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Product Development Of Towing Tractor Using Fuzzy QDF At PT. United Tractors Pandu Engineering

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Abstrak

Persaingan yang semakin ketat di dunia industri menyebabkan setiap perusahaan untuk meningkatkan kualitas produknya sesuai dengan permintaan konsumen. Salah satu cara dalam meningkatkan kualitas produk adalah melalui proses pengembangan produk dengan menggunakan Quality Function Deployment (QFD). Akan tetapi salah satu kelemahan QFD adalah adanya faktor subjektifitas dalam penentuan target dari karakteristik teknik. Dengan mempertimbangkan kenyataan tersebut, maka studi ini menggunakan metode Fuzzy QFD dalam menentukan nilai yang optimal dari karakteristik teknik untuk produk towing traktor pada PT. United Tractors Pandu Engineering. Dengan mempetimbangkan ketidakpastian dan ketidakjelasan, dalam studi ini ditentukan bobot kepentingan, hubungan antara atribut konsumen dengan karakteristik teknik, serta korelasi teknik dari towing traktor. Langkah pertama adalah menentukan koefisien parameter antar atribut dengan menggunakan fuzzy regresi linear. Koefisien yang didapat untuk selanjutnya digunakan sebagai fungsi pembatas dalam analisa keputusan berdasarkan multikriteria dalam menentukan nilai optimal dari karakteristik teknik.

Kata Kunci: *Pengembangan produk, regresi fuzzy, programa linier fuzzy dan QFD*

Abstract

The increasing competitiveness of today's industry forced each company to improve the quality of its products by considering customer demand. One way to improve the quality is by doing a product development process using the Quality Function Deployment (QFD). Regardless of all the benefits of QFD possessed, this method is subjective by nature, especially in the determination of engineering characteristics target efforts. This study uses Fuzzy QFD method to point out the optimal engineering characteristics value for towing tractor product, produced by PT. United Tractors Pandu Engineering, with special acknowledgement on uncertainties and vagueness in determining importance rating, satisfaction level, the relationship between customer attributes with engineering characteristics, and technical correlation. The first step is to decide on parameter coefficients between attributes using fuzzy linear regression technique. These coefficients will act as constraints in determining the optimal engineering characteristics value with the means of multiobjective decision making, along with other constraints.

Keywords: *Product development, fuzzy regression, fuzzy linear programming and QFD*

1. Introduction

The increasing competitiveness of the industrial world has forced each company to level up its capacity so that it can survive and win the competition. To win the competition, a company must strive to increase the quality of its products with costs as efficient as possible to satisfy the customers' needs. One of the ways that can be done by companies to increase its products' quality is by doing a product development process within the specification described by the customers while still withholding resources' effectiveness and efficiency [1]. One of the methods to identify the customer demand is through Quality Function Deployment (QFD). QFD is a structured product design and development method that enables a development team to identify the customer demand and evaluate systematically each product's ability in performing its desired task in fulfilling those demands [2].

Although QFD has some merits such as increasing the customers' satisfaction, it organizes data in a logical and systematic way,

and it reduces the product development time by 50%, still QFD is a qualitative method [3]. The relationship between the customer attributes with the engineering characteristics is vague and performance evaluation by the customers tends to be subjective and qualitative. This caused trouble, since on the next step the customer attribute will be translated into engineering characteristics that in general decided subjectively by the company through an agreement in the product development team so that it needs a long time. Another approach that can overcome this problem is through a method called the *Fuzzy Quality Function Deployment* (Fuzzy QFD). This technique is used to determine the optimal target value of the engineering characteristics with considerations on the information vagueness in the product design and development process.

PT United Tractors Pandu Engineering as one of the companies that work on the field of heavy-duty machinery, is continuously working to improve the quality of its products. One of the ways that can be done by PT United Tractors Pandu Engineering is to develop its towing tractor product, which in fact has been one of the favorites by airline companies in Indonesia. The product development, however, up to this moment is still inadequate especially in terms of the customers' needed specifications. Thus, a corrective action is needed for the development of the towing tractor type PTD-50 by implementing Fuzzy QFD so that the optimal engineering characteristics value for this product can be determined.

In this case, the product development of a towing tractor type PTD-50 has not been based on customer demand yet. This study attempts to fulfill this need of product development through the determination of optimal engineering characteristics value by implementing Fuzzy QFD.

