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Measuring Customer Satisfaction Using a Fuzzy Inference System

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Abstract: This study presents a new method called FCSMM (Fuzzy Customer Satisfaction Measurement Method) for measuring individual customer satisfaction using a fuzzy inference system. The main advantage of this method is its simplification in evaluation of Customer Satisfaction Index (CSI) based on simple linguistic statements collected from experienced people. In contrast with assumptions used in other methods such as linear regression principles and predefined criteria weights, the aforementioned statements form the FCSMM computational structure. Since the drivers of satisfaction and dissatisfaction and performance indexes can be simultaneously applied, concurrent direct and indirect customer satisfaction measurement is provided by the model. A set of average indexes is proposed for calculation of total CSI and average satisfaction index for each driver. Other analytical tools are applied to analyze results of this method. An example is provided in this study to demonstrate the implementation process of FCSMM.

Key words: Customer satisfaction index, inference engine, linguistic statement, rule base

INTRODUCTION

To be successful in the competitive marketplace, companies need to be more profitable and therefore should have more customers. If customers are satisfied by the company's products and services, they will try to keep their relationships with company and this makes profit. Hence the customer satisfaction is a key concern for all successful organizations. Customer satisfaction secures the customer loyalty and this generates superior long term financial performance for the organization (Jones and Sasser, 1995).

A variety of definitions for customer satisfaction has been adopted worldwide (Zeithaml *et al*., 1993; Oliva *et al*., 1995; Jones and Sasser, 1995; Ostrom and Iacobucci, 1995). In general, customer satisfaction is the degree of happiness that a customer experiences with a company's products or services resulting from the interaction and interrelationship of all people within the company (Desatnick, 1992).

For better financial and competitive situation in future, it is essential to evaluate the customer satisfaction. Quantitative methods and data analysis techniques (e.g., descriptive statistics, multiple regression analysis, factor analysis, probit-logit analysis, discriminant analysis, conjoint analysis and other statistical quantitative methods such as DEA, cluster analysis, probability-plotting methods), quality approach (e.g., Malcolm Baldridge award, European quality model, Ideal point approach, servqual), consumer behavioral analysis (e.g., expectancy disconfirmation model, equity theory, regret theory, motivation theories) and other methodological approaches (e.g., customer loyalty, Kano's model, Fornell's model) are the most important approaches among the others for measuring customer satisfaction (Grigoroudis and Siskos, 2002).

As shown in the above classification, several models and methods with different mathematical tools are used to evaluate customer satisfaction for each specific case. Usually the statistical methods are based on the size of surveyed customers. In some cases, increasing the number of surveyed customers may lead to infeasibility of mathematical model. These shortcomings are addressed in the proposed method.

A considerable amount of customer satisfaction measurement in the literature was focused on individual level known as disaggregate satisfaction based on the consumer behavior. Some of these methods such as multi criteria satisfaction analysis also aggregate the results of individuals to produce a market level satisfaction (Grigoroudis and Siskos, 2002). The proposed method, called FCSMM (Fuzzy Customer Satisfaction Method), is focused on the individuals using two new indexes for aggregation of results.

The proposed method is used a fuzzy inference system for measuring the degree of a specific customer satisfaction for a specific service or product. Because of the extensive area of fuzzy concept and its literature, the

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related materials are not discussed in this study as fundamentals and principles of fuzzy set theory, fuzzy inference systems and related topics are well presented and by Zadeh (1965, 1971, 1975a, b, c, 1978) and Zimmermann (1993).

Briefly, the objective of this study is to proposed a new method called FCSMM which is used a fuzzy inference process to evaluate the level of satisfaction for an individual customer.

METHOD DESCRIPTION

Basic concepts: There are countless vague concepts that can be easily described, understood and used in our daily communication. However, the traditional mathematics, including the set theory, is not realistically able to describe them as customer satisfaction may not be confidently adopted to a mathematical grade. In other words, customer satisfaction may be described using a simple statement used in our daily conversation. For instance, satisfaction level of an individual customer can be described as *high* instead of an exact number. In the same way, satisfaction or dissatisfaction drivers and performance indexes can also be considered as vague concepts. As mentioned in the literature, fuzzy sets enable to represent vague concepts expressed in natural language. Therefore, several fuzzy sets for customer satisfaction, drivers (criteria) and performance indexes can be defined. Consequently, a fuzzy method can be used for measuring customer satisfaction.

