each centroid point are balancing points of each individual plane figure, and the Incentre of these Centroid points is a much more balancing point for a generalized trapezoidal fuzzy number. Therefore, this point would be a better reference point than the Centroid point of the trapezoid.

Consider a generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, (Fig. 4). The Centroids of the three plane figures are $G_1 = \left(\frac{a+2b}{3}, \frac{w}{3}\right)$, $G_2 = \left(\frac{b+c}{2}, \frac{w}{2}\right)$ and $G_3 = \left(\frac{2c+d}{3}, \frac{w}{3}\right)$ respectively.

Equation of the line $\overline{G_1G_3}$ is $y=\frac{w}{3}$ and G_2 does not lie on the line $\overline{G_1G_3}$. Therefore, G_1G_2 and G_3 are non-collinear and they form a triangle.

We define the Incentre $I_{\tilde{A}}(\bar{x}_0,\bar{y}_0)$ of the triangle with vertices G_1, G_2 and G_3 of the generalized trapezoidal fuzzy number $\tilde{A}=(a,b,c,d;w)$ as

$$I_{\tilde{A}}(\bar{x}_0,\bar{y}_0)=\left(\frac{\alpha\left(\frac{a+2b}{3}\right)+\beta\left(\frac{b+c}{2}\right)+\gamma\left(\frac{2c+d}{3}\right)}{\alpha+\beta+\gamma},\frac{\alpha\left(\frac{w}{3}\right)+\beta\left(\frac{w}{2}\right)+\gamma\left(\frac{w}{3}\right)}{\alpha+\beta+\gamma}\right) \tag{19}$$

Here

$$\alpha=\frac{\sqrt{(c-3b+2d)^2+w^2}}{6}$$

$$\beta=\frac{\sqrt{(2c+d-a-2b)^2}}{3}$$

$$\gamma=\frac{\sqrt{(3c-2a-b)^2+w^2}}{6}$$

As a special case, for triangular fuzzy number $\tilde{A}=(a,b,c,d;w)$, i.e. $c=b$ the incentre of Centroids is given by

$$I_{\tilde{A}}(\bar{x}_0,\bar{y}_0)=\left(\frac{x\left(\frac{a+2b}{3}\right)+yb+z\left(\frac{2b+d}{3}\right)}{x+y+z},\frac{x\left(\frac{w}{3}\right)+y\left(\frac{w}{2}\right)+z\left(\frac{w}{3}\right)}{x+y+z}\right) \tag{20}$$

Here

$$x=\frac{\sqrt{(2d-2b)^2+w^2}}{6}$$

$$y = \frac{\sqrt{(d-a)^2}}{3}$$

$$z = \frac{\sqrt{(2b-2a)^2 + w^2}}{6}$$

The ranking function of the generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, which maps the set of all fuzzy numbers to a set of real numbers is defined as,

$$R(\tilde{A}) = x_0 \times y_0 = \left(\frac{x\left(\frac{a+2b}{3}\right) + yb + z\left(\frac{2b+d}{3}\right)}{x+y+z} \times \frac{x\left(\frac{w}{3}\right) + y\left(\frac{w}{2}\right) + z\left(\frac{w}{3}\right)}{x+y+z} \right) \quad (21)$$

This is the Area between the incenter of the centroids $I_{\tilde{A}}(\bar{x}_0, \bar{y}_0)$ as defined in Eq. (19) and the original point.

The Mode (m) of the generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$m = \frac{1}{2}\int_0^w (b+c)dx = \frac{w}{2}(b+c) \quad (22)$$

The Spread(s) of the generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$s = \int_0^w (d-a)dx = w(d-a) \quad (23)$$

The left spread (ls) of thegeneralized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$ls = \int_0^w (b-a)dx = w(b-a) \quad (24)$$

The right spread (rs) of thegeneralized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$, is defined as:

$$rs = \int_0^w (d-c)dx = w(d-c) \quad (25)$$

Using the above definitions we now define the ranking procedure of two generalized trapezoidal fuzzy numbers.

