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Dealing with dissatisfaction in mathematical modelling to integrate QFD and Kano's model

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Abstract. The purpose of the study is to implement the integration of Quality Function Deployment (QFD) and Kano's Model into mathematical model. Voice of customer data in QFD was collected using questionnaire and the questionnaire was developed based on Kano's model. Then the operational research methodology was applied to build the objective function and constraints in the mathematical model. The relationship between voice of customer and engineering characteristics was modelled using linier regression model. Output of the mathematical model would be detail of engineering characteristics. The objective function of this model is to maximize satisfaction and minimize dissatisfaction as well. Result of this model is 62% .The major contribution of this research is to implement the existing mathematical model to integrate QFD and Kano's Model in the case study of shoe cabinet.

Keywords: QFD, Kano's model, mathematical model.

1. Introduction

Quality Function Deployment (QFD) is one of the most powerful tools in translating voice of customer to engineering characteristics. QFD also a methodology to develop a product design that enlighten the interrelationship between customer need and technical requirement/ engineering characteristic, to know exactly what is the customer wants and then assess each proposed design comprehensively [1].

Among many benefits of QFD, there were some flaws in interpreting the relation between voice of customer and engineering characteristic, the subjectivity in determining the relationship which is represented by weak, medium and strong relation in the House Of Quality [2],[3],[4]. To overcome the weakness in the QFD, a linier regression is used to modelled the relationship between voice of customer and engineering characteristics in the proposed mathematical model [5].

Conventional QFD assumes that maximizing the customer satisfaction will also effectively minimizing customer dissatisfaction, this is the theory of compensation. Meanwhile the MH-theory said that the source of satisfaction and dissatisfaction was different, so increasing the customer satisfaction was not directly minimizing customer dissatisfaction. It is very perilous to assume that the source of customer satisfaction and dissatisfaction is identical [6]. To overcome this flaw, Kano's model will contribute to the proposed mathematical model.

Kano's model concept was parallel to MH-theory. Kano's model categorised customer needs into several classifications. Customer is expected to respond questionnaire which is developed based on Kano's model. Dealing with those issues, we proposed a mathematical modelling to integrate QFD



and Kano's model, objective function of this model is to maximize customer satisfaction and minimize customer dissatisfaction as well. Shoe Cabinet is used to implement the application of this mathematical model.

2. Proposed Model

The proposed model will be presented below:

$$\text{Max } Z = \sum_i w_i \times (S_i + DS_i) \quad (1)$$

The objective function is to maximize customer satisfaction and minimize customer dissatisfaction, which values lies between 0 and 1.

w_i = relative importance weight for customer need i , $0 \leq w_i \leq 1$

S_i = satisfaction score i , $0 \leq S_i \leq 1$

DS_i = dissatisfaction score i , $-1 \leq DS_i < 0$

Subject to.

$$\forall i: P_i = \beta_{i0} + (\sum_j \beta_{ij} \times x_j^c) + \varepsilon_i \quad (2)$$

In the conservative QFD, association strength of customer need j and the engineering characteristics are equivalent by using subjective ratings, such as 1, 3, 9. To reduce the bias of the relationship evaluations, the regression technique is demonstrated. The regression function obtained is as in equation (2). P_i represents performance level to depict the need of customer i . β_{i0} and β_{ij} is regression function that represents the relationship strength between engineering characteristics i and customer need j .

$$\forall j: x_j^c = \frac{(x_j - L_j)}{(U_j - L_j)} \quad \text{for the bigger the better, or} \quad (3)$$

$$x_j^c = \left| \frac{(x_j - U_j)}{(U_j - L_j)} \right| \quad \text{for the lesser the better, } 0 \leq x_j^c \leq 1$$

$$\forall j: L_j \leq x_j \leq U_j \quad (4)$$

The engineering characteristic values should be given using equation (3) to remove the effect of different scaling of different engineering characteristics. For engineering characteristic i , its values lie between upper bound U_i and lower bound L_i (4).

$$B \geq \sum_j c_j \times |(x_j - x_j^0)| \quad (5)$$

B unit organization's supply such as R&D budget are available for product development project (5). $|(x_j - x_j^0)|$ denotes the amount of development for engineering characteristics, c_j means expenses needed of making one unit improvement of engineering characteristic

We use 0.5 in case of Kano's basic parameter, 1 in case of Kano's satisfier parameter and use 2 in case of Kano's attractive parameter [7].

