APPLICATION OF AN INTEGRATED QFD AND KANO'S MODEL CASE STUDY: CABINET DESIGN

by Dian Retno Sari Dewi

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ABSTRACT

QFD is a methodology that helps translating customer desires into technical specifications. Rating assessment in determining the relationship between customer need and engineering characteristics are often very subjective in QFD. QFD also assume that customer satisfaction is determined linearly with the need of customers. Yet according to the model of Kano, the increase in customer satisfaction is not linear with the need of customers. This study contributes to application the mathematical modeling to maximize customer need simultaneously in minimizing customer dissatisfaction to assign product development resources. The relationship between consumer desire and technical characteristics were obtained by regression. The model was applied to cabinet design. Results showed that the output obtained by the model can assign existing resources to improve customer satisfaction and dissatisfaction.

Keywords: customer satisfaction, Kano's model, optimization, product development, quality function deployment.

1. INTRODUCTION

Quality Function Deployment (QFD) is an important product development method, dedicated to translate client requirement into activities to develop products and services. However several difficulties in its application, among them: interpreting the customer voice, defining the correlation between quality demanded and quality characteristics, defining the projected quality due to the ambiguity in the quality demanded and quality characteristics, difficulty in working teams, and lack of knowledge about using the methods [1].

Furthermore, QFD methodology assumes that consumer satisfaction increases linearly with increasing customer needs. In addition, QFD assumes that the adding up of customer satisfaction will automatically eliminate customer dissatisfaction. This is not always true, because the trigger of satisfaction and dissatisfaction are not always the same. To explain this, Kano model is used. With the integration model of Kano and QFD is expected allocation of resources can be done properly in order to maximizing customer satisfaction and minimizing customer dissatisfaction? Kano model classifies customer need into a number of categories, according to the impact on customer satisfaction [4]. Basic requirement is a basic need for customer, when the need has already fulfill doesn't mean that the customer satisfied. Fulfillment of satisfier category will increase linearly in customer satisfaction. Meanwhile, attractive category is not linearly increase in customer satisfaction.

We propose integration of Kano model into the mathematical model to improve the lackness of the previous works [2,3].Numerical example will be presented to give the better understanding of this model. The application of this model will be using cabinet design. The voice of customer will be collected using sampling of prime customers. We assume that aesthetic view and type of material will not be consideration of this model.

2. THE PROPOSED OPTIMIZATION MODEL

The proposed model will be presented below:

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

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, $0 \le w_i \le 1$

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

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

Subject to.

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

In the conventional QFD, association strength of customer need j and the engineering characteristics are represent by using subjective ratings, such as 1, 3, 9. To reduce the bias of the relationship evaluations, the regression technique is apply. The regression function obtained is as in equation (2). P_i represents performance level to overcome 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.

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

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

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

The engineering characteristic values should be implied using equation (3) to abolish the effect of different scaling of different engineering characteristics. For

engineering chacteristic i, its values lie between upper bound U_i and lower bound L_i (4).

$$B \geq \sum_j c_j \times \left| \left(x_j - x_j^0 \right) \right| \qquad (5)$$

B units organization's resource such as R&D budget are available for product development project (5). $\left| \left(x_j - x_j^0 \right) \right|$ denotes the amount of improvement for engineering characteristics, c_j means cost needed of making one unit enhancement of engineering characteristic. Equation (6) is based on Tan and Shen, 2000 [5] and then was adjusted related to Rahaju and Dewi, 2014 [2,3]. For practical reasons, the development team may use 2 for Kano's attractive parameter, 1 for Kano's satisfier parameter, and 0.5 for Kano's basic parameter.For each customer ($\forall i$):

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

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

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

Eq.6 and Eq. 7 explain that a must-be type of customer need is a kind of need that subjects to the customer dissatisfaction when unmet. The maximum customer dissatisfaction is scored as -1. It is measured as maximum dissatisfaction feeling that apparent by the customer. The negative value lower than -1 for the dissatisfaction score does not have significant meaning, thus it is transformed to -1. Furthermore, according to Eq. 6, a must-be type of customer need does not have contribution to customer satisfaction, even when the product has maximum capability in meeting it. As an adjustment of Tan and Shen's satisfaction function, -2 can be chosen as an option of n_i.