Let $\tilde{A} = (a_1, b_1, c_1, d_1; w_1)$ and $\tilde{B} = (a_2, b_2, c_2, d_2; w_2)$ be two generalized trapezoidal fuzzy numbers.

The working procedure to compare $\tilde{A}$ and $\tilde{B}$ is as follows:

Step 1: Find $R(\tilde{A})$ and $R(\tilde{B})$

Case (i) If $R(\tilde{A}) > R(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii) If $R(\tilde{A}) < R(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $R(\tilde{A}) = R(\tilde{B})$ comparison is not possible, then go to ***step 2***.

Step 2: Find $m(\tilde{A})$ and $m(\tilde{B})$

Case (i) If $m(\tilde{A}) > m(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii)If $m(\tilde{A}) < m(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $m(\tilde{A}) = m(\tilde{B})$ comparison is not possible, then go to ***step 3***.

Step 3: Find $s(\tilde{A})$ and $s(\tilde{B})$

Case (i) If $s(\tilde{A}) > s(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (ii)If $s(\tilde{A}) < s(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (iii) If $s(\tilde{A}) = s(\tilde{B})$ comparison is not possible, then go to ***step 4***.

Step 4: Find $ls(\tilde{A})$ and $ls(\tilde{B})$

Case (i) If $ls(\tilde{A}) > ls(\tilde{B})$ then $\tilde{A} > \tilde{B}$

Case (ii)If $ls(\tilde{A}) < ls(\tilde{B})$ then $\tilde{A} < \tilde{B}$

Case (iii) If $ls(\tilde{A}) = ls(\tilde{B})$ comparison is not possible, then go to ***step 5***.

Step 5: Examine w_1 and w_2

Case (i) If $w_1 > w_2$ then $\tilde{A} > \tilde{B}$

Case (ii) If $w_1 < w_2$ then $\tilde{A} < \tilde{B}$

Case (iii) If $w_1 = w_2$ then $\tilde{A} \approx \tilde{B}$

3. Proposed Appraisement Module

A fuzzy based service quality and performance appraisement module proposed in this paper has been present below. General hierarchy criteria (GHC) for evaluating overall service quality in relation to the hostel mess, adapted in this paper has been shown in Table 1. It consists of two-level index system; which aims at achieving the target to evaluate overall appraisement index. 1st level lists out a number of evaluation indices: tangibility, reliability, responsiveness, assurance and empathy; 2nd level comprises of various sub-indices. Procedural steps for quality and performance evaluation have been presented as follows:

1. Selection of linguistic variables towards assigning priority weights (of individual evaluation indices both at 1st as well as 2nd level) and appropriateness rating (performance extent) corresponding to each 2nd level sub-indices.

2. Collection of expert opinion from a selected decision-making group (subjective judgment) in order to express the priority weight as well as appropriate rating against each of the evaluation indices.

3. Representing decision-makers' linguistic judgments using appropriate fuzzy numbers set.

4. Use of fuzzy operational rules towards estimating aggregated weight as well as aggregated rating (pulled opinion of the decision-makers) for each of the evaluation index.

5. Calculation of computed performance rating of individual 1st level evaluation indices and finally overall performance index called Fuzzy Performance Index (FPI).

Appropriateness rating for each of the 1st level evaluation index U_i (rating of i_{th} 1st level index) has been computed as follows:

$$U_i = \frac{\sum U_{ij} \otimes w_{ij}}{\sum w_{ij}} \tag{26}$$

In this expression (Eq. 26) U_{ij} is denoted as the aggregated fuzzy appropriateness rating against j_{th} sub-index (at 2nd level) which is under i_{th} main index in the 1st level. w_{ij} is the aggregated fuzzy weight against j_{th} sub-index (at 2nd level) which is under i_{th} main index in 1st level.

The *Fuzzy Performance Index (FPI)* has been computed as:

$$U(FPI) = \frac{\sum U_i \otimes w_i}{\sum w_i} \tag{27}$$

In this expression (Eq. 27) U_i is denoted as the computed fuzzy appropriateness rating (obtained using Eq. 26) against i_{th} at 1st level main index. w_i is the aggregated fuzzy priority weight against i_{th} 1st level main index.

