

Product Design through QFD Approach with Hybrid of AHP and Fuzzy Logics

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Abstract. QFD is a customer oriented approach which captures customer voices and inculcates these in final product design leading to improvement in demand of product in market. The objective of this paper is to prioritize the needs of customer through AHP (analytic hierarchy process) and further their conversion into technical determiners leading to formation of HOQ (House of Quality).The relationships between customer voices and technical determiners are treated as linguistic variables, therefore fuzzy set theory is used to assign weights to technical determiners as relationships are subjected to uncertainty and vagueness. The result of this hybrid computational model would provide the best alternative from the set of technical design parameters which an organization can include in its design to make their product customer oriented.

Keywords: QFD, AHP, HOQ.

1. Introduction

QFD¹⁰ as name suggests is a “function” in which customer voices are input variables and “HOQ” is a basic computational model which generates important technical aspects as outputs which are necessary to inculcate in product design in order to make it customer favourable. In this paper through market surveys myriad customer voices are captured and prioritized through Analytic Hierarchy Process model. Author and author developed relationships between technical determiners and customer voices, which are treated as uncertain linguistic variables and the weights of technical determiners are evaluated through fuzzy algebra by converting customer weights into fuzzy duplet sets. Quality function deployment was developed by Yoji Akao² in Japan in 1966. By 1972 the power of the approach had been well demonstrated at the Mitubishi Heavy Industries Kobe shipyard (Sullivan, 1986) and in 1978 the first book on the subject was published in Japanese and then later translated into English in 1994. In Akao’s words, QFD “Is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer’s demand into design targets and major quality assurance points to be used throughout production phase. The concepts of fuzzy set and fuzzy logics were introduced by Zadeh in 1965. Zadeh was working in the field of control engineering. His intention behind introducing this fuzzy set theory was to deal with problem involving knowledge expressed in vague, linguistic terms. Analytic Hierarchy process (AHP) is a multi-criteria decision making (MCDM). The oldest reference that we have found dates from 1972 (T.SATTY)⁷. Then a paper in the journal of mathematical Psychology (T.SAAY 1977) precisely described the method. The vast majority of the applications still use AHP as described in the first publication. AHP has been used long time before by psychologists e.g (Thurstone, 1972, Yokoyama, 1921). The hierarchy formulation first proposed by Miller in his 1966 doctoral dissertation (J.Miller, 1966) and applied in (J.MILLER, 1969 and J MILLER, 1970). Several authors contributed their work on AHP and Fuzzy set theory for QFD problems, but their approach are either sole with AHP or Fuzzy set theory. No work has been reported with the dual application of these two heuristics i.e AHP or Fuzzy set theory to suggest a solution for product design problem through QFD. Hence attempt has been made by authors to develop systemize procedures to suggest the above mentioned problem with the help of AHP and Fuzzy set theory. It has been quite interesting and feasible to suggest the solution for product design problem through QFD with these two heuristics.

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2. Description of the Problem and Solution Methodology

2.1 Description of the Problem⁴

An intelligible case is taken here in which various job seekers are compared to customers and the jobs which they are looking forward are compared to technical design parameters. The first step will be to capture customer voices and prioritize them by using AHP⁷. Customer voices will be captured through surveys as according to first basic step of QFD approach. Then using statistical techniques importance ratings will be given to all voices as compared to other ones. The importance ratings will be used further to develop pairwise comparison matrix in AHP tool. The various urges of job seeker's (customer voices) are given below;

1. High starting salary (SAL)
2. Quality of life in city where job is located (QL)
3. Interest in work (IW)
4. Job location near family and relatives (NF).

So, by using AHP technique these voices are prioritized by assigning weights and as these weights are subjected to some amount of uncertainty which arises while giving importance ratings so weights will be further converted into fuzzy sets which will deal with this small amount of uncertainty. After that HOQ matrix is made between customer voices and technical determiners and fuzzy set theory is further applied to get solution in the form of most suitable job(technical design parameter) for the job seeker(customer).

2.2 Weighing Customer Voices using AHP^{5,6}

Obtaining weights for each objective suppose in above case it will be 4×4 matrix known as pairwise comparison matrix. The entry in row i and column j of A (call it A_{ij}) indicates how more important objective i is to objective j which is established through statistical survey. "Importance" is to be measured on an integer valued 1-9 scale and following convention is used:

Table 1: Importance Ratings for Pairwise Comparison Matrix^{5,6}

1	Objective i and j are of equal importance.
3	Objective i is weakly more important than objective j .
5	Experience and judgement indicate that objective i is strongly more important than objective j .
7	Objective i is very strongly or demonstrably more important than objective j .
9	Objective i is absolutely more important than objective j .
2,4,6,8	Intermediate values e.g a value of 8 means that objective i is midway between strongly and absolutely more important than objective j .