In contrast with the traditional methods, where assumptions such as linear regression principles and predefined criteria weights are used, the key advantages of FCSMM is to employ experts' knowledge and experiences as a basis for its computational structure. The knowledge is contributed into this method using linguistic IF-THEN statements. For example, if quality of product is low and the price is high then the customer satisfaction will be low. A set of similar fuzzy production rules, known as knowledge base, is used in the main core as the body of FCSMM computation.

Finally, the knowledge base leads to design an inference engine that transforms the input of FCSMM (value of drivers and performance indexes) to output (level of customer satisfaction). In other words, all of computational comments are done by inference engine according to the knowledge which is formed by simple IF-THEN rules.

Instruction: The following instruction has been adapted to the FCSMM method to evaluate customer satisfaction index:

1. Articulate the knowledge on customer satisfaction in terms of simple IF-THEN rules
2. Specify the inputs of problem in the rule base, e.g., drivers of satisfaction or dissatisfaction, performance indexes
3. Fuzzify the inputs of problem, e.g., drivers of satisfaction
4. Fuzzify the output of problem, i.e., customer satisfaction
5. Determine the data gathering procedure
6. Redesign the rule base and change the inputs if needed
7. Design the inference engine and find the output fuzzy set
8. Defuzzify the output fuzzy set

Since a Fuzzy Inference Process is used in FCSMM to evaluate the Customer Satisfaction Index (CSI), some of the above steps are similar to the steps considered in fuzzy inference processes. It should be noted that the aforementioned steps, especially steps 1 to 4, have some overlap and may be conducted simultaneously. So specifying a crisp boundary for them is not desirable. Further information on the aforementioned steps is provided in the following sections.

Articulate the knowledge about customer satisfaction: The first step is to collect information on customers, their expectations, company's business situation, market condition and etc. It helps to draw a map of customers thought about the company, its products and drivers of his/her satisfaction and dissatisfaction. Generally, people who are involved in customer relationships, e.g., retailers, salespersons and marketing personnel, have some worthy knowledge and experiences that can be translated to some simple rules and form the knowledge. This collection of rules is called rule base. This step aims to formulate some true IF-THEN statements to form the rule base and describe customers thought about their satisfaction. Many useful statements can be found in terms of simple IF-THEN rules that can relate the drivers of satisfaction or dissatisfaction and performance indexes to the level of customer satisfaction. For example, the statement *more quality leads to more satisfaction* can be translated to *IF quality is high THEN satisfaction is high.*

In addition, results of previous research can be adopted into the proposed method to enrich the knowledge as linguistic statements are generally used in previous findings. Hanan and Karp (1989), Armistead and Clark (1994), Hradesky (1995) and Sharma *et al.* (1999) presented some worthy findings which can be used to form a rich rule base according to identified drivers and performance indexes.

As mentioned by Mihelis *et al.* (2001), the following questions may be useful in this step:

- Which are the satisfaction drivers and which is their impact on customer behavior?
- Which is the satisfaction level according to the characteristics to the provided service?
- Which are the weak and strong points of the company?

Note that interviews and informal discussions (with involved people, industry informants, experts and ...), archival data, complaints, annual reports, minutes of meetings, company statistics and information together with other data collection techniques can be also used to form the knowledge base.

More accurate information leads to more detailed set of IF-THEN rules, but it is not necessary to investigate all details at the first time. A simple model can be set up first and be improved later as the experience increases and the knowledge enriches.

The gathered knowledge can be articulated in terms of simple IF-THEN rules, linguistically as:

IF (antecedent) THEN (consequence)

Or in fuzzy form as:

If x is A then y is C

where, A and *C* are linguistic values defined by fuzzy sets on the ranges of X and Y, respectively. An example of such a rule might be

If *quality* is *high* then *customer* is *satisfied*

It is important to note that the antecedent and consequence can have multiple parts, like

If (quality is high) AND (service is good) then customer is very satisfied

In these cases all parts should be considered simultaneously using fuzzy operators or implication functions.

Finally it should be noted that these rules would produce an approximate decision, just a customer would. It means that the rule base should be rich enough to simulate the behavior of customers in experience of company's product or services. On the other hand, more rules are not necessarily going to improve the quality of inference process performance. In other words, the number of rules, their combination and selection of appropriate ones are the most important things in this step which needs the analyst knowledge and experience.