The specific objectives of this study are to obtain the customers' needs and each of its importance rating of the towing tractor product, to obtain the optimal engineering characteristics target of the towing tractor, and to propose a towing tractor type PTD-50 product development plan that meets the customers' needs.

For the purpose of this study, the observed customers are the Indonesian customers. The study is limited to the first step of QFD (House of Quality).

2. Methods

The first phase of this study is preliminary data collecting in regards of product information, customer data, and competitors of the PTD-50 product data. An interview with the customers located in Jakarta is conducted to define the customer attributes for the PTD-50 towing tractor. Those customer attributes will be the input of survey questionnaire.

The questionnaire, which has undergone validity and reliability test, are distributed to all of PTD-50 Indonesian customers. The questionnaire results will be the main data in the data processing phase. In data processing phase, the first step is determining the importance rating and satisfaction level for each customer attribute. Then, a discussion with the company has been conducted to determine the relationship between customer attributes and engineering characteristics and the technical correlation. After that, the optimal engineering characteristic targets are set up by using Fuzzy QFD method. This method uses two main approach, which are fuzzy linear regression and multiobjective decision making. Finally, a House of Quality (HOQ) is made.

QFD is a methodology to plan and develop a product that enables the company to define specifically the customer demand and then evaluate each proposed products of its service capabilities to fulfill those needs. In general, the QFD process consists of 4 phases, which are [5].

1. Product planning that consists of the customer demand and its technical requirements.
2. Part planning that consists of technical requirements and parts characteristics.
3. Process planning that consists of parts characteristics and process characteristics.

4. Production planning that consists of process characteristics and production requirements.

In this study, the QFD process is done until the first phase only. The matrix for the first process is called the customers' needs planning matrix or widely known as the *House of Quality*, as shown in the figure 1.

Next, Fuzzy Quality Function Deployment (Fuzzy QFD) is a method that uses the fuzzy theoretic modeling approach to QFD by developing and illustrating a fuzzy multiobjective model to aid a development team in choosing target levels for the engineering characteristics in various environments.

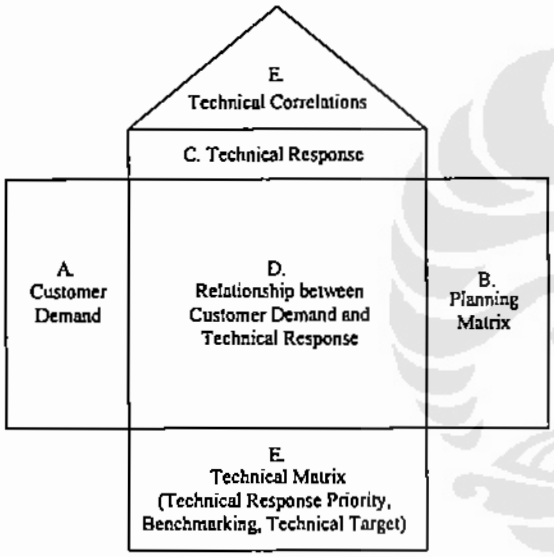

Figure 1.
House of Quality

The target determination process of the engineering characteristics in QFD can be formulated in an optimization model. The symbols used are:

z_i = customers' perception about the degree of satisfaction level from the customer attribute i, where i = 1, ..., m.

x_j = target value of engineering characteristic j, where j = 1, ..., n.

f_i = the functional relationship between the customer attributes and the engineering characteristics, where i = 1, ..., m; and $y_i = f_i(x_1, ..., x_n)$.

g_j = the functional relationship between the engineering characteristics with other engineering characteristics, where j = 1, .., n.