For each customer ($\forall i$):

If customer i is a Kano must-be/ basic type of customer :

$$S_i = 0 \quad (6)$$

$$DS_i = \max \left(\left[\left(\frac{P_i}{P_i^*} \right)^{n_i} \times DS_i^* \right], -1 \right) \quad (7)$$

Eq.6 and Eq. 7 clarify a basic type of customer need, score of the customer satisfaction is zero but when this basic need is not fulfilled then maximum dissatisfaction score will be -1 when it is not performed. The negative value lower than -1 for the dissatisfaction score do not have important meaning, thus it is transformed to -1. Moreover, according to Eq. 6, a basic type of customer need did not have contribution to customer satisfaction, even though they reach the maximum value.

If customer i is a Kano satisfier type of customer :

$$F_i = \alpha_i \times P_i + \theta_i, \quad (8)$$

$$\text{if } F_i \geq 0 \text{ then } (DS_i = 0, S_i = \min(F_i, 1)),$$

$$\text{if } F_i < 0 \text{ then } (DS_i = \max(F_i, -1), S_i = 0)$$

Satisfier customer is the type of customer that will be delighted if the need is satisfied, increasing of the product performance will also linearly increase the satisfaction, but it will affect the dissatisfaction as it is not satisfied. The satisfaction or dissatisfaction that is perceived by the customer is represented by a linear function F_i . α_i is the slope and θ_i is the intercept of the function. The function F_i can be determined using the survey, respondents were asked to determine their emotion about at least four different levels of product performance. F_i can be in both the negative or positive value. Customer satisfaction is represented by positive value of F_i , meanwhile customer dissatisfaction is represented by negative value of F_i .

If customer i is a Kano attractive type of customer :

$$DS_i = 0 \quad (9)$$

$$S_i = \min\left(\left[\left(\frac{P_i}{P_i^*}\right)^{m_i} \times S_i^*\right], 1\right), m_i > 1 \quad (10)$$

Customer do not aware for these needs, this need is categorized as an effect of surprised. It will give high satisfaction if this need is fulfilled, but it also will not affect dissatisfaction if it is not fulfilled. As a modification of Tan and Shen's satisfaction function, 2 can be chosen as a choice of n_i [7]. Score of DS_i^* and S_i^* can be obtained through surveys.

3. Numerical Example

Shoe cabinet was used for numerical examples purposes. Thirty customers as a direct user of Shoe cabinet were interviewed. The need for thirty customers as follows: have space enough (CN₁) which means that customer need a large space enough to store their shoe, sturdy (CN₂) which means that the shoe cabinet is sturdy enough to hold and keep things safely, adjustable height of rack (CN₃) which means that the customer want to adjust height, table have storage for keeping shoe accessories (CN₄) which means that customer want a space for keep their shoes accessories, easiness to clean under the cupboard (CN₅) which means that customer need a space to clean under shoe cabinet. Engineering characteristics related to each customer needs were: volume of cupboard (EC₁), thickness of material (EC₂), area of cupboard leg (EC₃), adjustable rack (EC₄), availability of drawers (EC₅), leg height (EC₆). We also used Kano's questionnaire to ask how they feel about the each customer need. It is found that CN₁ and CN₅ were classified as one dimensional category, CN₂ was classified as must be category, CN₃ and CN₄ were classified as attractive categories.

The House of Quality is presented in Figure 1. The relative importance weight for each customer needs were obtained from the average of the customer questionnaire. The association between customer needs and engineering characteristics were scored by the expert. Three competitors were presented in figure 1, The benchmark score for the three competitors were obtained from the average of the respondent answer. Respondents were asking to give a score in the range of 0 to 5 for each customer needs. There are five customers need that should be translated to engineering characteristics. The top roof part of the HOQ is not defined, because we assumed that all engineering characteristics are independent. A linear regression model was used to portray the relationship between the customer needs and engineering characteristics.

