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04.	Ignatius Jaka Mulyana, STP.,MT.	531.98.0325	*Optimization of Cambering Process by Determination of Process Parameter to Improve of Parabolic Leaf Spring*

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APPLICATION OF OPTIMIZATION MODELING TO DERIVE AN ENGINEERING CHARACTERISTICS IN QFD

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ABSTRACT

Quality Function Deployment (QFD) is an important tool to translate the customer requirement needs into technical specifications or engineering characteristics. Conversely, there were many difficulty of using QFD such as defining the correlations between customer needs and engineering characteristics that was very subjective. In order to overcome difficulties, we develop the mathematical model based on Askin and Dawson model to capture the customer needs and translate them into engineering characteristics. We provided a numerical example by using table as object to demonstrate the developed model. Collection of the data were using questionnaire that asking about customer needs and product competitors. Based on the data, we had a set of independent and dependent variables to make linier regression that portray the relation between customer needs and engineering characteristics. The constrained in this mathematical modeling would be the range of engineering specification, budget constraint to develop the engineering characteristic and normalization value of engineering characteristics. The weight for each customer needs were obtained from questionnaire. Result showed that the model could work well under the constrained to gain the customer satisfaction. Value of customer satisfaction is high because the model could distribute optimally for each constraint.

Keywords: mathematical modeling, QFD, customer satisfaction.

1. INTRODUCTION

The development of product design needed many parties that involved as a team. To develop a new product needed an solid team to capture all needed concurrently. One of well known tool is Quality Function Deployment (QFD). QFD is a powerfull development product design to translate the voice of customers into related technical requirements, Akao (1990), Cohen (1995). Conventional QFD considered how to maximize the customer satisfaction without seeing the budget to fulfill that need. The output of solution will not sufficient since its ignore the limitation of budget constraint.

To overcome the lackness of conventional QFD, we proposed the integration QFD and mathematical model. This implementation of the integration can be seen also in Bode (1998), Rahaju (2014) and Dewi (2016). This model has already considered all the constrained to fulfill the objective function. The objective function is to maximize the overall customer satisfaction.

Also QFD have several limitations, how to translate the customer voice, lack of knowledge of using QFD, barrier in working with large teams, and subjectifity of defining the correlation between customer needs and technical requirement. Though the difficulties related to subjective perspectives in relation between the customer needs and technical requirements still open for discussion. To overcome the lackness in this area, we proposed the linier regression model to portray the relation between customer needs and technical requirement or engineering characteristics. We assumed that the relation between customer need and engineering characteristic was linier. Model of Askin and Dawson (2000) was adopted for this model.

Numerical example will be provided to gain the better understanding to this model. Table for study was used as object, we surveyed several lead customers to identify the requirement for the table and then we selected several requirements as an input to model. We ignored some requirement such as the design and the materials. The subjective function of this model is to maximize the overall customer satisfaction under several constraints that will explain further. Result of this model gives the optimum allocation for constraint in order to fulfill the objective function.

2. THE PROPOSED OPTIMIZATION MODEL

The proposed mathematical model is presented below:

Max [illegible] ....(1)

subject to

[illegible] ....(2)

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

(if the improvement activity was conducted in series)

[illegible]

(if the improvement activity was conducted in pararel)

[illegible] = relative weight of customer need *j*

[illegible] =performance to fulfill need *j*

[illegible] = minimum value of performance to fulfill need *j*

[illegible] =lower bound for engineering characterisic *i*

[illegible] =upper bound for engineering characteristic *i* [illegible] represent *technically achieveable range*

[illegible] = normalized engineering characteristic value, value between -1 to 1

[illegible] = initial value of engineering characteristic

[illegible] = improvement value on engineering characteristics

[illegible] = production cost per one unit of engineering characteristics improvement

[illegible] = production limitation budget

[illegible] = R&D cost for improve per unit engineering characteristic

[illegible] =R&Dlimitation budget

[illegible] = time needed for one unit improvement

[illegible] = allocation time available

The objective function is to maximize the customer satisfaction. [illegible] score was in the range between lower bound and upper bound. The lower bound and upper bound were set by the expert judgment. Normalization value of [illegible] to eliminate bias. The value of [illegible] was set in the interval of [illegible] 1. This constraint enlighten of sources constraint. In this case was the source to improve the engineering characteristics.

3. NUMERICAL EXAMPLE

Before conducting market survey, we were survey several lead customers who uses table for study and work everday. Using interview methods we discovered several customer needs. We designed a questionnaire based on interview result and conducted survey for 300 respondents. We asked for how they felt about the need and also gave opinion for competitor products. The customer need were: sturdy table (CN_1), there was enough space for printer (CN_2), there was enough space for work (CN_3), comfortable table (CN_4), there was enough space to keep things(CN_5). Related engineering characteristics is leg cross section wide (EC_1) , printer area (EC_2), table area (EC_3), leg wide (EC_4), and spacious volume (EC_5).