6. Investigation for identifying ill-performing areas those seek for future improvement.

4. Numerical Illustrations

The proposed appraisement module has been implemented in a hostel mess at NIT Rourkela, India. The module encompasses of various evaluation indices at different levels. An evaluation team has been deployed to assign priority weights (importance extent) against different evaluation indices considered in the proposed appraisement model. A questionnaire has been formed and circulated among the decision-makers (experts) to provide the required detail. Collected data has been explored to investigate application feasibility of the proposed appraisement platform. After critical investigation and scrutiny each decision-maker has been instructed to explore the linguistic scale (Table 2) towards assignment of priority weight and appropriateness rating against each evaluation indices. Appropriateness rating for 2nd level sub-indices has been furnished in Table 3. Tables 4-5 provide subjective judgment of the evaluation team members expressed through linguistic terms in relation to weight assignment against various evaluation indices (both at 1st and 2nd level), respectively. These linguistic expressions (human judgment) have been converted into appropriate generalized trapezoidal fuzzy numbers as presented in Table 2. The method of *simple average* has been used to obtain aggregated priority weights and aggregated ratings of 2nd level sub-indices (Tables 6). Computed fuzzy performance ratings (obtained by using Eqs. 27) and aggregated fuzzy priority weight for 1st level main indices and tabulated in Table 7. Finally, Eq. 28 has been used to obtain overall FPI.

Overall FPI thus becomes: (0.036, 0.589, 3.478).

The concept of '*Ranking of fuzzy numbers*' [Thorani et al. (2012)] has been adapted here to indentify ill-performing areas in relation to hostel mess service. 2nd level sub-indices have been ranked based on their individual *Fuzzy Performance Importance Index* (FPII) [Lin et al., 2006]. It has been computed as follows:

$$FPII_j = \left[1 - w_{ij}\right] \otimes U_{ij} \tag{28}$$

Here $FPII_j$ is denoted as the *Fuzzy Performance Importance Index* of j_{th} sub-index; whose aggregated performance rating is U_{ij} and aggregated priority weight w_{ij}. The equivalent crisp measure corresponding to $R(FPII_{Individual})$ has been computed; thus, 2nd level sub-indices have been ranked accordingly (Table 8).

5. Conclusions

The present work proposes to develop a service quality model in relation to a hostel mess, which describes how the quality of services is perceived by customers. The work examines that quality dimensions are interrelated and that the importance of image should be recognized.

The contribution of this research has been furnished below.

1. Development of fuzzy-based integrated service quality and performance appraisement module in relation to a hostel mess. Industries/ enterprises/ service sectors can utilize this appraisement module as a test kit to assess and improve overall performance extent.
2. Estimation of overall performance index; identification of ill-performing areas.
3. Based on estimated overall performance index; different service sectors (of similar type: hostel mess in the present case) can be ranked accordingly (benchmarking).

6. References

1. S.S. Andaleeb and C. Conway, 'Customer satisfaction in the restaurant industry: an examination of the transaction-specific model', *Journal of Services Marketing*, 20/1 (2006) 3–11.
2. I. Hau-siu Chow, V.P. Lau, T. Wing-chun Lo, Z. Sha, H. Yun, 'Service quality in restaurant operations in China: Decision- and experiential-oriented perspectives', *Hospitality Management*, 26 (2007) 698–710.
3. L. Ko, and K. Har, 'Service dimensions of service quality impacting customer satisfaction of fine dining restaurants in Singapore', Master in Hospitality Administration, William F. Harrah College of Hotel Administration, Graduate School, University of Nevada Las Vegas, January 2008.

