

Optimization of Selection Parameters through QFD-AHP-TOPSIS Methodology

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Abstract

It is very difficult to understand all the wants of customer and to make a product which will fulfill the demands completely. The designer always tries to design a product with reference to ideal one. The distance between customer imagination and designer thinking may be reduced by using combination of decision making tools i.e. Quality Function Deployment (QFD) with AHP, TOPSIS. QFD is a powerful tool for designing the product and prioritizing the customer needs. For the complicated decision making problem including qualitative and quantitative factors, different decision making techniques such as Analytic Hierarchy Process (AHP), TOPSIS can also be used with QFD for better results. In this paper, a model of QFD, AHP with TOPSIS technique is formulated and the study is executed with an example of two wheeler selection problem in Indian market.

Keywords: Quality Function Deployment, Fuzzy Logic, AHP, TOPSIS, House of Quality.

1. INTRODUCTION

In present market purchasing of bikes is very tough task for customer because of sudden changes in design and technical specifications. The customer tries to select best option but decision varies from person to person, therefore to overcome from these types of confusions some optimization techniques are required. QFD is a tool to understand the customer demand and to prioritize the voice with best selection verses alternatives and

attributes AHP-TOPSIS technique can be used to achieve the best solution.

In order to meet the customer expectations the manufacturing industries are looking for design a product under market oriented approach. QFD is the best approach to identify and prioritize the customer demands using House of Quality (HoQ) (shown in fig.1). QFD introduced in late 1960s and early 1970s in Japan by Akao (1990) the primary functions of QFD at the beginning are product development, quality management and analysis of customer demand. With the developments the application areas of QFD are extended in wider fields including Decision Making, Planning, Operations and Engineering Design etc.

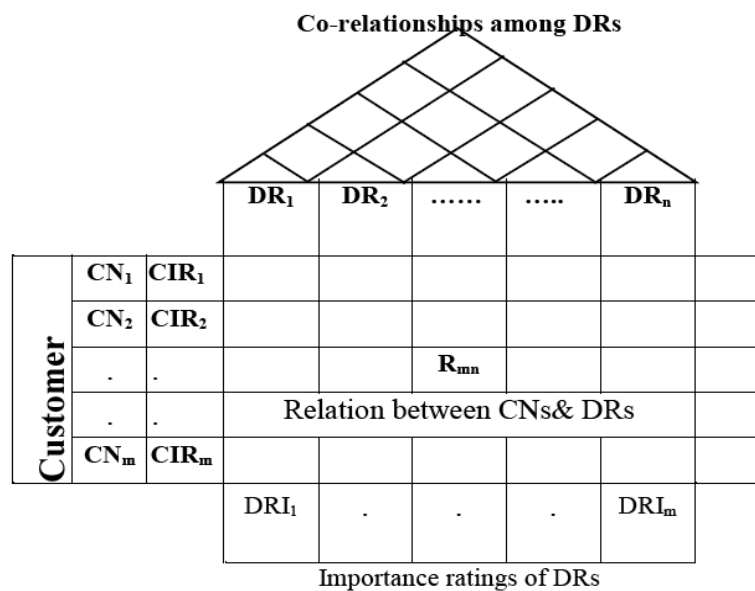


Figure 1. House of Quality

AHP (Analytical Hierarchy Process) is a powerful tool for organizing and analyzing complex problems. In 1970s Thomas Saaty was developed AHP. As per their research, AHP has three steps Structuring Hierarchy, Pairwise Comparison, Synthesis of Result (Saaty 1994, 2008). AHP has ability to handle decision making and to measure consistency of performance (Triantaphyllon, 2000). In the traditional AHP the final weightages calculated through eigen vectors. Lootsma (1998) suggested that the normalization of raw and columns shows that the values are equivalent to normalized Eigen vector. Kwong & Ban(2002) proposed fuzzy analytical hierarchy process for calculating the weight of customer voice and proposed a model based on fuzzy for calculating the weights of customer voice.

