Analysis of Product Quality using Fuzzy QFD Principles in Manufacturing Industry

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Abstract:- Quality Function Deployment (QFD) is a product development process in order to maximize customer satisfaction. Related to product performance engineering characteristics are specified for this purpose. Treatment, fuzziness in the product design process, fuzzy method is applied to represent the DR where customer requirements (CRS) and engineering design requirements (DRS), and between relationships. New measures to normalize relations assessments have been blurred. Fuzzy method is developed to determine the maximum customer satisfaction and technical difficulty in the resource constraints and market competition considerations, the extent of implementation of each of DR. This paper presents a comprehensive framework for the formulation of organizational strategy. This work provides a methodology to develop the manufacturing sector expanded (FBQFD) application based on fuzzy quality function. This article by the FBQFD background related research work, review and point production environment development. Then, it describes the need for the development of the fuzzy QFD based, because of the existing human expert in product development and to avoid a lack of expansion caused by the availability of human, to achieve the uncertainty can be described assuming the customer's language specialist environmental aspects of product quality requirements, so that it can be used to retrieve the design and manufacturing data providing system. In this competitive environment, it is necessary to evaluate the design of enterprise time and effort in the early stages of product development. However, in the system in a way analysis of product design product development time (PDT) deficiency. Discussion PDT intelligent methods to assess this purpose, this article. In the early stage of development, product designers are lack of adequate information, and it is difficult to determine PDT subjective evaluation. Therefore, the quality (FM-HOQ) method of a fuzzy measure of the house is proposed to provide engineering information can be measured. Quality Function Deployment (QFD) is a combination of "function → Principles → structure" mapping modes, product features extracted from the customer's demand. Here are based on statistical process control (SPC) production process quality evaluation index selection, their interpretation and evaluation of fuzzy sets, which gives us the means to provide the oversight and review of the phenomenon is inaccurate, incomplete or ambiguous information work . Systems exist to use the program and its toolbox Matlab and fuzzy logic to evaluate the possibility of describing the quality of fuzzy theory based on the manufacturing process.

Keywords: Quality Function Deployment, Fuzzy Logic, Product Design, Quality Control, House

I. INTRODUCTION

QFD stands for Quality Function Deployment. Quality Function Deployment is a structured method in which customer requirements are translated into appropriate technical requirements for each stage of product development and production (Koronacki ,J. & Thompson, J.R. 2001). The QFD process is often referred to listen to the voice of the customer, is considered to be concurrent engineering tools. Basically, the customer requirements involved QFD (product specification), to the product design parameters mathematically. The result is a product design driven by mathematics.

Quality function deployment based on customer demand aiming at guiding the process of product development is an integrated system. During the product development needs of customers, products and parts design requirements, process planning, and manufacturing specifications works by connecting together. In fact, it is based on the needs of customers using successively product features and product and process engineering parameters are changed, the cross-linked matrix tables. During the procedure, fuzzy logic relationships and correlation matrix of the numerical values of the necessary decisions to translate linguistic basis. Today the world's managers have to rethink about production techniques, new theories, models and approaches to the global advancement of science and technology-rich, is witnessing. Short product lifecycles, increased product variety, and further intensification of the challenges of global competitors, to move in the direction of new manufacturing techniques has led to several construction companies.

The advantages that would be realized through the use of QFD include a reduction in the time required for product design as well as a reduction is those costs associated with the process. This is possible because the design alternatives are realized much earlier in the process thus reducing the number of corrections and design errors. Also, a higher level of clarity for decision making is gained through the use of this tool.

Quality Function Deployment (QFD) is a unique quality tool that allows businesses to plan and design products with the customers' needs in mind. QFD is a structured method for product or service planning. QFD lets a project team specify the customers' needs and then evaluate how the organization is meeting those needs. By using QFD, a business is motivated to focus on its customers and translate customer requirements into internal product specifications. With good initial requirements the customer obtains a higher quality product in a shorter time.

