

A Fuzzy Hypothesis Test Based Model For Customer Satisfaction Measurement

(Case Study in PARS KHODRO CO.)

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Abstract- The article proposes a model for customer satisfaction measuring, which is adapted to use in automobile industries. The proposed methodology evaluates the satisfaction level of a set of customers in different aspect of customer focus based on hypothesis values. It permits to evaluate the validity of a service/manufacturing operation from the point of view of consumers. The main advantages of this method are fully considered the qualitative form of customers' judgments through fuzzy theory and evaluate customers' satisfaction in different aspect of customer focus. This model also allows fully evaluates by analysis of all possible hypothesis cases. In the end, we implement our model in KHODRO CO. in IRAN and show the results. This research does asking the opinions of the experts through a number of questionnaires related to the L90 auto customers of PARS KHODRO CO. in 5 fields. Customer's satisfaction of L90 auto in above fields attains among 81 hypotheses and concludes the following result:

"Product quality is good, financial problems is good, Total quality of services is good and Guarantee is medium then customer satisfaction is good". Finally, future research directions are provided.

Keywords- fuzzy hypothesis test; customer satisfaction analysis; subjective judgments

I. Introduction

Paper's introduction is in two parts as customer satisfaction models and fuzzy hypothesis testing. According to our knowledge and researches, there is not a method for customer satisfaction measuring based on fuzzy hypothesis testing approach.

A. Customer satisfaction models

Globalization and free trade carry on remodeling the business environment and expanding global competition. Customer satisfaction is a resume notion and show the actual state of satisfaction which can vary from person to person and product/service to product/service. Therefore, customer satisfaction should be determined and rendered into a number of quantifiable parameters [1]. Also Since, customer satisfaction index (CSI) have been widely developed in both theory and applications [2, 3, 4, 5], especially in the fields of marketing, education, medical treatment, guesthouse management ,therefore customer satisfaction has been one of the most frequently surveyed topics in literature. The work done by Berry et al. [6] between 1985 and 1988 delivered SERVQUAL (it is a service-quality scheme that has been incorporated into customer-satisfaction surveys [7]), supports the basis for the measurement of customer satisfaction with a service by using the gap between the customer's expectation of achievement and their perceived experience of achievement. In 1989, the first model of CSI was built by Swedish researchers [8]. The American customer satisfaction index (ASCI) was set up in 1994 [9]. Another well-known CSI was built by 11 countries of European Union in 1999 [10, 11]. Some researchers introduce modified CSI for using in the different fields. Hsu (2008) proposes an index for online customer satisfaction, which was adapted from an American Customer Satisfaction Index (ACSI). It predicts customer loyalty and overall customer satisfaction via a way that was similar to the average for the online retail industry in ACSI and the partial least squares (PLS) method [12]. Web-based customer satisfaction don't terminate in the above paper. Customer satisfaction measurement index system via mail service is designed by LIU et al. (2006) [13]. Some of researches also focused on the relationship between customer satisfaction and financial performance [14, 15,16]. According to Grigoroudis et al. (2000), customer satisfaction information is analyzed based

on a preference disaggregation model. Their tool (Software) is termed as TELOS that follows the principles of Multicriteria analysis and uses subjective customers' judgments [17]. Therefore, they propose a model that called MUSA (Multicriteria Satisfaction Analysis). It is a preference disaggregation model following the principles of ordinal regression analysis. Same as their mentioned paper, MUSA model uses subjective customers' judgments, too [18]. The Research of Mihelis et al are concerned with a model that is based on the principles of Multicriteria analysis and preference disaggregation modeling and it is implemented in private bank sector. It determines critical service dimensions and the investigation to customer classes with distinctive preferences and expectations [19]. Jaime and Fonseca (2009) consider the latent segment models (LSM) approach for evaluation of customer's service satisfaction that quantified through multiple indicators. They selected a three latent segment model that represents "The Very Satisfied", "The Well Satisfied" and "Satisfaction Demanders" [20]. Since Zadeh introduces fuzzy set theory in 1965 [21], researchers intend to use it in their quests. For example, Xiaohong (2008) introduce new method for calculating the e-commerce customer satisfaction index (ECSI), using fuzzy techniques [22], so that ECSI obtains by fusion of comparison customers' cognition in e-commerce and their acclaims and complaints.