4. D. Xue, Q. Zhao, and X. Guo, ‘TOPSIS Method for Evaluation Customer Service Satisfaction to Fast Food Industry’, ©2008 IEEE.
5. S. Markovic, S. Raspor, and K. Šegaric, ‘Does Restaurant Performance Meet Customers’ Expectations? An Assessment Of Restaurant Service Quality Using A Modified Dineserv Approach’, *Tourism and Hospitality Management*, 16/2 (2010) 181-195.
6. Shi Yu-Qiang, Wang Jun-Jia ©2011 IEEE, ‘Evaluation of Service Quality of Restaurant Enterprise Based on SERVQUAL’.
7. S.A. Al Khattab, J.S. Aldehayyat, ‘Perceptions of Service Quality in Jordanian Hotels’, *International Journal of Business and Management*, 6/7 (2011) 226-233.
8. F. Mola and J. Jusoh, ‘Service Quality in Penang Hotels: A Gap Score Analysis’, World *Applied Sciences Journal 12 (Special Issue of Tourism & Hospitality)*, (2011) 19-24.
9. H. Min, and H. Min, ‘Benchmarking the service quality of fast-food restaurant franchises in the USA: A longitudinal study’, *Benchmarking: An International Journal*, 18/2 (2011) 282 – 300.
10. M. Haghighi, A. Dorosti, A. Rahnama and A. Hoseinpour, ‘Evaluation of factors affecting customer loyalty in the restaurant industry’, African Journal of Business Management, 6(14) (2012) 5039-5046.
11. A. Ihtiyar, Fauziah Sh. Ahmad□ □and Mohd Hassan Mohd Osman, Determinant Factors of Perceived Service Quality in the Food Retail Industry of Turkey, 2012 International Conference on Economics, Business Innovation IPEDR vol.38 (2012) © (2012) IACSIT Press, Singapore.

12. A Nicolaides, Service quality provision in upmarket restaurants: a survey of diners in three restaurants in a Gauteng casino complex, African Journal of Hospitality, Tourism and Leisure Vol. 2 (2) - (2012), pp. 1-21.

13. Seung Ah Yoo, Customer Perceptions of Restaurant Cleanliness: A Cross Cultural Study, Master of Science In Hospitality and Tourism Management, July 9, 2012, Blacksburg, Virginia.

14. Zadeh, L.A., 1965, "Fuzzy sets, Information and Control", Vol. 8, No. 3, pp. 338–353.

15. Zadeh, L.A., 1975, "The concept of a linguistic variable and its application to approximate reasoning-I and II", *Information Sciences*, Vol. 8, No. 3(I) 4(II), pp. 199–249(I) 301–357(II).

16. Buckley, J.J., 1985, "Fuzzy hierarchical analysis", *Fuzzy Sets and Systems*, Vol. 17, No. 3, pp. 233–247.

17. Negi, D.S., 1989, "Fuzzy analysis and optimization", *Ph.D. Dissertation, Department of Industrial Engineering*, Kansas State University.

18. Kaufmann, A., and Gupta, M.M., 1991, "Introduction to Fuzzy Arithmetic: Theory and Applications". *Van Nostrand Reinhold Electrical/Computer Science and Engineering* Series, New York.

19. Klir, G.J., and Yuan, B., 1995, "Fuzzy Sets and Fuzzy Logic: Theory and Applications", Prentice-Hall Inc., USA.

20. Zimmermann, H.J., 1991, "Fuzzy Set Theory and its Applications", second eds. *Kluwer Academic Publishers,* Boston, Dordrecht, London.

21. Moeinzadeh, P., and Hajfathaliha, A., 2010, "A Combined Fuzzy Decision Making Approach to Supply Chain Risk Assessment", *International Journal of Human and Social Sciences*, Vol. 5, No. 13, pp. 859-875.

22. Chen, S.H., 1985, "Ranking fuzzy numbers with maximizing set and minimizing set", *Fuzzy Sets and Systems*, Vol. 17, No. 2, pp. 113-129.

23. Chen, S.M., and Chen, J.H., 2009, "Fuzzy risk analysis based on ranking generalized fuzzy numbers with different heights and different spreads", Expert Systems with Applications, Vol. 36, No. 3, pp. 6833-6842.

24. Chen, S.J., and Chen, S.M., 2003, "A new method for handing multi-criteria fuzzy decision-making problems using FN-IOWA operators", Cybernetics and Systems, Vol. 34, No.2, pp. 109-137.

25. Y. L. P. Thorani, P. Phani Bushan Rao and N. Ravi Shankar, Ordering Generalized Trapezoidal Fuzzy Numbers, Int. J. Contemp. Math. Sciences, Vol. 7, 2012, no. 12, 555 – 573.