If customer i is a Kano attractive type of customer:

$$DS_i = 0 \qquad (8)$$

$$S_i = min\left(\left[\left(\frac{P_i}{P_i^*} \right)^{m_i} \times S_i^* \right], 1 \right), m_i > 1 \qquad (9)$$

Attractive type of customer is a group of customer who doesn't aware of these needs. Logically if these needs are not met, consumers will not be disappointed, even low performance will provide an element of surprise. As an adjustment of Tan and Shen's satisfaction function, 2can be chosen as an option of n_i.Score of DS_i^* and S_i^* can be obtained through surveys and can be determined using the equation above.

If customer i is a Kano satisfier type of customer:

$$F_i = \propto_i \times P_i + \theta_i, \qquad (10)$$

$$if F_i \geq 0 \, then \left(DS_i = 0, S_i = min(F_i, 1) \right),$$
$$if F_i < 0 \, then \left(DS_i = max(F_i, -1), S_i = 0 \right)$$

The satisfier type of customer need is the one that subjects to customer satisfaction when met, but also subjects to customer dissatisfaction when it is not properly fulfilled. As stated in Eq. 10, the customer satisfaction increases in a linear manner as the product capability in meeting the respective need improves. The satisfaction or dissatisfaction that is perceived by the customer is represented by a linear function F_i. $\propto_i$ and θ_i are slope and intercept of the function. The function F_i can be constructed using the result survey, respondents are asked to measure their feeling about at least two different levels of product performance. F_i could be in both the negative or positive value. When F_i is a positivevalue means the customer satisfaction score meanwhile when F_i is negative means the customer dissatisfaction score.

3. AN ILLUSTRATIVE EXAMPLE

We were using cabinet design to give an example how the mathematical model works. Output of this model was target specification of cabinet. Ten customers as a lead user of cabinet were interviewed. Those customer needs as follows: large space for keeping things (CN$_1$) meant that customer need a large space enough to keep things in cabinet as storage, well-built (CN$_2$) meant that the cabinet sturdy enough to hold and keep things safely, conformity of things and height of shelves (CN$_3$) meant that customer wanted rack flexibility so that they could keep things adjusted to the rack , Ease of cleaning the bottom of the cabinet (CN$_4$) meant the customer want the ease of cleaning dirt below the cabinet, assurance of goods during storage (CN$_5$) meant that the cabinet could keep things in good condition. Related engineering characteristic were: volume (EC$_1$), thickness of wooden material (EC$_2$), amount of rack in the cabinet (EC$_3$), height of cabinet (EC$_4$), leg cross sectional area of cabinet (EC$_5$). Category of Kano were determined by Kano questionnaire, CN$_1$ and CN$_2$ were classified as basic category, CN$_3$ was classified as satisfier category and CN$_4$ and CN$_5$ were classified as attractive category.

The HOQ of the cabinet is presented by Table-1. Relative importance weight is obtained from survey. Questionnaire was made to conduct the survey. The relative importance weight number in Figure-1 was obtained from average value from each customer need. Two competitor cabinet design were using as benchmark, i.e. product B, product C. Respondents were asking to give a score of each design with a scale of 0 to 1. The average of respondents will be presented in the right column of HOQ matrix. The roof part of the HOQ was not defined, because we assumed that all engineering characteristics were independent. That way, linear regression could be modelled between the customer need and engineering characteristics.

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Table-1. House of quality.