The purpose of our study is to utilize the fuzzy hypothesis testing for customer satisfaction measuring, such that, satisfaction level is caused by six fields as product quality, financial problems, total quality of services, guarantee, complaints and loyalty. The fuzzy hypothesis test is developed crisp hypothesis testing but it challenge the all possible hypotheses. In other hand, it utilizes ambiguity and vagueness of subjective judgments by fuzzy logic.

B. Fuzzy hypothesis testing

As discussed in previous section, main structure of our method is based on fuzzy hypothesis testing. In the real world, sometimes data cannot be recorded or collected precisely. Therefore, the fuzzy sets theory is naturally used as an appropriate tool in modeling the statistical models when the fuzzy data have been observed [23]. The concept of fuzzy sets used here was originally introduced in [21] and described in more detail e.g. in [24, 25]. It should be noted that in this paper only the hypotheses are allowed to be fuzzy and the data are assumed to remain crisp. Furthermore, the 'classical' way of statistical inference is generalized to fuzzy hypothesis. Note that there is a fundamental difference between a membership function of a linguistic term and a prior probability distribution. The membership function just gives a description of the linguistic term, whereas a prior probability distribution gives prior information about the truth of the hypotheses under consideration. Arnold [26, 27] proposed the fuzzification of

usual statistical hypotheses and considered the hypotheses testing under fuzzy constraints on the type I and II errors. Casals and Gil [28] and Son et al. [29] considered the Neyman–Pearson type testing hypotheses. Saade [30, 31] considered the binary hypotheses testing and discussed the fuzzy likelihood functions in the decision making process by applying a fuzzified version of the Bayes criterion. Gil et al. [32] also discussed the likelihood ratio test for goodness of fit with fuzzy observations by means of the minimum inaccuracy principle of point estimation. Casals and Gil [33], Casals and Gil [34], and Gil et al. [35] considered the Bayesian sequential tests and χ^2 tests for goodness of fit with fuzzy observations by means of the notion of fuzzy information. Grzegorzewski [36], Watanabe and Imaizumi [37] proposed the fuzzy test for hypotheses testing with vague data, and the fuzzy test gave the acceptability of the null and alternative hypotheses. Niskanen [38] discussed the applications of soft statistical hypotheses in the human sciences. The fuzzy hypothesis testing is developed of classic statistical hypothesis testing which zero and one are using for acceptance or rejection of any hypothesis. However, fuzzy hypothesis testing has two strength points versus classic statistical hypothesis testing. They are: (1) it considers all the possible hypotheses and (2) accepts them relatively by numbers in [0,1]. The fuzzy hypothesis testing – like the classic statistical hypothesis testing – has four steps: hypothesis formulation, sampling, hypothesis testing and decision-making. In hypothesis formulation step, all the possible hypotheses are formulated. Classical hypotheses define two type hypotheses as null hypothesis and alternative. However, fuzzy hypotheses formulated by a block consist of hard-core and associated auxiliary hypotheses. In the sampling step, subsets of all data are selected. The sample should have enough data to be a good indication of the all data. In hypothesis testing step, fuzzy conclusion for any hypothesis is done and then, results are aggregated by aggregation function. In final step, total result has to be analyzed and associated decisions made.

The paper organization is according to the follows:

Section II, describes information collection tools, its validity and reliability, and some information about case location. Section III, is describes our methodology which is consist of fuzzy hypothesis concept, structure of our approach, model implementing and its finding. Finally the last section, conclude the models efficiency and results.

II. Information Collection

A. Case Location and Sampling

Pars Khodro Company (P.K.C.) is an automobile manufacturer company that is established in 1956 and since then is operational. In P.K.C. the environment of the competitive markets changes intensely and it is necessary to improve the manufacturing quality continuously. Hence, we introduce a way to evaluate the P.K.C's manufacturing quality, which is based on the degree of user satisfaction. The statistical universe of this

paper is considered from total customers of L90 (one of the Pars Khodro products started in 2009) .In this paper, random systematic method for sampling is used [39] and due to list of total customers of L90 in 2009, Morgan table is utilized for numbers of samples [40] in which the best sample numbers corresponded to any universe cardinality. Accordingly, a sample of 380 from 20000 customers is considered as good representative of total data.