Table 1. House Of Quality

Customer Needs	Relative Importance Weight	Engineering Characteristics					Benchmark	
		EC_1	EC_2	EC_3	EC_4	EC_5	A	B
CN_1	4.33	9					4.47	3.25
CN_2	3.17		9				4.4	3.2
CN_3	4.5			9			2.85	4.58
CN_4	4.8				9		2.76	4.38
CN_5	4.17					9	4.47	2.91

Table 2. Product specifications

Engineering Characteristics	Product A	Product B
EC_1 (cm)	15	18
EC_2 (cm^2)	200	250
EC_3 (cm^2)	4000	7000
EC_4 (cm)	50	60
EC_5 (cm^3)	408.500	422.000

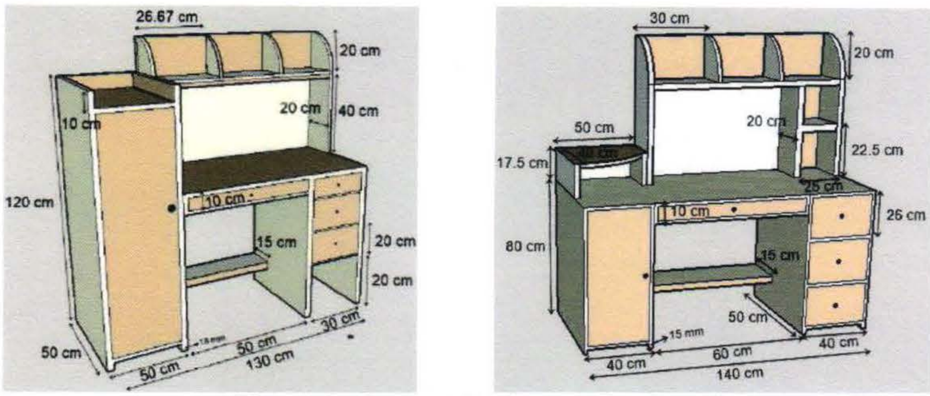

Figure 1. Concept Design product A and B

Figure 1 showed the 3D of the concept designs of product A, and B, while Table 1 contained the specifications details. The feasible range of engineering characteristics were defined as follows: 15 to 18 cm for EC_1, 200 to 250 cm^2 for EC_2, 4000 to 7000 cm^2 for EC_3, 50 to 60 cm for EC_4, 408.500 to 422.000 cm^3 for EC_5. Those range showed the technically acceptable for manufacturing process. The relationship between product performances and engineering characteristics were represented by linier function. The product performances were the dependent ones and the engineering characteristics were the independent variables. The linier regression results are presented below.

```
The regression equation is
CN1 = 3.86 + 0.610 EC1
Predictor          Coef SE Coef  T        P
Constant         3.86126 0.02893133.45 0.000
Leg cross sec     0.60995 0.0289321.08 0.000
S = 0.565520    R-Sq = 53.9%   R-Sq(adj) = 53.8%

The regression equation is
CN2 = 3.80 + 0.599 EC2
Predictor                Coef SE Coef      T        P
Constant              3.80366 0.03289  115.660.000
Printer area          0.59948 0.03289   18.23  0.000
S = 0.642763    R-Sq = 46.7%   R-Sq(adj) = 46.5%
```

```
The regression equation is
CN3 = 3.72 + 0.866 EC3
Predictor              Coef SE Coef        T       P
Constant            3.71990 0.03444   108.00   0.000
Table area          0.86649 0.03444    25.16   0.000
S = 0.673209   R-Sq = 62.5%   R-Sq(adj) = 62.4%

The regression equation is
CN4 = 3.55 + 0.785 EC4
Predictor             Coef  SE Coef        T       P
Constant           3.54974  0.03182   111.57   0.000
Leg wide           0.78534  0.03182    24.68   0.000
S = 0.621867   R-Sq = 61.6%   R-Sq(adj) = 61.5%

The regression equation is
CN5 = 3.69 + 0.785 EC5
Predictor            Coef  SE Coef        T       P
Constant          3.69110  0.03278   112.61   0.000
Spacious vol      0.78534  0.03278    23.96   0.000
S = 0.640616   R-Sq = 60.2%   R-Sq(adj) = 60.1%
```

Using $\alpha = 5\%$, the significant predictors were those that P value < 0.05, all parameters are below 0.05 which are significant. In this example, the source constraint was the reachable budget for product improvement, i.e. IDR 325,000. The incremental improvement costs for engineering characteristics were IDR 0.23 per cm for EC_1, IDR 7.9 per cm for EC_2, IDR 7.9 per cm for EC_3, IDR 1066.5 per cm^2 for EC_4, and IDR 39.5 per cm for EC_5. The other resources, such as development time, were deliberated unbounded. The complete mathematical modeling was as follows.

Max [illegible] ....(11)

[illegible] ....(12)

[illegible] ....(13)

[illegible] ....(14)

[illegible] ....(15)

[illegible] ....(16)

[illegible] ....(17)

[illegible] ....(18)

[illegible] ....(19)

[illegible] ....(20)

[illegible] ....(21)

[illegible] ....(22)

[illegible] ....(23)

[illegible] ....(24)

[illegible] ....(25)

[illegible] ....(26)

[illegible] ....(27)

[illegible] ....(28)

[illegible] ....(29)

[illegible] ....(30)

[illegible] ....(31)

[illegible] ....(32)

[illegible] ....(33)

[illegible] ....(34)

[illegible] ....(35)

[illegible] ....(36)

[illegible] ....(37)

[illegible] ....(38)

[illegible] ....(39)

[illegible] ....(40)

[illegible] ....(41)

[illegible] ....(42)

Using LINGO software, the result of the model as follow, EC_1 is 18 cm, EC_2 is 250 cm^2, EC_3 is 6.972,286 cm^2, EC_4 is 60 cm, and EC_5 is 415.863,4 cm^3 and it gives customer satisfaction value at 90,26%. We also conducted sensitivity analysis for the model. All engineering characteristics had the characteristics of the larger the better, that's why increasing of the parameters of engineering characteristics will increase the customer satisfactions. Since the criteria of the selection is the larger the better, meanwhile all of the resource should follow constraints, that's why the output of this model will attain product B. EC_3 and EC_5 didn't meet the maximal value since the constraint of the budget limit the movement.

4. CONCLUSION

Overcoming the weakness of QFD in general, we propose a model that has already applied in this paper. Objective function of this model is to maximize customers satisfaction and the result of this model is fulfill that criteria. We have done the validation and the result is that all constraints are not infringed and that the model can work properly.