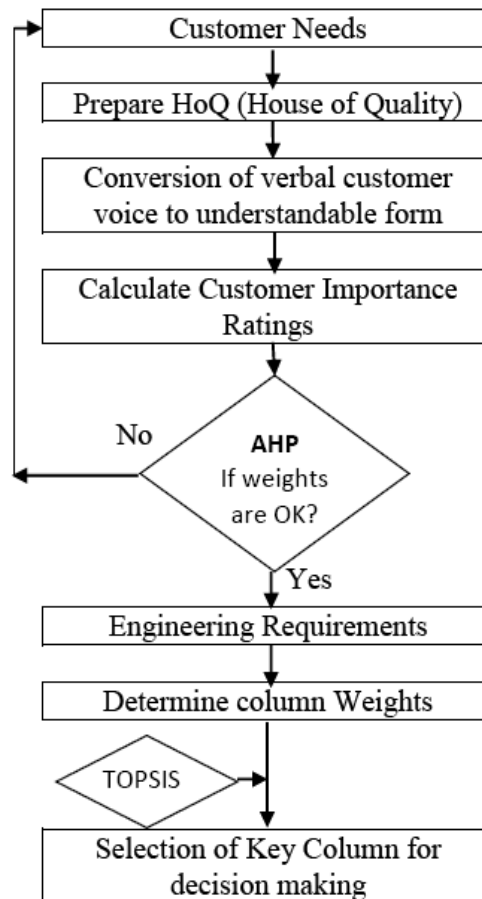
TOPSIS(Technique for Order Preference by Similarity by Ideal Solution) method was developed by Hwong & Yoon in 1981. In this method ranking of alternatives will be based on distance from Ideal Positive and Ideal Negative. The best alternative should

have least distance from positive ideal and farthest from negative ideal.

Baky and Abo-Sinna (2013) presented TIPSIS for solving problems in bi-level MODM tools. Rao (2006) proposed a model using graph theory for material selection. Cheng (2008) presented the effective approach by adopt TOPSIS for solving problem on MCDM. Gercia-Cascales & Lamata (2012) proposed modified algorithm of Hawang & Yoon TOPSIS Method. Zhang & Yo (2012) Presented extended TOPSIS for ranking of all the alternatives.

Karimi-Nasab and Seyedhoseini (2013) applied TOPSIS for ranking of performance indexes in job shop environment. Khademi-Zare et al. presented two methods for prioritization using FQFD for ranking of strategic actions of cellular telecom in Iran by using of AHP considered more factors of CA. Fuzzy factor was also introduce in those models. Chen and Tong presented weighted average method with grey rational analysis for ranking materials. Gunasekaran et al. proposed an MCDM method for optimizing supply chain by using Monte Carlo simulation and FQFD.

2. METHODOLOGY



2.1 QFD

Quality Function Deployment (QFD) is a powerful tool for product development process based on customer needs. It is an integrated process of linking customer demand, product characteristics, process planning and manufacturing through structured formulation of customer voice and design characteristics. The QFD methodology is consisting of the following steps:

1. Customer portion: The customers always express their feelings/ wants in their linguistic form. Formation of these voices in a systemic and understandable form is covered in this section.
2. Technical portion: Translation of customer voice into measurable and quantitative form.
3. Determining Relationship: The relations between voices are denoted by using suitable scale for Strong, Medium and weak relationship. This shows the effect and linkage between voices.
4. Customer Competitive Evaluation: It shows the position of own product as compared to others.
5. Target Weights: After getting the target value of each technical requirement and correlation between technical requirement the final weight is calculated.

On the basis of these steps, determine part characteristics, process and production control to assure achievement of critical changes in product.

Weights to each attribute have been calculated from customer importance rating in QFD matrix and analyzed the authenticity through AHP.

2.2 AHP steps

Analytic Hierarchy Process is developed by T.L. Saaty (Saaty 1980). It is a systemic approach for decision making based on mathematical principles. The essential steps of AHP methodology are as:

1. Determine hierarchical structure objective → attribute → alternative levels.
2. Determination of relative importance by construction of pair wise comparison matrix. The rating is denoted by using fundamental scale of AHP. The numbers 3, 5, 7 and 9 for Moderate, Strong, Very Strong and absolute can be used for importance.
3. Determine normalized weight (w_j) of each attribute:

$$w_j = \frac{Gm_j}{\sum_{j=1}^m Gm_j}$$

Where; Gm_j = Geometric mean

1. Determination of Eigen value λ_{max} , and calculate consistency Index(CI) & Consistency Ratio(CR):

$$CI = \frac{\lambda - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

Where; RI = Relative Index

The acceptable CR value is 0.1 or less.

2. Now compare the attributes between each other and find how well the attributes serve each attribute.
3. Now summering the scores by multiplying w_j of each attribute with their normalized value of each alternative.

2.3 TOPSIS Method

In 1981 Hwang & Yoon proposed the Technique for order Preference by Similarity to Ideal Solution (TOPSIS). This method has two main functions; 1. To calculate maximum distance of alternative from the negative ideal solution. 2. Chose the alternative having shortest distance from ideal solution.

The TOPSIS method is an effective and practical approach for solving decision problems. This method was used successfully to solve multi-criteria decision making problems in different fields. It is also used to calculate the competitive benchmarking in product designing. Some integrated methods of TOPSIS and other optimization methods have been developed also to solve different decision specific problems. The procedure of TOPSIS method is described below:

Step 1: To determine the objective.