B. Tools

In this paper, main information collecting tool is questionnaires and interviews. Interview is used to analyze customers' viewpoints before questionnaire designing. Questionnaire also is used to measure the satisfaction samples in framework of hypothesis. Initial questionnaire has six essential fields and each field has several sub-fields as follows:

1. Product quality
 - 1.1. Apparent form
 - 1.2. Safety
 - 1.3. Car body specifications
 - 1.4. Motor power and fuelling
 - 1.5. Good ventilation and power means
 - 1.6. Technical documents quality
2. Financial problems
 - 2.1. Cost of product
 - 2.2. Fair relation between cost and quality
 - 2.3. Purchase styles
 - 2.4. Financial operation rapidity
 - 2.5. Attention and clarity in financial affairs
3. Total quality of services
 - 3.1. Managers and experts communication manner
 - 3.2. Inform manner quality
 - 3.3. Delivery quality
 - 3.4. Guarantee conditions
4. Guarantee
 - 4.1. Provide the spare parts
 - 4.2. Parts ampleness and quality
 - 4.3. Guarantee access
 - 4.4. Repairs quality
 - 4.5. Guarantee cost and wage
5. Complaints
 - 5.1. Complaints receiving ways
 - 5.2. Complaints investigation quickness
 - 5.3. Complaints consideration

6. Loyalty

- 6.1. Continuing cooperation
- 6.2. Looking forward to the fresh products
- 6.3. Suggest to other peoples

After the initial collection of 30 questionnaires and evaluation of feedbacks, we integrate them with experts' opinions. Accordingly, due to overlapping and concluded by another, loyalty eliminated from questionnaires and then, final questionnaire is formed. The Response of any question was set according to Likert scale [41], which scaled as: poor satisfaction ‘ Medium poor satisfaction ‘ Fair ‘ medium good satisfaction and good satisfaction.

C. Validity and Reliability

The method of explority factor analysis has been used to analyze the questionnaire validity [39]. The KMO* value of questionnaire is 0.895 in 0.01 significant level which imply to sampling sufficiency for method of explority factor analysis. Varimax rotation was used for explority factor analysis, and result implies that: first factor (product quality) explains the 75% changes, second factor (financial problems) explains the 81% changes, third factor (Total quality of services) explains the 73% changes, Guarantee factor explains 74% changes and finally, complaints factor explains the 79% changes. Generally, the questionnaire forecast the 73% changes that indicate the validity. Of course, load factor of fields was greater than 0.5. The Cronbach's alpha method has been used to analyze the questionnaire reliability [42] which was calculated Cronbach's alpha for product quality , 75% ; financial problem , 79% ; Total quality of services , 72% ; Guarantee , 80% and complaints, 79%. This result indicates the reliability of customer satisfaction measurement scale. It is necessary to mention that the investigations have been done by MINITAB 15.0 software.

III. Mathematical Framework of Fuzzy Hypothesis Testing

Fuzzy hypothesis test is extension of classical statistics hypothesis test. It leads to importance degree of each hypothesis compare with auxiliary rules. Let, X be universes of discourse, $D = \{x_1, x_2, \dots, x_n\}$ be sample set and $H = \{H_1, H_2, \dots, H_n\}$ be if-then rule statements. In this view, we can demonstrate a fuzzy if-then rule as follows:

H_i : IF {Condition 1, Condition 2, ..., Condition k} to be considered true, THEN x is a member of F by membership degree $\mu(x)$.Nevertheless, general structure of fuzzy hypothesis test is as Table 1:

*Kaiser - Meyer- Olkin

TABLE1. Fuzzy hypothesis test matrix

If-then statements	Samples				$M_j(D)$
	x_1	x_2	$\dots$	x_n	
H_1					
H_2					
$\vdots$					
H_r					
					Summation=1

It should be noted that, auxiliary rules are in $\{\text{Condition 1, Condition 2, } \dots, \text{Condition } k\}$ and main hypothesis is included in F notation. The if-part of the rule is called the antecedent, while the then-part is called the consequent or conclusion. Each sample x_i satisfies condition 1, condition 2 through condition k within $\mu_1(x_i)$, $\mu_2(x_i)$ through $\mu_k(x_i)$, respectively. In other hand, x_i satisfies the consequent within $\mu(x)$ that is defined as:

$$\mu : (H, x) \rightarrow [0,1] \quad (1)$$

Due to multiple parts related to the antecedent and consequent, apply fuzzy logic operators and resolve them to a single number between 0 and 1, therefore we apply multiplication operator (P.M. Larson relation) for combining the antecedent and consequent such as fuzzy logic operators. So, satisfaction degree of each hypothesis by x_i sample calculates by equation (2). Hence, attain associated array of j^{th} row and i^{th} column for Table (1).