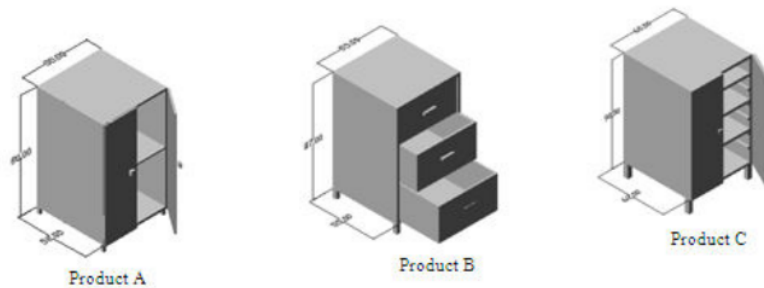| Customer needs	Relative importance weight	Engineering characteristics					Benchmark		
		EC_1	EC_2	EC_3	EC_4	EC_5	Product A	Product B	Product C
CN_1	0.26	9					0.45	0.7	0.95
CN_2	0.23		9			3	0.5	0.75	0.98
CN_3	0.12			9			0.15	0.69	0.98
CN_4	0.21				9		0.5	0.78	0.89
CN_5	0.18		9	3			0.53	0.79	0.96

Figure-1. Concept designs.

Figure-1 shows the 3D of the concept designs of product A, B, and C, while Table-2 contains the specifications details.

Table-2. Product specifications.

Engineering characteristics	Product A	Product B	Product C
EC_1 (cm^3)	208.000	263.175	334.800
EC_2 (cm)	1.55	2.2	2.5
EC_3 (pc)	2	3	adjustable
EC_4 (cm)	4.5	7	12
EC_5 (cm^2)	4.3	9	16

The range of engineering characteristics were as follows: 207500 to 334800 cm^3 for EC_1, 1.5 to 2.5 cm for EC_2, 2 to adjustable pc for EC_3, 4 to 12 cm for EC_4, 4 to 16 cm^2 for EC_5. Those ranges showed technically feasible specifications. The relationship between the customer need and engineering technical characteristic was modelled using linear regression. The independent variables were engineering characteristics while the dependent variables were product performances.

The regression equation is
$CN_1 = 0.640 + 0.343 EC_1$

Predictor	Coef	SECoef	T	P
Constant	0.63973	0.01565	40.87	0.000
EC_1	0.34331	0.01910	17.97	0.000

S = 0.0605555   R-Sq = 96.1%   R-Sq(adj) = 95.8%

The regression equation is
$CN_2 = 0.559 - 0.299 EC_2 - 0.110 EC_5$

Predictor	Coef	SECoef	T	P
Constant	0.55900	0.01428	39.14	0.000
EC_2	-0.29918	0.04361	-6.86	0.000
EC_5	-0.10982	0.04454	-2.47	0.030

S = 0.0451664   R-Sq = 98.6%   R-Sq(adj) = 98.4%

The regression equation is
$CN_4 = 0.627 - 0.329 EC_4$

Predictor	Coef	SECoef	T	P
Constant	0.62745	0.02518	24.91	0.000
EC_4	-0.32939	0.03037	-10.84	0.000

S = 0.0970463   R-Sq = 90.0%   R-Sq(adj) = 89.3%

The regression equation is
$CN_5 = 0.568 - 0.358 EC_2$

Predictor	Coef	SE Coef	T	P
Constant	0.56762	0.02569	22.09	0.000

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EC_2 -0.35785 0.03028 -11.82 0.000
S = 0.0982636   R-Sq = 91.5%   R-Sq(adj) = 90.8%

Using α = 5%, the significant predictors were those which P value < 0.05. All of the parameters were significant and R^2 is high, in that way that regression equation could be incorporated into model. Amount of rack in the cabinet (EC_3) had not continuous scale; the range was two rack and adjustable rack. Adjustable design meant that the design will be accommodated maximum amount of rack in the design but the usefulness of rack was depend on customer policy. Based on survey, the result showed that adjustable design was outperform compared to not adjustable. Initial score of satisfaction and dissatisfactionare obtained through focus groups who were consisting of experts furniture. Available budget for product improvement was IDR 300.000, and improvement cost for EC_1 was IDR 4150 per cm^3, for EC_2 was IDR 1100 per cm, EC_3 was 2150 per pc, EC_4 was 950 per cm and EC_5 was 1150 per cm^2. The complete model example is as follows.