For all i , it is necessary that $A_{ii} = 1$. If eg $A_{13} = 3$, Objective 1 is weakly more important than objective 3. If $A_{ij} = 1/k$ then $A_{ji} = k$ must hold i.e if $A_{13} = 3$, then $A_{31} = 1/3$ means that objective 3 is weakly less important than objective 1.

	<i>SAL</i>	<i>QL</i>	<i>IW</i>	<i>NF</i>
<i>SAL</i>	1	1/5	1/2	1/4
<i>QL</i>	5	1	2	1/2
<i>IW</i>	2	1/2	1	2
<i>NF</i>	4	2	1/2	1

For each of A's columns, do the following. Divide each entry in column I of A by the sum of entries in column i. This yields a new matrix C call it ANORM for normalized.

$$A_{NORM} = \begin{bmatrix} .08 & .054 & .125 & .066 \\ .4166 & .270 & .5 & .133 \\ .166 & .135 & .25 & .53 \\ .33 & .5405 & .125 & .266 \end{bmatrix}$$

$$Now W_{SAL} = \frac{.08 + .054 + .125 + .066}{4} = .08125$$

$$W_{QL} = \frac{.4166 + .270 + .5 + .133}{4} = .3299$$

$$W_{IW} = \frac{.166 + .135 + .25 + .53}{4} = .27025$$

$$W_{NF} = \frac{.33 + .5405 + .125 + .266}{4} = .315373$$

So, this is the AHP process and weights are assigned to customer needs as shown above.

3. Results and Illustration on Sample Problem

Weighting Technical Determiners using Fuzzy Set Theory^{5,6}

As above assigned weights to customer voices deals with some amount of uncertainty, So the concept of fuzzy logics is used. Fuzzy set theory offers a precise mathematical form to describe such fuzzy terms in the form of fuzzy sets of a linguistic variables. To represent the shades of membership or the concept of possibility values of membership has been introduced. We write U(x) to represent the membership of some object in the set converted into linguistic variables with doublet fuzzy sets in the form [a, b]. The value of U(x) in this case is taken 1.

Table 2: Conversion of Customer Weights into Fuzzy Sets^{1,8,9}

WEIGHTS	LINGUISTIC VARIABLE	FUZZY SET
W_{SAL}	LOW	[0, .1]
-	MEDIUM	[.1, .2]
W_{IW}	HIGH	[.2, .3]
W_{NF}, W_{QL}	VERY HIGH	[.3, .4]

(Membership function x axis vs Linguistic Variables y axis8)

Suppose there are four firms offering jobs J1, J2, J3, J4. A relationship matrix is established forming HOQ using linguistic variables strong, medium, weak between voices of job seekers (customer voices) and job firms (technical determinants) in this case.

Table 3: Fuzzy Sets Assigned to Linguistic Variables^{1,8,9}

LINGUISTIC VARIABLE	FUZZY SET
STRONG ↑	[4 , 6]
MEDIUM ↔	[2, 4]
WEAK ↓	[0, 2]

	J ₁	J ₂	J ₃	J ₄	
SAL	[0 , .1]	↑	↔	↓	↔
QL	[.3 , .4]	↑	↓	↔	↔
IW	[.2 , .3]	↓	↑	↕	↔
NF	[.3 , .4]	↔	↑	↑	↑
Weights(determiners)		[.45 , 1.30]	[.5 , 1.35]	[.65,1.5]	[.45,1.25]

Table 4: HOQ Matrix Computing Optimized Solution of Given Problem Inculcating Customer needs^{1,8,9,11}.

$$W_j = 1/k\{(R_{j1} \times W_1) + \dots + (R_{jk} \times W_k)\}$$

K= Customer voices

WJ= Weight of technical determiners

Now as J3 has got the maximum weight so it is most suitable job for the job seekers.

4. Conclusion

In this paper we combined the QFD model with hybrid of AHP and fuzzy logics to get decision by the product designer based on customer views. The idea behind this paper was to design a product incorporating customer voices. As the customer voices are subjected to vagueness and uncertainty. The implementation of these two heuristics i.e AHP and Fuzzy set theory make the solution of the QFD problem much easier and palpable. The above mentioned model may also be used to select a given product from the no of products based on customer perception as described by the example illustrated in this paper. This Methodology can further be enhanced by combining it with Neural Networks for more accurate and optimized results.

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