Specify the inputs of problem in the rule base: Also this step is considered as the second step but it has some overlap with step 1. The aim of this step is to find the inputs of problem in the knowledge base representing by the rule base. Let the set of satisfaction drivers (inputs) and *i*th member of it are denoted as D and d_i, respectively. As mentioned earlier in this document, the antecedent of a rule consists of at least one part. Each part is defined by a member of D and a linguistic variable specified by a fuzzy set. In this step each item of antecedents should be only specified. For example, if it identifies that customer satisfaction can be effected by quality, after sale service and price; it may be defined as follows:

D = {quality, aftersale service, price}

Fuzzify the inputs of problem: The drivers of satisfaction, drivers of dissatisfaction and performance indexes are considered as inputs of fuzzy inference process. In order to describe a real world measurement as a fuzzy label, it is essential to define two or more fuzzy sets on that particular input (variable). The fuzzification process is finished once the number of linguistic terms has been clarified, their shape was specified and the complete set of fuzzy membership functions was achieved.

Membership functions represent a degree of membership between 0 and 1 to each element of a fuzzy set. Whilst membership functions relate the input space to linguistic sets, the values of membership function show the degree of membership for that set. Therefore, fuzzification refers to selecting a suitable membership function for each element of a fuzzy set.

Every function that varies between 0 and 1 can be considered as a membership function. Fuzzy software usually provides some well known membership functions, e.g., triangular, trapezoidal, Gaussian and let the users to define more. In addition, some studies have been conducted on selecting the shape of membership functions and neurofuzzy networks are used to compute the membership function parameters in some cases. In general, two questions should be considered: (a) how many sets are necessary and sufficient? (b) How should the shape of sets be determined? According to fuzzy sets theory the choice of the shape and width are subjective, but the following points may be useful:

- A term set should be sufficiently wide to cover possible noise in the measurement
- A certain amount of overlap is desirable

Consequently, desired membership functions based on its simplicity and nature of the problem can be arbitrarily chosen. It should be mentioned there are some methods (e.g., indirect methods, sample data) in fuzzy

Table 1 : Membership functions formulas

Triangular	Trapezoidal	Gaussian
$f(x;a,b,c)=\begin{cases} 0 & x\le a \\ \frac{x-a}{b-a} & a\le x\le b \\ \frac{c-x}{c-b} & b\le x\le c \\ 0 & c\le x \end{cases}$	$f(x;a,b,c,d)=\begin{cases} 0 & x\le a \\ \frac{x-a}{b-a} & a\le x\le b \\ 1 & b\le x\le c \\ \frac{d-x}{d-c} & c\le x\le d \\ 0 & d\le x \end{cases}$	$f(x;a,\sigma)=e^{\frac{-(x-a)^2}{2\sigma^2}}$

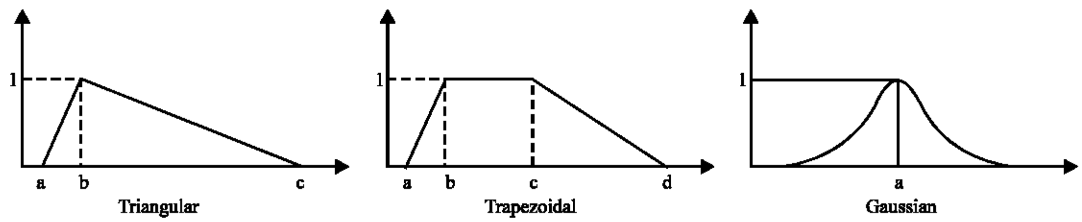

Fig. 1: The shape of membership functions in Table 1

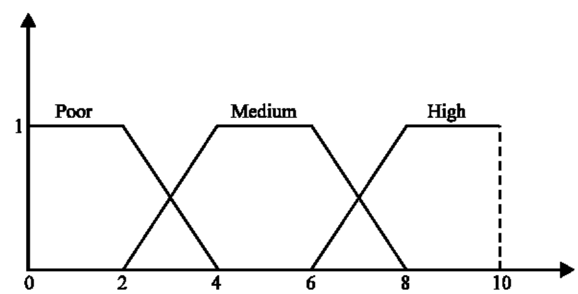

Fig. 2: An example of fuzzified quality

literature to define membership functions. However, they reduce this arbitrariness. Triangular, trapezoidal and Gaussian membership function formulas and their shape, which are used in this study, are presented in Table 1 and Fig. 1, respectively.