For customers who require the ability to assess the manufacturer's process, this information provides evidence that the product is in a stable production conditions and requirements are met quality standards of production. In order to make an effective use of knowledge about the manufacturing process, it is necessary that any who make the decisions necessary to provide for. One possibility is the application of fuzzy logic, in order to obtain information about the quality of the manufacturing process of the state-related information, such as the industrial practice of diagnostic real situation, provides such great extent incomplete, inaccurate information this makes a lot of difficulty with the traditional method of evaluation and decision-making.

1.1 Fuzzy Concept

Zadeh (1965) introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function, which assigns to each object a grade of membership ranging between zero and one.

In the classical theory, an element could belong to a set or not. But fuzzy sets and membership developed this concept and introduces raised rate membership. Therefore an element could be a member of a set to a degree. In this theory membership is showed with μ(x) symbol. This value is always between zero and one, as is shown:

$$\tilde{A} = \{(x, \mu A(x) \mid x \in x\}$$

Considering GDM, this study develops a systematic procedure for constructing the HOQ in a fuzzy environment based on the consensus of the QFD team members. Given that the QFD team members are cross-functional expertise, allowed the evaluation of the different representations of fuzzy preference relations and utilities function, the database of choice, a preference ordering, and linguistic preference relations. Unlike existing methods, and representations are converted into digital values or fuzzy numbers. A modified fuzzy clustering approach has been developed to evaluate segment is transformed to an agreement for the construction of the QFD team HOQ. Based on the HOQ approaches to determine the importance of the priorities of the DRS.

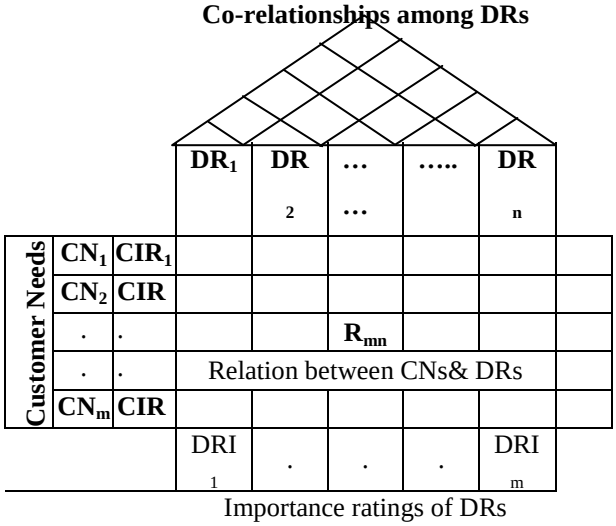

Fig. 1. House of Quality

The Fuzzy numbers are in many shapes, but triangular and trapezoidal fuzzy number forms are used more. In this study we use the triangular fuzzy numbers. Membership function of triangular fuzzy numbers (a,b,c) are defined as follow:

$$\mu(x) = \begin{cases} \frac{x-a}{b-a} \\ \frac{c-x}{c-b} \\ 0 \end{cases}$$

$\tilde{A} = (a_1, b_1, c_1)$ *and* $\tilde{B} = (a_2, b_2, c_{21})$ are two triangular fuzzy numbers, Algebraic mathematical operations on them are defined as below:

$$\tilde{A} + \tilde{B} = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \qquad \tilde{A} - \tilde{B} = (a$$

$$\tilde{A} \times \tilde{B} = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2) \qquad \frac{\tilde{A}}{\tilde{B}} =$$

Traditional point scales (e.g. 1–3–5, 1–9) are used to evaluate the performance of a product (Hauser & Clausing, 1988, 1996). This matrix is usually obtained from customer surveys. However, this is only an ideal situation. Crisp numbers cannot clearly identify the true performance of a product. In practice, different customers have different attitudes toward the same product. Their rating cannot be the same as each other. What is needed is a suitable tool to capture this information. Fuzzy mathematics is a good tool to capture the highly uncertain information.