$x_j = g_j(x_1, ..., x_{j-1}, x_{j+1}, ..., x_n)$

The first step of Fuzzy QFD is determining inter-attribute functional relationship by using fuzzy regression. It is used to model the doubt phenomena and imprecision by using the fuzzy parameter. The qualitative scale that is generally used to measure the customers attribute, doubt or imprecision of the relationship between the customers attribute with the engineering characteristics, or between engineering characteristics are the main sources of vagueness. Thus, the fuzzy regression would be of best use and it can result in an estimation of the parameter system that is reliable in modeling QFD in an industrial environment, which can be formulized as follow:

$$\text{Min} \left\{ \sum_{j=i}^{m} \sum_{j=1}^{n} c_k x_{jk} \right\} \quad (1)$$

Constraints:

$$\sum_{j=1}^{n} a_m x_{jk} + \left|1 - H\right| \sum_{j=1}^{n} a_{sj} \left| x_{jk} \right| \geq y_k, \quad (2)$$

$$-\sum_{j=1}^{n} a_{mj} x_{jk} + \left|1 - H\right| \sum_{j=1}^{n} a_{sj} \left| x_{jk} \right| \geq -y_k, \quad (3)$$

α_{mj} is the median of α_j dan α_{sj} is the width or variation of α_j around α_{mj}. The median shows the most likely value for α_j. The variation indicates the precision of α_j value. H value shows the degree of fit from the fuzzy linear estimation model. The H value, which is between 0 and 1 is decided unanimously by the decision maker.

After obtaining inter-attribute functional relationship, optimal engineering characteristics are set by using multiobjective decision making. In linear programming, it is always assumed that there is only one objective (usually symbolized by z). In the real world, it is much more often that the decision makers find a situation where he must fulfill several objectives at once in making a decision. A trade-off between an objective to another is not a rare practice at all.

The crisp objective function can be shown as:

Find $x_1, x_2, ..., x_n$ that,

$$\text{Max } V(z_1, z_2, \ldots, z_m) \quad (4)$$

where $V(z_i, ..., z_m)$ is a MAV function that is connected to the level of customers' satisfaction $(z_i,..., z_m)$. The MAV function can be added, timed, or multilinear, depending on the customers' preference structure. For example, for addition MAV function, the multiobjective equation can be written as:

$$\text{Max } V(z_1, z_2, \ldots, z_m) = \sum_{i=1}^{m} w_i V_i(z_i) \quad (5)$$

The following is the basic (crisp) model in the form of linear programming to find the optimal engineering specifications, i.e., to find the engineering characteristic target values $x_1,x_2,\ldots,x_n$ which maximize the overall customer satisfaction or:

$$\text{Max } V(z_1, z_2, \ldots, z_m) \quad (6)$$

Constraints:

$$z_i = f_i(x_1, x_2, \ldots, x_n),\ i = 1,\ldots,m \quad (7)$$

$$x_j = g_j(x_1, \ldots, x_{j-1}, x_{j+1}, \ldots, x_n),\ j = 1,\ldots,n \quad (8)$$

With respect to the linear programming model, the engineering characteristic target determination is divided into three-model components (functional relationship parameter, objectives and constraints).

1. Functional Relationship Parameters:
   In the functional relationship parameters in HoQ and QFD, there are adjoined cells between WHAT and HoQ and on the roof (between engineering characteristics). Traditional QFD treats these parameters as vague (fuzzy) or imprecise. By using equations (4) through (6), it will be obtained the linear functions and parameters of:

$$\tilde{z}_i = \tilde{f}_i(x_1,\ldots,x_n) \quad (9)$$

$$\tilde{x}_j = \tilde{g}_j(x_1,\ldots,x_{j-1},x_{j+1},\ldots,x_n) \quad (10)$$

   With the assumption that TFN (Triangular Fuzzy Number) is being used in fuzzy regression, after the fuzzy number arithmetic process has been done, each of equations (9) and (10) can be translated into three crisp equations as follows.

$$z_i = f_i(x_1,\ldots,x_n),\ i = 1, 2, \ldots, m \quad (11)$$

$$z_i^L \le f_i^L(x_1,\ldots,x_n),\ i = 1, 2, \ldots, m \quad (12)$$

$$z_i^R \le f_i^R(x_1,\ldots,x_n),\ i = 1, 2, \ldots, m \quad (13)$$

$$x_j = g_j(x_1,\ldots,x_{j-1},x_{j+1},\ldots,x_n),\ j = 1,2,\ldots,n \quad (14)$$

$$x_j^L \le g_j^L(x_1,\ldots,x_{j-1},x_{j+1},\ldots,x_n)\ j = 1,2,\ldots,n \quad (15)$$

$$x_j^R \le g_j^R(x_1,\ldots,x_{j-1},x_{j+1},\ldots,x_n)\ j = 1,2,\ldots,n \quad (16)$$

where f_i, f_i^L, f_i^R, (dan g_j, g_j^L, g_j^R) are real linear vectors of mean value and left and right spreads of the estimated fuzzy parameters of $\tilde{f}_i$ (and $\tilde{g}_j$). Also, zi, z_i^L, z_i^R (and x_j, x_j^L, x_j^R) are real linear vectors of mean value and left and right spreads of the estimated fuzzy parameters of $\tilde{z}_i$ (dan $\tilde{x}_j$).