Suppose D = {quality, aftersale service, price} and the set of linguistic labels associated with d_i is denoted as Ld_i. Hence, for the first member of D, i.e., quality, we have Ld_i = {Poor, Medium, High}. Now a membership function ($\mu_{LDij}(x)$) should be assigned to jth element of Ld_i. Figure 2 shows one way to fuzzify *quality*. It should be noted at this stage that the range of each membership function can be defined arbitrary according to the supposed interval which is considered for fuzzified variable. This range can be adjusted in the inference process if needed.

Fuzzify the output of problem: Individual customer satisfaction level is considered as the output of this problem. Therefore, the fuzzy inference process of FCSMM has one output and n(D) inputs. Fuzzification of satisfaction is similar to fuzzification of inputs. In other words, a set of linguistic labels should be firstly defined for satisfaction denoted as S. Subsequently, the membership function for each element of S and μ_{Si} should be specified.

Determine the data gathering procedure: The aim of this step is to select the appropriate way for collecting the input values for each specific driver. These input values can be collected directly from customers or indirectly from performance indexes according to the nature of defined drivers.

The most common direct way is questionnaire though other direct ways such as interviews, mail and email are possible. One question is usually considered for each driver. Preparing a consistent family of questions depends on several parameters especially the adequacy of drivers. It should be considered when designing a rule base. Further information on designing a questionnaire can be found elsewhere (Alreck *et al*., 1995). In this method, it is also possible to use some of performance indexes as drivers of satisfaction if their impacts on satisfaction are identified. Measuring the customer satisfaction by using the performance indexes is called indirect customer satisfaction measurement. FCSMM enables to perform direct and indirect customer satisfaction measurement separately and even both simultaneously.

It should be noted that the domain for each driver should be defined. It could be a continuous interval or a discrete sample set such as {1, 2, 3, 4, 5} in accordance with the nature of driver, for example performance indexes usually have continuous domains. In addition, FCSMM enables the analyst to use different scales for each criteria or performance index. FCSMM prefers to work with continuous intervals and hence, it is desirable that customers are asked to express their level of satisfaction by a number between 0 and 100.

Redesign the rule base and change the inputs if needed: Fuzzification process usually forces to redesign the rule base, especially when there isn't any rule for some linguistic terms in the rule base. It shows the inadequacy of rule base or existence of redundant linguistic term for a driver. In this case, the analyst should make decision on omitting that linguistic term and refuzzification of that driver or making some new rules for the rule base. It depends on analysts experience and the related knowledge collected in the previous steps. It is also possible to generate more rules based on available rules. It helps the analyst to better arrange the rule base.

It is also possible that the rules base doesn't include a specific driver which is identified by the analyst according to his/her knowledge or experience. It should be added to the rule base in a suitable manner. In addition, the collected data may help to change some rules or define new ones. For example, it may be found that the size of product batch is a driver of satisfaction but it hasn't been considered in the rule base yet. Hence, a new member and some related IF-THEN rules should be added to D and the rule base, respectively.

Alternatively, it may be useful to consider the most complete case which contains all possible rules. Usually, some of these rules are redundant or covered by each other and several sets of others can be combined into alternative rules. According to several combination and selection processes, the number of rules in the rule base is reduced and consequently the required time for computational effort is decreased. It should be noted that the most complete case is seldom automatically occurred and it is not practically applied in real world cases. It should be emphasized again that the combination and selection process of rules depends on analyst knowledge and experience.

It should be noted that in some markets, different categories of customers may be found by different behaviors in experience of company's products or services. FCSMM should be separately conducted for each specific group of customers in these cases. In other words, various fuzzification process and rule bases are needed for each subset of customers. Other alternative solutions are being investigated by authors.

In addition, it can be useful and in some circumstances may be required to validate the rule base, fuzzification process and adequacy of criteria using real world data, focus group technique, board of directors' approval and etc.

As it was mentioned before, this step can be continuously done with any priority if needed.

Design the inference engine and find the output fuzzy set: The aim of this step is to find the output of each antecedent, consequence and the final fuzzy set of inference process. The process of drawing conclusion from available data is called inference and the computational efforts are done by inference engine.