Step 2: Formation of matrix based decision table in which each row of the matrix is allocated to one alternative and each column to one attribute.

$$A = \begin{bmatrix} C11 & \cdots & C1n \\ \vdots & \ddots & \vdots \\ Cm1 & \cdots & Cmn \end{bmatrix}$$

Step 3: Calculate normalized matrix:

$$R_{ij} = \frac{m_{ij}}{\sqrt{\sum_{j=1}^M m_{ij}^2}}$$

Step 4: Decide the relative weights(w_{ij}) of attributes.

Step 5: Find weighted normalized matrix V_{ij}

$$V_{ij} = w_{ij}R_{ij}$$

Step 6: Find the best positive idea and worst negative ideal.

$$V^+ = \max\{V_1^+, V_2^+, \dots, V_j^+\} j=1, 2, \dots, n.$$

$$V^- = \min\{V_1^-, V_2^-, \dots, V_j^-\} j=1, 2, \dots, n.$$

Step 7: Develop the distances between each alternative. The distances of each alternative from ideal solution can be calculated by the equation given below:

$$P_i^+ = \sqrt{\sum_{j=1}^M (V_{ij} - V_j^+)^2}$$

$$P_i^- = \sqrt{\sum_{j=1}^M (V_{ij} - V_j^-)^2}$$

Step 8: Find the closeness of alternatives

$$C_i = \frac{P_i^-}{(P_i^+ + P_i^-)}$$

Rank the alternatives the preference order can be find in step 8, which is close to the ideal solution and far from the negative ideal solution. Recommend the best alternative. The preferred alternative is the one with the maximum value of C_i .

3. EXAMPLE

An example is considered to demonstrate the methodology of selection of bike.

3.1 QFD House of Quality

On the basis of collected customer voice HoQ is prepared as:

check.

For consistency we need a weight sum vector named as “Ws”, which is a multiplication of comparison matrix and weight factor matrix . Refer to table 2.

Table. 2. Weight sum vector

Ws
0.19
0.39
0.38
1.05
1.52
3.10

Now, Taking average of the “Ws dot 1/w” matrix which is 6.42 and this value called as element of consis and shown by λ .

To get consistency index, this formula is applied

$$\text{Consistency Index (CI)} = \frac{\lambda - n}{n - 1}$$

Where n is the no of alternatives and here we have 6 aspects or alternatives. So the CI is 0.08 and to get the consistency ratio we have to divide the CI by random index “RI” which depends on number of alternatives shown in table3.

Table. 3. Random Index

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.2	1.24	1.32	1.41	1.45	1.49

Here for 6 alternatives the value of Random index would be 1.25.

So The Consistency Ratio “CR” is 0.07.

The best consistency ratio would be if it's less than 0.1 and when it goes equal or higher then it mean the comparison should be rechecked.

Now we got that Average is the aspects which have higher weight value.

Now the same AHP process would be followed for these three chosen bike models for each alternative. So for each alternative we have one weight factor matrix.

By multiplying all six weight factor matrix with the weight factor matrix from the main comparison matrix as shown in table 4.

Table 4. Wait matrix

	Design	Service Availability	Power	Comfort	Price	Mileage	w
Bike-A	0.11	0.19	0.11	0.11	0.48	0.41	0.03
Bike-B	0.26	0.08	0.26	0.26	0.41	0.48	0.06
Bike-C	0.63	0.72	0.63	0.63	0.11	0.11	0.06
							0.16
							0.22
							0.46

Now, various steps of the methodology, shown in Section 2.3, are carried out and the relative closeness values are found for different alternatives 1, 2 and 3 as shown below:

$$C_1 = 0.50198$$

$$C_2 = 0.58664$$

$$C_3 = 0.43891$$

The three alternatives for bike selection are ranked on the basis of relative closeness values are shown below (table 5):

Table 5. Ranking for bike selection

	Design	SA	P	Com.	Price	Mileage	P _i ⁺	P _i ⁻	C _i	Rank
Bike-A	0.11	0.19	0.11	0.11	0.48	0.41	0.137059	0.138150	0.50198	2
Bike-B	0.26	0.08	0.26	0.26	0.41	0.48	0.122055	0.17322	0.58664	1
Bike-C	0.63	0.72	0.63	0.63	0.11	0.11	0.170200	0.13314	0.43891	3

4. CONCLUSIONS

The study shows the correlation between customer demand and product characteristics. The proposed methodology is helpful for the decision makers. By reducing complex decisions through pair-wise comparison, then analyzing the closeness or farthestness to the ideal positive or negative solutions and synthesizing the results, decision makers arrive at best decision. The integrated QFD-AHP-TOPSIS method proposed in this paper for bike selection problem, this method is also useful in analysis and calculation of weights of technical and process parameters in QFD stages.

The proposed analysis model has practical application as Bike Section problem shown further more proposed method is also used to solve other optimization problems in many industries.

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