To present the true rating information, we use the fuzzy performance-rating matrix. Suppose that there are k companies (competitors) and m customer needs denoted by Ck and CNm, respectively. Here x_{mk} means the k^{th} company's performance on the m^{th} customer requirement.

$$\begin{array}{c} \\ CN_1 \\ CN_2 \\ \vdots \\ \vdots \\ CN_m \end{array} \begin{bmatrix} C_1 & C_2 & - - - & - - - & C_k \\ x_{11} & x_{12} & - - - & - - - & x_{1k} \\ x_{21} & x_{22} & - - - & - - - & x_{2k} \\ \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & & \ddots & \vdots \\ \vdots & \vdots & & & \vdots \\ x_{m1} & x_{m2} & - - - & - - - & x_{mk} \end{bmatrix}$$

Fig. 2. Performance rating Matrix

Table 1: Fuzzy Numbers of the linguistic term.

Label	Linguistic Term	Notation	Fuzzy Number
S_1	None	N	(0,0,0.166)
S_2	Very Low	VL	(0,0.166,0.333)
S_3	Low	L	(0.166,0.333,0.5)
S_4	Medium	M	(0333,0.5,0.667)
S_5	High	H	(0.5,0.667,0.833)
S_6	Very High	VH	(0.667,0.833,1)
S_7	Excellent	E	(0.833,1,1)

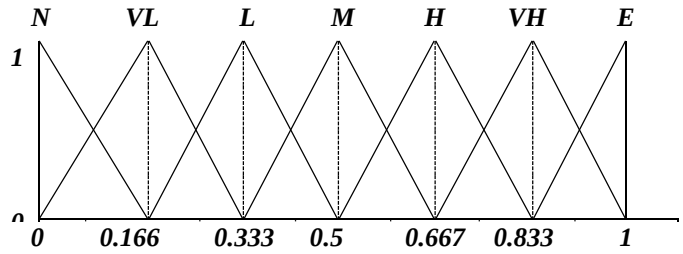

Fig.3. Fuzzy Scale

1.2 Terms of Quality Control

Each product has a certain dimension. This size is out of tolerance limits, then as a waste product, is classified as non-compliant means. As a result, losses of companies and so they put increased emphasis on compliance with these requirements. Such economic losses expressed mathematical function called the loss of function. Taguchi loss function all changes are based on a cost, even when the change without departing from the map data defined by the mode control assumptions. This concept is most useful, which is expected from the desired deviation is expensive. Taguchi assumed that all deviations from the target, resulting in customer dissatisfaction. Taguchi loss function to enable enterprises to calculate the financial consequences of the process of change, making it useful to meet the design decisions. Mathematical expression of this function is:

$$L = k(x - T)^2)$$

Where:
k - Loss coefficient
x - Measured value
T - Target value
In this case we assume required value T such as centre of tolerance limits. Mathematical expression is :

$$T = \frac{UCL - LCL}{2}$$

Process Capability Index (Cp index) compares the required tolerance limits with natural tolerance limits of a process. It indicates what the process would be like if it were centered. It is assumed normal distribution.

$$C_p = \frac{UCL - LCL}{6\sigma}$$

Where s is the standard deviation of the process.

C_{pk} index

$$C_{pk} = min\left\{\frac{UCL - \mu}{3\sigma}; \frac{LCL - \mu}{3\sigma}\right\}$$

Where σ is the arithmetic mean of the measured values. The following table presents the evaluation process in terms of comparison indices C_p and C_{pk}.

Table 2: C_p and C_{pk} indices depends

$C_p = C_{pk}$	The process is centered in tolerance interval
$C_p > C_{pk}$	The process is not ideally centered
$C_{pk} = 0$	The process is centered on one of tolerance limits
$C_{pk} < 0$	Process is centered out of the tolerance limits

Index K

$$K = \frac{|T - \mu|}{\frac{UCL - LCL}{6\sigma}}$$

If
K = 0 - the mean value of the process is identical to the desired target value
0 < K < 1 - mean the process is within tolerance limits
K > 1 - the mean value of the process is out of the tolerance limits.