$$Max Z = 0.26 \times (S_1 + DS_1) + 0.23 \times (S_2 + DS_2) + 0.1200 \times (S_3 + DS_3) + 0.21 \times (S_4 + DS_4) + 0.18 \times (S_5 + DS_5)$$

s.t.
$$P_1 = 0.802 + 0.951 \times x_1^c$$
$$P_2 = 0.752 - 0.65 \times x_2^c \quad - 0.949 \times x_5^c$$
$$P_4 = 0.758 - 0.982 \times x_4^c$$
$$P_5 = 0.271 - 0.975 \times x_2^c$$
$$x_1^c = \frac{(x_1 - (207500 + 334800)/2)}{(344800 - 207500)/2}$$
$$x_2^c = \frac{(x_2 - (2.5 + 1.5)/2)}{(2.5 - 1.5)/2}$$
$$x_4^c = \frac{(x_4 - (12 + 4)/2)}{(12 - 4)/2}$$
$$x_1^c = \frac{(x_5 - (16 + 4)/2)}{(16 - 4)/2}$$
$$207500 \leq x_1 \leq 334800$$
$$1.5 \leq x_2 \leq 2.5$$
$$x_3 \in \{0,1\}$$
$$4 \leq x_4 \leq 12$$
$$4 \leq x_5 \leq 16$$
$$300000 \geq 4150 \times (x_1 - 207500) + 1100 \times (x_2 - 1.5) + 2150 \times (x_3 - 0) + 950 \times (x_4 - 4) + 1150 \times (x_5 - 4)$$
$$S_1 = 0$$
$$DS_1 = max\left(\left[\left(\frac{P_1}{0.7}\right)^{-2} \times -0.12\right], -1\right)$$
$$S_2 = 0$$
$$DS_2 = max\left(\left[\left(\frac{P_1}{0.05}\right)^{-2} \times -0.55\right], -1\right)$$
$$x_3 = 0 \Rightarrow (S_3 = 0; DS_3 = 0)$$
$$x_3 = 1 \Rightarrow (S_3 = 1; DS_3 = 0)$$
$$f_4 = 0.027 + 0.81 \times P_4$$
$$if \, f_{4 \geq 0} \rightarrow DS_4 = 0, S_4 = min([0.81 \times P_4 + 0.027], 1)$$
$$if \, f_{4 < 0} \rightarrow S_4 = 0, DS_4 = max([0.81 \times P_4 + 0.027], -1)$$
$$f_5 = 0.06 + 0.69 \times P_5$$
$$if \, f_{5 \geq 0} \rightarrow DS_5 = 0, S_5 = min([0.69 \times P_5 + 0.06], 1)$$
$$if \, f_{5 < 0} \rightarrow S_5 = 0, DS_5 = max([0.69 \times P_5 + 0.06], -1)$$

Optimal solution was found using Lingo 13.0 as follows: EC_1 was 207,567.4 cm3, EC_2 was 2.5 cm, EC_3 was adjustable rack, EC_4 was 7.6 cm and EC_5 was 16 cm2. Available budget was allocated for basic need EC_2 and satisfied need EC_4 and EC_5 and attractive need EC_3. Allocation for basic need didn't improve the satisfaction score, meant that the previous design not capable enough to fulfill basic need. Cost of improvement was used for improve the basic need. Weight for basic need was 0.49 (high enough), while the basic needs didn't contribute to the satisfaction score. The consequence is that the objective function cannot be high (0.451).

4. CONCLUSIONS

Integrating Kano model into optimization modelling gave better understanding in maximising satisfaction and at once minimizing dissatisfaction score. Linier regression modelling was capable to identify the relationship between customer needs and engineering characteristics. By using proposed model the available resource will be allocated effectively to increase customer satisfaction and at once decreasing customer dissatisfaction.

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