26. Ching-Torng Lin, Hero Chiu, Po-Young Chu, Agility index in the supply chain, International Journal of Production Economics, Volume 100, Issue 2, April 2006, Pages 285–299.

Table 1: A Fuzzy Based Performance Appraisement Module for Mess Service Quality Evaluation in Hostels

Goal	1st level main indices	2nd level sub-indices
Mess service quality and performance, C	Tangibility, C_1	Comfortable environment, C_{11}
		Dish tastes good (Food Quality: fresh, hot served, well cooked, well presented), C_{12}
		Reasonable charge, C_{13}
		Dishes quantity enough (Food Quantity), C_{14}
		Staff appearance clean and tidy/ Employee cleanliness and tidiness, C_{15}
	Reliability, C_2	Timely perform commitment, C_{21}
		Staff is enthusiasm, C_{22}
		Service is appropriate, C_{23}
	Responsiveness, C_3	Service time, C_{31}
		Speedy service, C_{32}
		Service initiative, C_{33}
		Prompt in meeting all promises, C_{34}
	Assurance, C_4	Staff is polite (Employee politeness/ behavioral characteristic friendly and courteous), C_{41}
		Mess sanitation, C_{42}
		Mess safety, C_{43}
		Ability to recover mistakes, C_{44}
		Care about customer complaints, C_{45}
	Empathy, C_5	Category of dishes enough (Product/ food variety), C_{51}
		Solve customer's problem timely (Problem solving capability), C_{52}
		Understand customer (Customer understanding), C_{53}
		Business time is reasonable, C_{54}
		Employees are empowered to provide compensations for inaccurate service, C_{55}

Table 2: Five-member linguistic terms and their corresponding fuzzy numbers

Linguistic terms for weight assignment	Linguistic terms for ratings	fuzzy numbers
Very low, VL	Very poor, VP	(0.0, 0.0, 0.25)
Low, L	Poor, P	(0.0, 0.25, 0.5)
Medium, M	Medium, M	(0.25, 0.5, 0.75)
High, H	Satisfactory, S	(0.5, 0.75, 1.0)
Very High, VH	Extremely Satisfactory, ES	(0.75, 1.0, 1.0)

Table 3: Appropriateness rating (in linguistic scale) of 2nd level indices assigned by DMs

2nd level indices	Appropriateness rating (in linguistic scale) of 2nd level indices assigned by DMs															
	DM21	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	DM12	DM13	DM14	DM15	DM16
C_{11}	M	S	S	VP	M	M	S	M	M	M	M	VP	M	S	M	M
C_{12}	S	S	M	P	P	VP	M	M	M	P	S	P	P	P	P	P
C_{13}	M	P	ES	M	VP	P	M	M	S	VP	ES	P	P	P	P	S
C_{14}	S	P	P	S	VP	VP	P	M	S	VP	P	P	M	P	M	S
C_{15}	P	S	M	S	M	ES	S	S	M	M	S	S	M	S	M	M
C_{21}	P	S	M	M	M	P	S	S	P	M	M	S	M	S	M	M
C_{22}	M	M	M	P	M	S	M	M	M	M	M	M	P	P	P	P
C_{23}	P	M	M	P	M	M	M	S	M	M	M	M	P	P	P	P
C_{31}	S	P	M	VP	M	P	P	S	P	M	S	S	P	S	M	M
C_{32}	P	VP	M	P	P	P	P	S	S	P	M	M	M	M	M	S
C_{33}	M	P	M	P	P	M	P	S	S	P	M	P	P	VP	M	M
C_{34}	P	VP	P	M	VP	VP	M	S	M	VP	M	P	P	VP	P	P
C_{41}	M	VP	M	P	VP	VP	VP	S	M	VP	M	M	M	S	M	M
C_{42}	S	ES	S	S	M	M	M	M	M	M	S	S	M	S	S	M
C_{43}	S	S	S	P	S	M	S	S	M	S	S	S	P	S	S	S
C_{44}	P	P	P	VP	VP	M	M	M	M	VP	P	P	M	M	P	P
C_{45}	P	VP	P	VP	P	P	M	P	P	P	VP	VP	P	VP	P	P
C_{51}	M	VP	VP	S	VP	M	P	M	P	VP	M	P	P	VP	S	M
C_{52}	P	VP	P	VP	P	P	P	P	P	P	P	P	M	VP	P	P
C_{53}	S	P	P	VP	VP	M	M	M	M	VP	P	P	P	P	P	P
C_{54}	M	VP	P	S	VP	P	P	S	M	VP	M	VP	M	P	P	M
C_{55}	M	VP	P	VP	P	M	M	P	M	P	M	P	M	M	M	M