Using fuzzy operators, i.e., AND and OR the output of antecedent is calculated. It is possible to define each operator arbitrary but as it is common, they are defined in such a way that the AND operator simply selects the minimum of two membership values and OR selects the maximum of two values. In other words, if the fuzzy intersection of two sets A and B refers to a linguistic statement of the form:

x is A AND y is B

where, x and y refer to the same variable, a new fuzzy membership function, which is generated by this operation, is defined as below:

$$\mu_{A\cap B}(x) = \min\{\mu_A(x), \mu_B(x)\} \tag{1}$$

Similarly,

$$\mu_{A\cup B}(x) = \max\{\mu_A(x), \mu_B(x)\} \tag{2}$$

There are other complex operators in fuzzy literature (Zimmermann, 1993).

The results of consequences are achieved by implication methods. The input for the implication process is a single number given by the antecedent and the output is a fuzzy set. In other words, the implication process reshapes the membership function of consequence. Similar to fuzzy operators, favorite implication functions can be defined. But, minimum of each point is generally considered as new reshaped membership function of consequence.

Finally, the results of all rules should be combined into a single fuzzy set. The final fuzzy set is defined by selecting the maximum point of each rule implication result. This combination process is called *aggregation* process. In other words, if the outputs of *i*th rule and inference process are denoted by O_i and F, respectively then we have

$$F = O_1 \cup O_2 \cup O_3 \cup \ldots \cup O_n \tag{3}$$

where, n is number of rules in the rule base.

Defuzzification: As the final desired output for each customer is his/her level of satisfaction and should be reflected by a crisp number and the final output of inference process is a fuzzy set (F), the final fuzzy set should be related to a number by defuzzification process. There are several defuzzification methods in fuzzy literature. Generally, the center of area under the curve is considered as the final output of the fuzzy inference process and represents the level of individual customer satisfaction. In other words, the crisp output value, CSI_i, is the abscissa under the center of gravity of the fuzzy set:

$$CSI_i = \frac{\int_x x\mu_F(x)dx}{\int_x \mu_F(x)dx} \quad (4)$$

where, the $\mu_F(x)$ is the membership function of fuzzy inference process output (F) and CSI_i represents the satisfaction level of ith customer.

It should be mentioned that some mathematical softwares e.g., SAS and MATLAB and nearly all programming languages e.g., C, Pascal can be used for the FCSMM computational efforts.

RESULTS OF FCSMM

The main result of FCSMM is the level of satisfaction for each individual customer (CSI_i). For aggregation of obtained CSIs and summarizing the input data, the total satisfaction index for total set of customers and the average satisfaction index for each driver are separately suggested which can be widely used by analysts in their studies as the same ones are used.

Average satisfaction indices: Let AS_i denotes the average satisfaction index for the *i*th driver (d_i). Then for a set of n customers, AS_i can be calculated as follows:

$$AS_i = \frac{1}{\sum_{j=1}^{m}\sum_{k=1}^{n}\mu_{LD_{ij}}(r_{ik})}\sum_{j=1}^{m}\left[w_{LD_{ij}}\left(\sum_{k=1}^{n}\mu_{LD_{ij}}(r_{ik})\right)\right] \quad (5)$$

where, m is the number of linguistic labels associated with d_i, r_{ik} is the input value of ith driver regarding to the kth customer and w_{LDij} is defined by:

$$w_{LD_{ij}} = \frac{\int_x x\mu_{LD_{ij}}(x)dx}{\int_x \mu_{LD_{ij}}(x)dx} \quad (6)$$

Total satisfaction index: As mentioned before, CSI_i is considered as the satisfaction level of ith customer, individually. Regardless of how these individual indexes are obtained, some procedures aggregate the individual results to achieve total satisfaction index. Nearly all of these methods can be used to aggregate the obtained results of FCSMM, too.

Similar to average satisfaction index, the total customer satisfaction index (TCSI) for a set of n customers is given by:

$$TCSI = \frac{1}{\sum_{i=1}^{m}\sum_{k=1}^{n}\mu_{S_i}(CSI_k)}\sum_{i=1}^{m}\left[w_{s_i}\left(\sum_{k=1}^{n}\mu_{S_i}(CSI_k)\right)\right] \quad (7)$$

where, m is the number of linguistic labels defined for satisfaction (n(S)) and w_{Si} is introduced as:

$$w_{s_i} = \frac{\int_x x\mu_{S_i}(x)dx}{\int_x \mu_{S_i}(x)dx} \quad (8)$$

AN ILLUSTRATIVE EXAMPLE

Here, the implementation of FCSMM is presented through an illustrative example. Although the assumptions of this example may not be in conjunction with real world cases, they considered in such a way to demonstrate the abilities of this method.