1.3 Fuzzy Multivariate Control Charts

Fuzzy set theory was introduced first by Zadeh7. Fuzziness in data can refer to various types of vagueness and uncertainty but particularly to the vagueness related to human linguistics and thinking or the lack of information or measurement systems. Many studies have been done to combine several statistical methods and fuzzy set theories, called fuzzy statistics. Two approaches for constructing control charts to monitor multivariate attribute processes when data set is presented in linguistic form are suggested. The most common type of control charts used in a production process is the Shewhart control chart. A multivariate QCs process could be monitored by applying a univariate Shewhart control chart for each QC. If these QCs are independent of each other, this would be an adequate procedure. However, in many production processes,

multivariate QCs tend to be correlated and therefore results could be misleading and difficult to interpret.

To plot easily sample characteristic values and to maintain the basic form of multivariate control charts, fuzzy subsets associated with linguistic terms in each term set should be converted into scalar values. These values are called representative values. There are four transformation methods: fuzzy median, fuzzy mode, α-level fuzzy midrange and the fuzzy average, see Raz and Wang. However there is no theoretical backup for choosing one transformation method. In this chapter fuzzy median is adopted for the ease of its computation.

Let there be q_j linguistic variables on the term set c_j, and let them be c_{jh}, $h=1,\ldots,q_j$. Let the fuzzy set for each linguistic variable be F_{jh} which is characterized by the membership function μ_{jh}.

A sample from observations is then expressed by: *An*

$$A = \left[\{(f_{11}, n_{11}), \ldots . (F_{1q_1}, n_{1q_1})\}; \{(F_{p_1}, n_{p_1}), \ldots . (F_{pq_p}, n_{pq_p})\}\right]$$

where n_{jh} is the number of observations classified by linguistic variable *cjh*. Using fuzzy arithmetic, each QC c_j is then associated with only one fuzzy subset in the following way:

$$F_j = \frac{1}{n}\sum_{h=1}^{q_j} n_{jh}F_{jh}$$

Then, each fuzzy subset F_j is transformed into its representative value using fuzzy median transformation method. Kaufmann and Gupta(1985) showed that the multiplication of a triangular fuzzy number (TFN) **T** by a real number **k** is also a TFN. The addition of two TFN **T** and **S** is shown to be a TFN. Then a linear combination of TFN gives a TFN. For example if **T** and **S** are represented by triplets (t_1,t_2,t_3) and (s_1,s_2,s_3) respectively, then a linear combination $\mathbf{C=k_1T+k_2S}$ should be represented by triplet$(k_1t_1,k_2s_1,k_1t_2+k_2s_2,k_1t_3+k_2s_3)$. By assuming that fuzzy variables F_{jh} are TFNs, hence, each fuzzy number F_j is also a TFN and can be written as (a_{1j},a_{2j},a_{3j}).

The procedure requires computing the representative values of fuzzy subsets Fj from a sample size of n. The test statistic being plotted on the control chart for each sample is,

$$T^2 = (R - \mu')\sum^{-1}(R - \mu)$$

Where μ′= [μ1, μ2,……. μp] is the vector of in-control means for each QC and Σ is the covariance matrix of QCs.

Two approaches are posed to deal with a multivariate process when more than one multinomial QCs is monitored. The first is based on fuzzy theory and the other is based on probability theory. The plotted statistic in the fuzzy approach is obtained after transforming fuzzy observations into their representative values. Its empirical distribution is investigated using bootstrap resampling method.

Fuzzy Logic Toolbox in MATLAB

Fuzzy Logic Toolbox allows you to do many things, but the most important thing is that you can create and fuzzy inference system allows editing. You can use the graphical tools or command line operations, these systems can make by hand, or you or adaptive neuro-fuzzy clustering technique can either generate them automatically. Runs with MATLAB Simulink® simulation tool, we can easily block diagram of a fuzzy system can test our simulation environment.

Fuzzy QFD Modeling in MATLAB

We can use two types of models in Matlab:

Model of Sugeno : This model can be easily used especially to approximate nonlinear dependences. Working with them is comfortable, especially when we know the rules which also imply that we have done the state space decomposition for the number of cells characterized by fuzzy selected fuzzy sets.