Table 4: Priority Weight (in linguistic scale) of 2nd level indices assigned by DMs

2nd level indices	Priority Weight (in linguistic scale) of 2nd level indices assigned by DMs															
	DM21	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	DM12	DM13	DM14	DM15	DM16
C_{11}	M	H	H	VH	H	M	M	M	M	M	H	M	M	M	M	M
C_{12}	M	VH	H	VH	VH	VH	H	VH	H	VL	H	H	H	H	M	H
C_{13}	M	H	VH	H	M	M	H	M	M	VH	VH	M	M	M	L	M
C_{14}	M	VH	H	M	H	H	M	M	H	VL	M	H	M	H	L	M
C_{15}	L	VH	H	H	VH	VH	H	H	VH	M	H	M	H	M	M	H
C_{21}	H	H	M	M	H	M	M	VH	H	H	VH	L	VH	L	M	H
C_{22}	H	H	H	M	M	M	M	H	M	M	H	M	M	M	M	M
C_{23}	H	VH	H	H	VH	H	H	H	L	VL	H	M	H	M	M	M
C_{31}	M	VH	M	H	H	H	M	H	H	L	H	L	M	L	L	M
C_{32}	H	VH	M	H	M	H	M	H	H	M	M	L	M	L	M	H
C_{33}	L	VH	H	VH	H	M	M	H	H	L	H	L	M	M	L	M
C_{34}	L	VH	H	H	VH	H	H	VH	H	VL	H	M	H	H	L	VH
C_{41}	L	VH	H	H	VH	H	M	H	H	L	VH	H	M	M	M	H
C_{42}	M	VH	H	VH	M	M	H	VH	H	M	M	M	H	H	H	VH
C_{43}	M	H	H	VH	H	M	H	M	H	M	M	H	M	H	M	M
C_{44}	L	H	VH	VH	VH	H	H	H	H	VL	M	H	H	M	M	H
C_{45}	L	VH	VH	H	VH	VH	H	H	M	VL	M	H	M	H	VL	H
C_{51}	M	VH	H	H	H	M	H	M	M	L	M	H	M	H	M	M
C_{52}	L	VH	VH	VH	VH	H	H	H	M	L	M	M	M	M	L	M
C_{53}	L	VH	VH	M	VH	H	H	H	H	VL	M	M	L	H	L	H
C_{54}	M	H	H	H	M	H	M	H	M	M	H	H	L	M	L	M
C_{55}	M	VH	H	VH	H	H	H	M	H	L	M	M	M	M	M	M

Table 5: Priority Weight (in linguistic scale) of 1st level indices assigned by DMs

1st level indices	Priority Weight (in linguistic scale) of 1st level indices assigned by DMs															
	DM21	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	DM12	DM13	DM14	DM15	DM16
C_1	M	H	H	H	M	H	H	M	M	M	H	M	M	M	M	H
C_2	H	H	M	H	L	H	M	H	H	L	H	M	H	M	M	M
C_3	M	VH	H	H	L	H	M	H	M	L	M	L	M	L	L	M
C_4	M	H	H	VH	M	M	H	H	M	M	H	H	M	H	M	H
C_5	H	VH	VH	H	L	M	H	H	H	L	H	M	L	M	M	M

Table 6: Aggregated Fuzzy Priority Weight and Aggregated Fuzzy Rating of 2nd level indices