Suppose an analyst is appointed by CEO to conduct an evaluation of customer satisfaction. After collecting information on customer needs and their feelings, the initial collected information is translated in the following simple statements:

- The level of each customer satisfaction can be affected by quality, price and delivery time
- Delivery times are saved in the company database and used to evaluate the delivery performance index for each customer
- If the quality is high, delivery is on time and price is reasonable then the customer is very satisfied
- If quality is poor then customer is dissatisfied
- If price is expensive and quality is very high then customer is satisfied
- …

Assuming that the above statements form the knowledge about company's customers' satisfaction, three drivers for this problem were considered as follows:

$$D = \{\text{quality}, \text{delivery time}, \text{price}\}$$

Then, the following linguistic terms are considered for identified drivers and satisfaction, respectively:

Table 2: Linguistic terms and their membership functions

Variable	Linguistic term	Membership function	MF. parameters
Quality	Very poor	Trapezoidal	(0,0,2,3)
	Poor	Trapezoidal	(2,3,4,5)
	Medium	Trapezoidal	(4,5,6,7)
	High	Trapezoidal	(6,7,8,9)
	Very high	Trapezoidal	(8,9,10,10)
Delivery time	Very late	Trapezoidal	(0,0,0.5,2)
	Late	Trapezoidal	(0.5,2,3,4.5)
	On time	Trapezoidal	(3,4.5,5,5)
Price	Cheap	Trapezoidal	(5,9,10,10)
	Medium	Triangular	(1,5,9)
	Expensive	Trapezoidal	(0,0,1,5)
Satisfaction	Very dissatisfied	Gaussian	(0,15)
	Dissatisfied	Gaussian	(35,10)
	Neutral	Gaussian	(60,10)
	Satisfied	Gaussian	(85,10)
	Very satisfied	Gaussian	(100,5)

Table 3: The rule base of the example

	Antecedent			Consequence
Rule	Quality	Delivery time	Price	Satisfaction
1	High	Late	Cheap	Satisfied
2	High	On	Cheap	Very satisfied
3	High	Late	Not cheap	Neutral
4	High	On	Expensive	Neutral
5	High	On	Medium	Satisfied
6	High	Very late	---	Neutral
7	Medium	Late	---	Dissatisfied
8	Medium	On	Cheap	Satisfied
9	Medium	On	Expensive	Dissatisfied
10	Medium	On	Medium	Neutral
11	Medium	Very late	Cheap	Dissatisfied
12	Medium	Very late	Not cheap	Very dissatisfied
13	Poor	Not on	---	Very dissatisfied
14	Poor	On	Cheap	Neutral
15	Poor	On	Not cheap	Very dissatisfied
16	Very high	Late	---	Satisfied
17	Very high	On	Cheap	Very satisfied
18	Very high	On	Not cheap	Satisfied
19	Very high	Very late	Expensive	Neutral
20	Very high	Very late	Not expensive	Satisfied
21	Very poor	On	Cheap	Neutral
22	Very poor	On	Not cheap	Very dissatisfied
23	Very poor	Not on	---	Very dissatisfied

$$L_{d_{quality}} = \{\text{very poor, poor, medium, high, very high}\}$$
$$L_{d_{delivery}} = \{\text{very late, late, On time}\}$$
$$L_{d_{price}} = \{\text{cheap, medium, expensive}\}$$
$$S = \left\{\begin{matrix}\text{VeryDissatisfied, Dissatisfied,} \\ \text{Neutral, Satisfied, VerySatisfied}\end{matrix}\right\}$$

The membership functions in Table 2 are assigned to linguistic terms and consequently the fuzzification phase ends.

Designing the rule base requires more details about customer behavior and may be started with a few rules. The knowledge which is communicated among experts or informant people is used in form of simple IF-THEN rules to simulate the customer behavior in each case. In this way, the experts' opinions and their knowledge form the initial rule base which is completed by some rule base adequacy considerations on number of drivers and defined fuzzy sets. The final rule base is presented in Table 3.