Model of Mamdani

The default system has one input and one output and uses the Mamdani inference and an aggregation method. This editor also illustrates the three aspects of a fuzzy controller; fuzzification, inference, and defuzzification. To begin, let us define the membership functions.

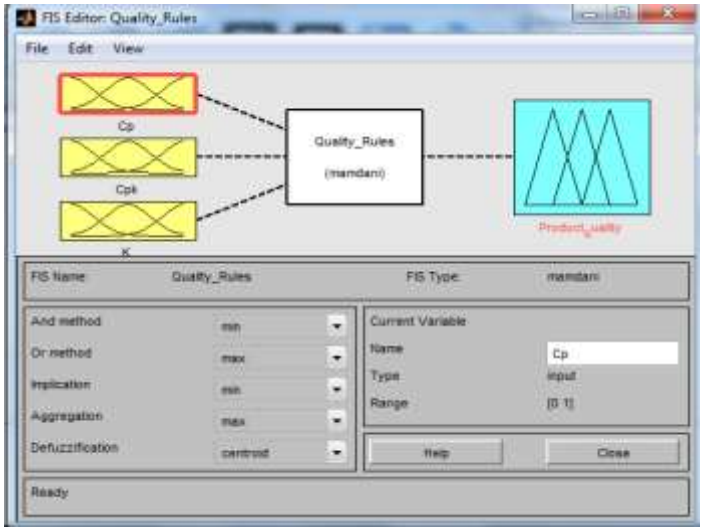

Fig. 4 FIS Editor

1.4 Membership Function

FIS membership function editor to edit some of the features, you can display the input and output variables and fuzzy inference system and all member functions. Membership function editor stock, editing tools. Members show varying membership function in a function graph. Us. This will affect the selected and from page to page using the mouse can work with these tasks as needed to move it a membership function in the chart in a given membership function associated with a

given value of the mathematical variables details of the value of the variables associated with.

(a)

(b)

(c)

Fig.5a,b,c: Membership Function Editor

1.5 Rules

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. But in order to say anything useful we need to make complete sentences. Conditional statements, if-then rules, are the things that make fuzzy logic useful. A single fuzzy if-then rule assumes the form.

if *x* is A then *y* is B

A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion.

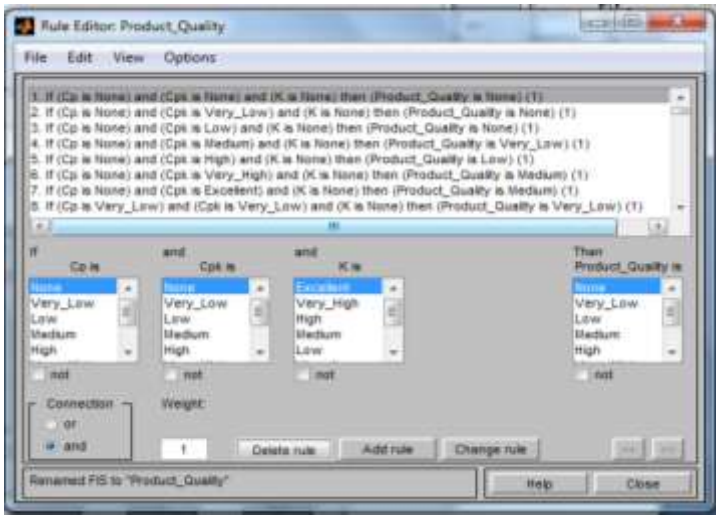

Fig.6: Rule Editor

Editor, will be used to display the rules and production standards for graphical computing. Basically it is the absolute path of fuzzy manufacturing process. They are defined by the law of each line representing the exact sequence "Rule Editor". Input parameters put for calculation, you may once again be done in two ways. You can edit line entitled we "input" or graph of any. This has been set to the desired level, move the mouse to click the mouse on the vertical line that is being used.