2nd level indices	Aggregated Fuzzy Priority Weight, w_{ij}	Aggregated Fuzzy Rating, U_{ij}
C_{11}	(0.344,0.594,0.828)	(0.281,0.500,0.750)
C_{12}	(0.516,0.750,0.922)	(0.156,0.391,0.641)
C_{13}	(0.375,0.625,0.828)	(0.219,0.438,0.656)
C_{14}	(0.344,0.578,0.813)	(0.172,0.375,0.625)
C_{15}	(0.469,0.719,0.906)	(0.375,0.625,0.859)
C_{21}	(0.406,0.656,0.859)	(0.281,0.656,0.781)
C_{22}	(0.328,0.578,0.828)	(0.186,0.438,0.688)
C_{23}	(0.406,0.641,0.859)	(0.172,0.422,0.672)
C_{31}	(0.313,0.563,0.797)	(0.234,0.469,0.719)
C_{32}	(0.344,0.594,0.828)	(0.188,0.469,0.672)
C_{33}	(0.328,0.578,0.797)	(0.156,0.391,0.641)

C_{34}	(0.453,0.688,0.875)	(0.098,0.266,0.516)
C_{41}	(0.422,0.650,0.875)	(0.188,0.391,0.609)
C_{42}	(0.406,0.719,0.906)	(0.391,0.641,0.875)
C_{43}	(0.391,0.641,0.875)	(0.406,0.625,0.906)
C_{44}	(0.438,0.672,0.875)	(0.094,0.297,0.547)
C_{45}	(0.422,0.641,0.828)	(0.016,0.188,0.438)
C_{51}	(0.359,0.609,0.844)	(0.141,0.303,0.563)
C_{52}	(0.375,0.625,0.813)	(0.016,0.219,0.469)
C_{53}	(0.375,0.609,0.813)	(0.094,0.297,0.547)
C_{54}	(0.328,0.578,0.828)	(0.141,0.328,0.578)
C_{55}	(0.375,0.625,0.844)	(0.141,0.359,0.609)

Table 7: Aggregated Fuzzy Priority Weight and Computed Fuzzy Rating of 1st level indices

1st level indices	Aggregated Fuzzy Priority Weight, w_i	Computed Fuzzy Rating, U_i
C_1	(0.359,0.609,0.859)	(0.115,1.287,1.485)
C_2	(0.344,0.594,0.844)	(0.096,0.509,1.595)
C_3	(0.266,0.516,0.750)	(0.071,0.393,1.455)
C_4	(0.406,0.656,0.891)	(0.102,0.432,1.424)
C_5	(0.359,0.609,0.828)	(0.046,0.303,1.266)

Table 8: Ranking order of 2nd level indices

2nd level indices	FPII	Crisp Value	Ranking Order
C_{11}	(0.184,0.203,0.129)	0.064	3
C_{12}	(0.076,0.098,0.050)	0.029	18
C_{13}	(0.137,0.164,0.113)	0.051	9
C_{14}	(0.113,0.158,0.117)	0.048	11
C_{15}	(0.199,0.176,0.081)	0.058	6
C_{21}	(0.167,0.226,0.110)	0.068	2
C_{22}	(0.125,0.185,0.118)	0.055	8
C_{23}	(0.102,0.151,0.095)	0.045	12
C_{31}	(0.161,0.205,0.146)	0.063	4
C_{32}	(0.123,0.190,0.116)	0.056	7
C_{33}	(0.105,0.165,0.130)	0.050	10
C_{34}	(0.054,0.083,0.065)	0.025	20
C_{41}	(0.109,0.137,0.076)	0.041	14
C_{42}	(0.232,0.180,0.082)	0.062	5
C_{43}	(0.247,0.224,0.113)	0.075	1
C_{44}	(0.053,0.097,0.068)	0.029	19
C_{45}	(0.009,0.067,0.075)	0.020	22
C_{51}	(0.090,0.118,0.088)	0.036	16
C_{52}	(0.010,0.082,0.088)	0.025	21
C_{53}	(0.059,0.116,0.102)	0.036	17
C_{54}	(0.095,0.138,0.099)	0.042	13
C_{55}	(0.088,0.135,0.095)	0.040	15