$$\text{Sat}_{x_i}(H_j) = \mu_1(x_i) \times \mu_2(x_i) \times \dots \times \mu_k(x_i) \times \mu(x_i) \quad (2)$$

To determine the verification degree of each hypothesis (claim), so it is necessary to calculate all possible $\text{Sat}_{x_i}(H_j) \forall i, j$ and then, find arithmetic mean as follows:

$$M_j(D) = \frac{\sum_{i=1}^n \text{Sat}_{x_i}(H_j)}{n} \quad j = 1, 2, \dots, r \quad (3)$$

A. Fuzzy hypothesis testing in customer satisfaction measuring

In this section, we intend to introduce the set of hypothesis in our model. Claims $H = \{H_1, H_2, \dots, H_n\}$ have been introduced and are calculated verification degree of each $(\mu_k(x_i))$. As discussed in section II., five fields are used in this model; product quality, financial problems, Total quality of services, Guarantee are antecedents and then complaints is rule's consequent that implies to customer satisfaction level. We classify each of them in to the three scales as, good, medium and bad. As an example, Total qualities of services investigate in the three classes; good Total quality, medium Total quality and bad Total quality. So, to analyze the total classifications of fields, we will have $3 \times 3 \times 3 \times 3 = 81$ hypothezies. All hypothezies have been analyzed in our paper. As an example, one of the hypothesis could be "product quality is good, financial problem is good, Total quality of services is bad, Guarantee is medium and then customer satisfaction level (complaints) is medium". The fuzzy classifications are as shown in Fig. 1.

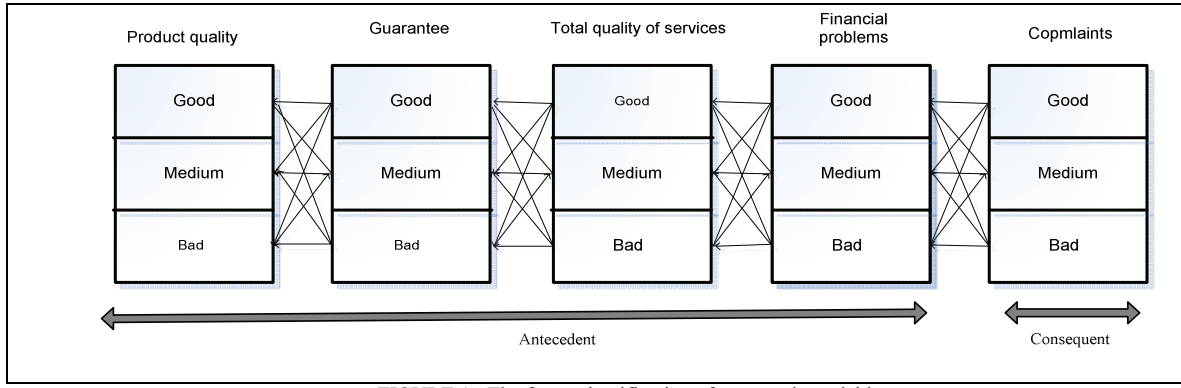


FIGURE 1 . The fuzzy classification of case study variables

As discussed in above, linguistic terms have been used in any classifications. Good , medium and bad are our linguistic terms. So, accordingly we need to design their fuzzy distributions. Fig. 2 demonstrates the linguistic values of any linguistic variable in which ranges have been got from interview with company experts. Note that, concept of

The parameters have been allotted as Fig. 2. So, the membership functions of good, medium and bad linguistic terms are indicated as follows:

"complaint" is negative, so, the more values imply to worse condition. Fig. 3 demonstrates the linguistic terms that are based on the parameters which are different in each field.

$$\mu_{good}(x) = \begin{cases} \frac{1}{e-d}(x-d) & x \in [d, e] \\ 1 & x \in [e, f] \end{cases} \quad (4)$$

$$\mu_{medium}(x) = \begin{cases} \frac{1}{c-b}(x-b) & x \in [b, c] \\ 1 & x \in (c, d] \\ \frac{-1}{e-d}(x-d) + 1 & x \in (d, e] \end{cases} \quad (5)$$

$$\mu_{bad}(x) = \begin{cases} \frac{1}{a}x & x \in [0, a] \\ 1 & x \in (a, b] \\ \frac{-1}{c-b}(x-c) & x \in (b, c] \end{cases} \quad (6)$$