Customer Needs	Kano	Weight	EC ₁	EC ₂	EC ₃	EC ₄	EC ₅	EC ₆	A	B	C
			CN ₁	O	0.221	9					
CN ₂	M	0.245		9				3	0.44	0.75	0.87
CN ₃	A	0.179			9				0.47	0.72	0.83
CN ₄	A	0.159				9			0	0	0.82
CN ₅	O	0.194					9		0.49	0.71	0.87
Dimension			cm ³	cm	-	-	cm	cm ²			

Figure 1. House of Quality

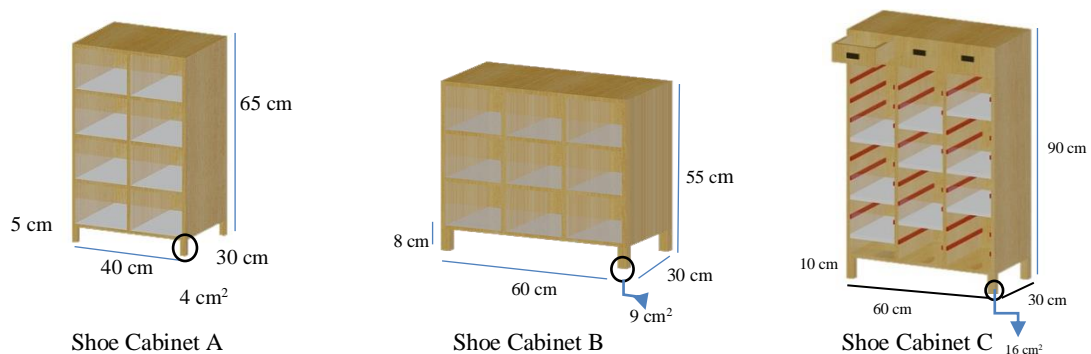


Figure 2. Product concept

Table 1. Product specifications

No.	Engineering Characteristics	Dimension	Product		
			A	B	C
1	EC ₁	cm ³	78000	99000	162000
2	EC ₂	cm	1.2	1.5	1.8
3	EC ₃	cm ²	4	9	16
4	EC ₄	-	Not adjustable	Not adjustable	Adjustable
5	EC ₅	-	None	None	Available
6	EC ₆	cm	5	8	10

The range of engineering characteristics are as follows: 78000 to 162000 cm³ for EC₁, 1.2 to 1.8 cm for EC₂, 4 cm² to 16 cm² for EC₃, not adjustable and adjustable for EC₄, exist or no exist of drawer for EC₅, 5 cm to 10 cm for EC₆. Range of engineering characteristics represent the feasible values. The relationship between the customer needs and engineering characteristics is obtained as linier regression. The dependent variables were the response of product performances while the

independent variables were engineering characteristics for each product, the linear regression is as follows.

$$\begin{aligned} CN_1 &= 0.69231 + 0.18985 EC_1 \\ CN_2 &= 0.63693 + 0.1638 EC_3 + 0.1628 EC_2 \\ CN_5 &= 0.67654 + 0.19042 EC_6 \end{aligned}$$

All of the parameters in linear regression were significant by using $\alpha = 5\%$ and high value of R^2 . The initial value of the design are: $EC_1 = 78000 \text{ cm}^3$, $EC_2 = 1.2 \text{ cm}$, $EC_3 = 4 \text{ cm}^2$, $EC_4 =$ not adjustable, $EC_5 =$ no drawer, $EC_6 = 5 \text{ cm}$. Budget allocation for this improvement is 10% from Cost of Goods sold which is the maximum range to improve the engineering characteristics, IDR 195,000. Improvement cost for EC_1 was IDR 9, EC_2 was IDR 11,388.8, EC_3 was IDR 1,428.5, EC_4 was IDR 30,000, EC_5 was IDR 60,650, and EC_6 was IDR 250. Example of the full numerical models is as follows:

Optimal solution is initiated using Lingo 13.0 as follows: EC_1 is 86791.64 cm^3 , EC_2 is 1.8 cm , EC_3 is 16 cm^2 , EC_4 is 1 (means adjustable rack is preferred), EC_5 is 1 (means drawer is preferred) and EC_6 is 10 cm . All of the improvement reach the maximal score except EC_1 . This need is categorized as one dimensional category. The score is not in the lowest score but it lies between the lowest and the highest. Since one of customer need is not fulfilled, so the overall satisfaction is not high, it is just only 62 %.

$$\text{Max} = 0.221 \times (S_1 + Ds_1) + 0.245 \times (S_2 + Ds_2) + 0.179 \times (S_3 + Ds_3) + 0.159 \times (S_4 + Ds_4) + 0.194 \times (S_5 + Ds_5) \quad (11)$$

$$\text{s. t. } P_1 = 0.69231 + 0.18985 \times x_1^c \quad (12)$$

$$P_2 = 0.63693 + 0.1628 \times x_2^c + 0.1638 \times x_6^c \quad (13)$$

$$P_5 = 0.67654 + 0.19042 \times x_6^c \quad (14)$$

$$x_1^c = \frac{(x_1 - (78000 + 162000)/2)}{((162000 - 78000)/2)} \quad (15)$$

$$x_2^c = \frac{(x_2 - (1.2 + 1.8)/2)}{((1.8 - 1.2)/2)} \quad (16)$$

$$x_3^c = \frac{(x_3 - (5 + 10)/2)}{((10 - 5)/2)} \quad (17)$$

$$x_4^c = \frac{(x_4 - (4 + 16)/2)}{((16 - 4)/2)} \quad (18)$$

$$78000 \leq x_1^c \leq 162000 \quad (19)$$

$$1.2 \leq x_2^c \leq 1.8 \quad (20)$$

$$650 \leq x_3^c \leq 850 \quad (21)$$

$$5 \leq x_5^c \leq 10 \quad (22)$$

$$4 \leq x_6^c \leq 16 \quad (23)$$

$$x_3 \in (0,1) \quad (24)$$

$$x_4 \in (0,1) \quad (25)$$

$$\begin{aligned} 195000 \geq & 9 \times (x_1 - 78000) + 113888.8 \times (x_2 - 1.2) + 30000 \times (x_3 - 0) + 60650 \times (x_4 - 0) + 250 \times (x_5 - 5) + \\ & 1428.5 \times (x_6 - 4) \end{aligned} \quad (26)$$

$$F_1=(0.636*P_1)+0.279 \quad (27)$$

$$F_1 \geq 0 \rightarrow (DS_1=0; S_1= \min F_1, 1) \quad (28)$$

$$F_1 < 0 \rightarrow (DS_1= \max(F_1, -1); S_1=0) \quad (29)$$

$$S_2=0; \quad (30)$$

$$DS_2= \max (((P_2/0.451)^{-2})*-0.3968), -1) \quad (31)$$

$$X_3=0 (S_3=0; DS_3=0) \quad (32)$$

$$X_3=1 (S_3=1; DS_3=0) \quad (33)$$

$$X_4=0 (S_4=0; DS_4=0) \quad (34)$$

$$X_4=1 (S_4=1; DS_4=0) \quad (35)$$

$$F_5=(0.909*P_5)+0.075 \quad (36)$$

$$F_5 \geq 0 \rightarrow (DS_5=0; S_1= \min F_5, 1) \quad (37)$$

$$F_5 < 0 \rightarrow (DS_5= \max(F_5, -1); S_5=0) \quad (38)$$

4. Conclusion

The integration of linear regression to accommodate the relation between customer voice and engineering characteristics and Kano model into mathematical modelling to maximize the customer satisfaction and minimize the customer dissatisfaction has been modelled. The numerical example of shoe cabinet has already presented to perform how the mathematical modelling works. As a result, the output of this model is optimal under many constraint restrictions given in the mathematical model. The output showed that the model has valid.

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