Graphical representation of the input value of the output variables and input variables are counted. Clear values that characterize the input is obtained, the left side of the red line shows us. Overlap his pace membership function, the output will change the way we think.

1.6 Evaluation of Process Quality

If it knows the number of the indices mentioned, the use of fuzzy logic box MATLAB tools, respectively, on the basis of the possibility of the above, we created a system based on fuzzy sets the final evaluation of the quality of the production process the user Write provides a possible approach. These indicators, as given the actual process control map, are available. Respectively, to maintain the profile of the manufacturing process, in determining the variable, it is an important aspect to know the influence of various indicators on the final quality. These efforts to meet customer requirements for the overall quality are based primarily on the target.

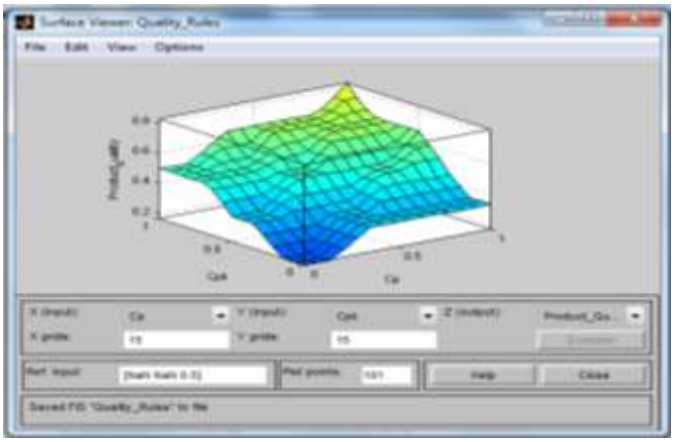

Fig. 7. Surface Viewer

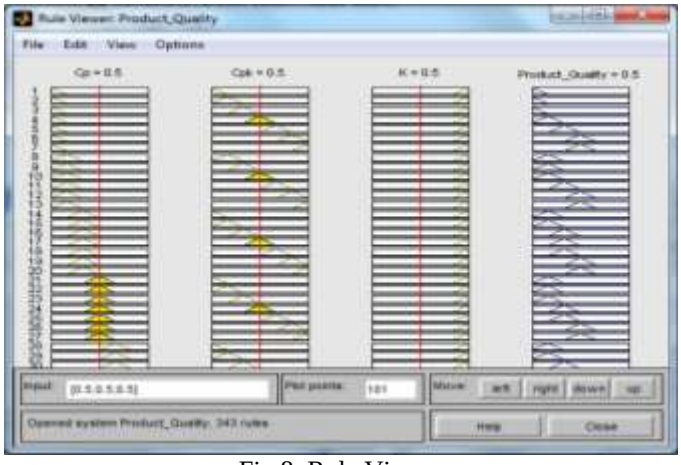

Fig.8. Rule Viewer

The input to the overall evaluation of the individual characteristics of the manufacturing process of analysis it is clear that the biggest change in this review by K. It is made, the contribution in this regard is the fact that the coefficient is given by the required limit values center ... using the resulting rule Viewer window, we can see the changes in the coefficient K is reflected in the final quality. The optimum value of the coefficient is between 0 and 0.3, which makes estimating the precision setting of the production process.

II. CONCLUSIONS

In this contribution we use the principles to the field of fuzzy logic approach are presented Assessment of quality production processes. Basic concepts of fuzzy logic tools for implementation in various areas related to the issues selected as explained. In a competitive environment, the success of a product depends not only on their own performance, but also its competitors. For example, it is. Its competitors are not as good, but the low level of customer satisfaction, however, stands out in this market can be. Poor performance in meeting a variety of customer needs can on the other hand, it can do much better, if your competitors are better to meet different customer needs. However, the product requires particular client can be seen to be relatively poor in this area. Knowledge and awareness to apply the knowledge of experts in attracting and keeping your plan production gives companies a competitive edge as well as the proposed procedures to allow the collection of data. Since, it Quality of the manufacturing process used for compliance with the long-term monitoring can be.

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