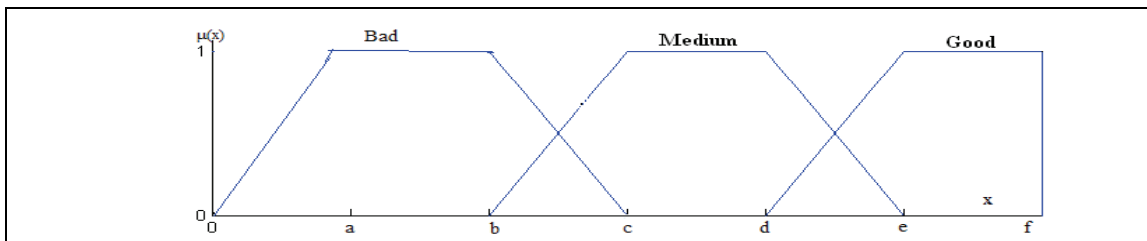


FIGURE 3 . Linguistic terms based on the parameters

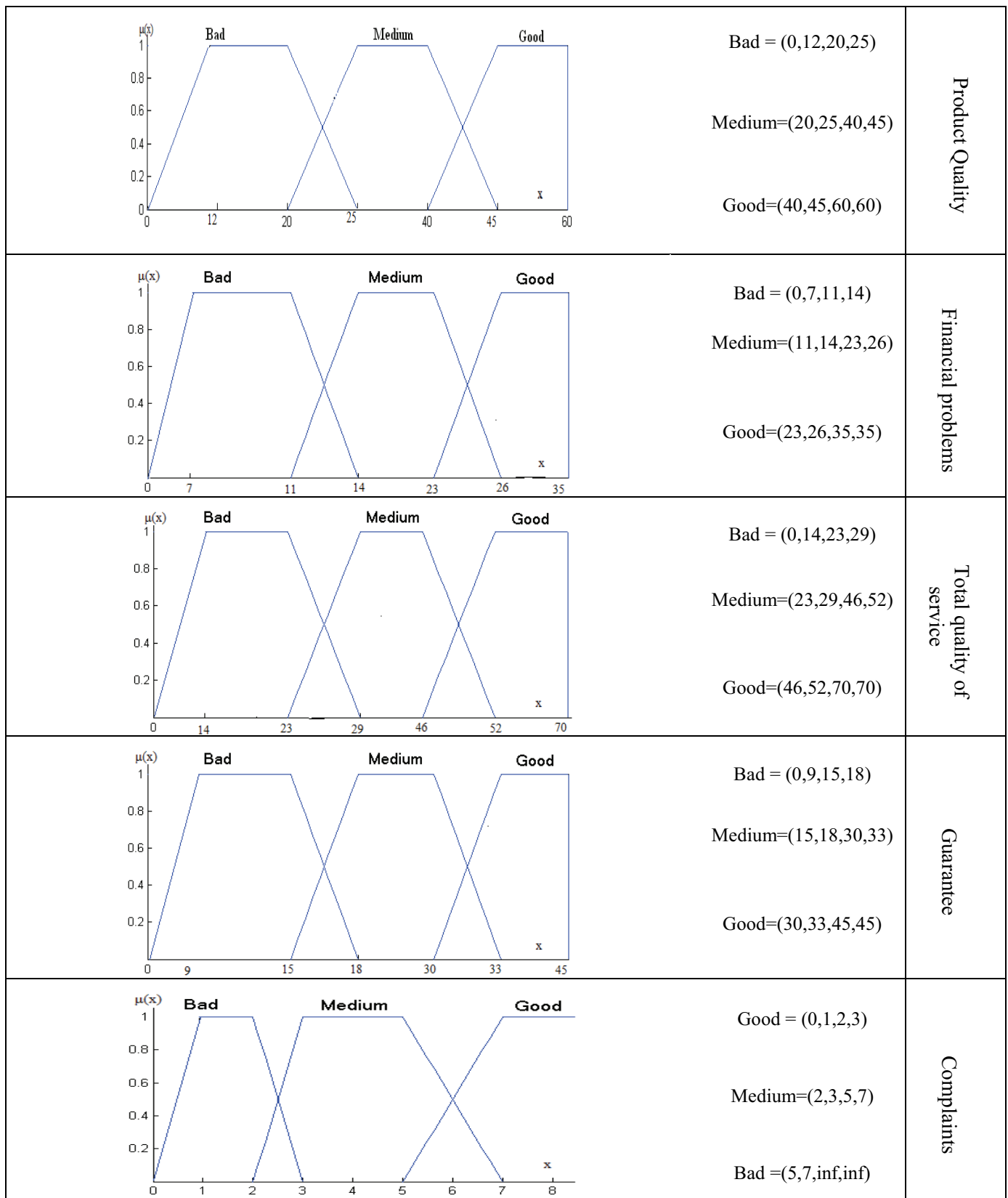


FIGURE 2 . Distribution of good, medium and bad linguistic values

In this stage, the verification degree of each claim has been calculated according to the customers' data. As an example, let "product quality is medium, financial problems is good, total quality of services is medium, Guarantee is medium and customer satisfaction level is medium" for one of the customer (Due to Table 2). So, the verification degree for this customer is $0.8 \times 0.25 \times 0.14 \times 0.87 \times 1 = 0.02$.

In a similar way, via each customer, the verification degree for other hypotheses has been calculated. This procedure repeats for other customers and the verification degree of each 81 hypothesis are calculated as described in section III. Note that, customer i play role of x_i that is explained in section III. Table 2 depicts satisfaction degree of each linguistic variable by one of the customer.

TABLE 2 . Satisfaction degree of each linguistic variable by one of the customer

Ling. variables	Product quality				Financial problem				Total quality of services				Guarantee				Customer satisfaction level (Complaint)			
Ling. values	G^1	M^2	B^3	Score	G	M	B	Score	G	M	B	Score	G	M	B	Score	G	M	B	Score
Sat. degree	0.2	0.8	.	42	0.25	0.75	.	36	0.86	0.14	.	32	0.13	0.87	.	35	.	1	.	4

1. G : Good 2. M : Medium 3. B : Bad

B. Findings

The results of hypotheses testing have been introduced as $M_{H_1}, M_{H_2}, \dots, M_{H_{81}}$ which are verification degrees of $H_1, H_2, \dots, H_{81}$ hypotheses. If verification degrees of H_i be greater than other hypotheses, then, we can conclude that H_i accuracy possibility is greater than others. As shown in Table 3, the top five highest verification degrees are shown and the hypothesis "product quality is good, financial problem is good, Total quality of services is good and

Guarantee is medium and as a result, customer satisfaction is good" has the highest verification degree among the others. So, we can say, this claim has the more conformances in company case. This findings lead to get safeguarding strategy in product quality, financial problem, Total quality of services fields and improvement strategy in Guarantee approach.