Input data for *quality* and *price* are directly collected from customers using a simple questionnaire. Delivery performance index, which is a number in the continuous interval [0.5], is considered as indirect input value for *delivery time* and hence, it comes from customer records. Table 4 includes the supposed input data and achieved results of FCSMM for a set of 20 customers.

For better understanding of computation process, calculation of CSI_1 is presented below:

First the result of each rule is calculated according to the crisp value of inputs:

Table 4 : Input data and calculated *CSIs* for the example

Customer	Quality	Delivery time	Price	Calculated CSI
1	7.0	4.30	9.0	87.73
2	5.5	4.86	7.0	70.63
3	5.0	4.22	7.0	64.18
4	8.0	3.51	7.5	73.22
5	8.5	3.96	6.5	72.21
6	6.5	4.06	8.5	62.73
7	8.0	3.63	8.0	74.94
8	8.0	4.53	6.5	83.29
9	7.0	4.00	8.5	77.56
10	8.5	3.12	9.0	82.98
11	8.0	3.78	8.0	74.31
12	9.0	3.87	7.5	83.68
13	9.0	3.68	8.0	83.25
14	7.5	4.16	8.5	77.67
15	9.5	4.91	6.0	83.44
16	8.0	4.03	9.0	84.54
17	8.0	4.41	10.0	90.71
18	9.5	3.93	9.5	83.96
19	10.0	4.52	9.0	96.01
20	9.5	3.91	9.5	83.86

$$\text{Rule 1: } AR_1 = \text{Min}\left\{\begin{matrix}\mu_{\text{Quality-High}}(7), \mu_{\text{Delivery-Late}}(4.30) \\ ,\mu_{\text{Price-Cheap}}(9)\end{matrix}\right\} = \text{Min}\{1, 0.133, 1\} = 0.133$$

$$\text{Rule 2: } AR_2 = \text{Min}\left\{\begin{matrix}\mu_{\text{Quality-High}}(7), \mu_{\text{Delivery-On}}(4.30), \\ \mu_{\text{Price-Cheap}}(9)\end{matrix}\right\} = \text{Min}\{1, 0.866, 1\} = 0.866$$

$$\text{Rule 3 to 23: } AR_i = \text{Min}\left\{\begin{matrix}\mu_{\text{Quality}}(7), \mu_{\text{Delivery}}(4.30) \\ ,\mu_{\text{Price}}(9)\end{matrix}\right\} = 0 \text{ , } i = 3, 4, 5, \ldots, 23$$

where, AR_i is the evaluated value for antecedent of ith rule. The consequent fuzzy set of each rule is modified by implication process using MIN operator. Assuming O_i represents the output of ith rule, the modified membership functions are calculated as follows:

$$\mu_{O_1}(x) = \begin{cases} e^{\frac{-(x-85)^2}{200}} & 0 \le x \le 64.91 \\ 0.133 & 64.91 < x \le 100 \end{cases}$$

$$\mu_{O_2}(x) = \begin{cases} e^{\frac{-(x-100)^2}{50}} & 0 \le x \le 97.31 \\ 0.866 & 97.31 < x \le 100 \end{cases}$$

Similarly,

$$\mu_{O_i}(x) = 0 \qquad \text{for } i = 3, 4, 5, \ldots, 23$$

Secondly, the results of all rules are combined into the final fuzzy set (F) and the following membership function is obtained:

$$\mu_F(x) = \begin{cases} e^{\frac{-(x-85)^2}{200}} & 0 < x \le 64.91 \\ 0.133 & 64.91 < x \le 89.95 \\ e^{\frac{-(x-100)^2}{50}} & 89.95 < x \le 97.31 \\ 0.866 & 97.31 < x \le 100 \end{cases}$$

Finally, CSI_1 is calculated as follows:

$$CSI_1 = \frac{\int_x x\mu_F(x)dx}{\int_x \mu_F(x)dx} = \frac{\int_0^{64.91} xe^{\frac{-(x-85)^2}{200}}dx + \int_{64.91}^{89.95}(0.133)x\,dx + \int_{89.95}^{97.31} xe^{\frac{-(x-100)^2}{50}}dx + \int_{97.31}^{100}(0.866)x\,dx}{\int_0^{64.91} e^{\frac{-(x-85)^2}{200}}dx + \int_{64.91}^{89.95}(0.133)\,dx + \int_{89.95}^{97.31} e^{\frac{-(x-100)^2}{50}}dx + \int_{97.31}^{100}(0.866)\,dx} = 87.73$$

The same process should be conducted for each customer survey. This process was simulated by the MATLAB for calculating the last column values (CSI) of Table 4.