TABLE 3. The top five highest verification degrees of hypotheses for L90

Priority	Hypothesis
1	product quality is good , financial problems is good, Total quality of services is good , Guarantee is medium and as a result, customer satisfaction is good
2	product quality is good , financial problems is good, Total quality of services is good , Guarantee is good and as a result, customer satisfaction is good
3	product quality is medium, financial problems is good, Total quality of services is medium , Guarantee is medium and as a result, customer satisfaction is medium
4	product quality is good , financial problems is medium, Total quality of services is medium , Guarantee is medium and as a result, customer satisfaction is medium
5	product quality is medium, financial problems is medium, Total quality of services is medium , Guarantee is bad and as a result, customer satisfaction is medium

IV. Conclusion

Due to increase global competition, customer satisfaction should be determined and rendered into a number of quantifiable parameters. Accordingly, different methods have been introduced to customer satisfaction measurement. Nevertheless, none of them did not use vagueness of customers' judgments and did not probe comprehensively the varied satisfaction fields. The proposed Method used the fuzzy hypothesis testing for utilizing the intuitive judgments and decision-making vagueness and Diagnoses the satisfaction customers associated fields. It

Leads to the real satisfaction level and specifies the foible, strength and improvement opportunity, which they are essential information in the strategic management and latest planning in a company. This paper was implemented in Pars Khodro Co. and study L90 satisfaction customers in 2009. Finally, the result of this research emphasize on "product quality is good, financial problem is good, Total quality of services is good and Guarantee is medium then customer satisfaction is good" hypothesis. Compare to the other researches, this approach presents more realistic results.

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