Using the data of Table 4, each part of the total customer satisfaction index formula can be calculated as follows:

$$w_{S_{VD}} = \frac{\int_0^{100} xe^{\frac{-(x-0)^2}{450}}dx}{\int_0^{100} e^{\frac{-(x-0)^2}{450}}dx} = 11.9683, \quad w_{S_D} = \frac{\int_0^{100} xe^{\frac{-(x-35)^2}{200}}dx}{\int_0^{100} e^{\frac{-(x-35)^2}{200}}dx} = 35.0087$$

$$w_{S_N} = \frac{\int_0^{100} xe^{\frac{-(x-60)^2}{200}}dx}{\int_0^{100} e^{\frac{-(x-60)^2}{200}}dx} = 59.9987, \quad w_{S_S} = \frac{\int_0^{100} xe^{\frac{-(x-85)^2}{200}}dx}{\int_0^{100} e^{\frac{-(x-85)^2}{200}}dx} = 83.6121$$

$$w_{S_{VS}} = \frac{\int_0^{100} xe^{\frac{-(x-100)^2}{50}}dx}{\int_0^{100} e^{\frac{-(x-100)^2}{50}}dx} = 96.0106$$

$$\sum_{i=1}^{5}\sum_{k=1}^{20}\mu_{S_i}(CSI_k) = \begin{bmatrix}(0.0003) + (0.0399) + (4.9730) \\ +(14.4635) + (0.9943)\end{bmatrix} = 20.47$$

$$\sum_{i=1}^{5}\left[w_{s_i}\left(\sum_{k=1}^{20}\mu_{S_i}(CSI_k)\right)\right]=\begin{bmatrix}(11.9365)(0.0003)+\\(35.0086)(0.0399)+\cdots\\+(96.0423)(0.9943)\end{bmatrix}=1604.56$$

Substituting the above results into the TCSI formula (7) gives the value of TCSI for the assumed set of customers:

$$TCSI=\frac{1}{\sum_{i=1}^{5}\sum_{k=1}^{20}\mu_{S_i}(CSI_k)}\sum_{i=1}^{5}\left[w_{s_i}\left(\sum_{k=1}^{20}\mu_{S_i}(CSI_k)\right)\right]=\frac{1604.75}{20.47}=78.38$$

Similarly, the average satisfaction indexes for quality, delivery time and price are computed as:

$$AS_{Quality}=7.85$$
$$AS_{DeliveryTime}=4.01$$
$$AS_{price}=7.92$$

CONCLUSION

A new method which is called FCSMM was introduced in this study. It uses a fuzzy inference process to evaluate the customer satisfaction individually. Two new indexes are also proposed for aggregation of results. The main advantage of this method is to use some linguistic statements which are gathered from informant and experienced people, results of researches, summary of annual reports, minutes of meetings, archival data and customer complaints, etc. Hence, it can use the knowledge which is communicated among people without any complexity. This knowledge forms the computational structure of this method. Related to the rule base adequacy and completeness, it can really simulate the behavior of each customer and his/her happiness with the provided service or product. Briefly, other advantages of FCSMM are as follows:

- It avoids some assumptions such as linear regression principles, predefined criteria weights and predefined crisp customer behaviors which are commonly used in current methods
- It provides concurrent (direct and indirect) satisfaction measurement
- The application of proposed method is not affected by the number of surveyed customers; hence it can be used in business to business (B2B) and business to consumer (B2C) markets
- It can use both continuous and discrete measurement scales for drivers, performance indexes and even satisfaction level
- Various domains can be considered for each driver and performance index in FCSMM
- This model can be set up even without any input data and can be used as a WHAT-IF analysis in simulation studies or prediction of future

It should be noticed this method can be applied in similar cases such as personnel performance appraisals, supplier performance assessment, etc.

Future research regarding the FCSMM can be conducted on the following topics:

- The implementation of this method in real world cases
- Comparison of achieved results with the other methods
- Designing the rule base using numerical input/output data, learning or optimization methods such as neural networks, genetic algorithms, etc.
- Using other operators and membership functions and comparison of results
- Extension of FCSMM in order to categorize the total set of customer into smaller subsets according to the specific characteristics
- Analysis of relation between the obtained results and financial indexes

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