2. Objective Function:

   Equation (4) shows that the objective is to find the specification level that can maximize the whole evaluation or the total satisfaction level of the customers.

3. Constraints:

   The constraints that are used are between parameters functional constraints. This constraint is a strict constraint in a sense that it has to be included in the model because this constraint shows how engineering characteristics might affect a performance characteristic or other engineering characteristics. The functional relationship constraints can be mathematically written as equation (11) through (16). Besides functional constraint, another constraint can be added minimum (or maximum) specification constraint, derived from benchmarking, which is optional and subjective. This constraint can be added into the model when benchmarking is done and the competition shows the specification level for particular engineering characteristic, which might cause product failure in the market if it cannot be reached. These constraints particularly form as followings:

$$x_j \geq x_j^{min}, \quad x_j \leq x_j^{min} \tag{17}$$

$$x_j \geq x_j^{max}, \quad x_j \leq x_j^{max} \tag{18}$$

where x_j^{min} and x_j^{max} show minimum, maximum, and the closest specification value to the competitor's target for technical characteristic j.

3. Results and Discussion

From the questionnaire, the customer information is obtained regarding the frequency of usage, the brand used, and the information source of towing tractor in use. Figure 2 shows towing tractors' brand used. From figure 2, it can be seen that the brand that gets the most usage is Patria and Toyota. Therefore, in the fuzzy QFD calculations, only those two brands are included. Then, the importance rating and satisfaction level for each customer attribute is the next thing to be considered.

The scale to be used to measure the customers' satisfaction level and importance rating is the Likert scale (1-5). The importance rating and satisfaction level calculation is being done by calculating the median for each attribute's results because the Likert scale is that of an ordinal type. The results are summarized in table 1.

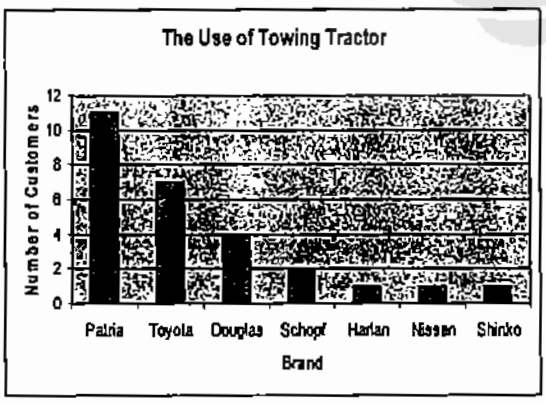

Figure 2.
Towing Tractor In Use

The importance rating data and the satisfaction level data are then utilized in determining the optimal engineering characteristics by using fuzzy QFD.

The first step is determining the parameter coefficients between the customer attributes and the intra-engineering characteristics using fuzzy linear regression. Then the parameter coefficient that has been obtained becomes the constraint in determining the optimal engineering characteristics with the multiobjective constraints. Aside from the constraints that had been determined beforehand, there are also other constraints defined by the technical specifications regulated by IATA (International Air Transport Association) which is an international foundation that regulates the airline service's activities, and of course the constraints given by the company itself. The constraints added are:

1. Minimum underclearance of 200 mm, which means the constraint of $x_9 \geq 200$.
2. Minimum centerheight of drawbar of 400 mm, meaning the constraint of $x_{10} \geq 400$.
3. The drawbar pull must be more than 5000 kg, meaning the constraint of $x_1 > 5000$.

The engineering characteristic value calculation is done using the LINGO version 7 software. The result can be seen on table 2. From the calculation, it can be seen that there are improvements and degenerations for most of the engineering characteristics. This would be the trade-offs that occur when a characteristic improves of degenerates, it will affect other characteristics. The value of λ, which is 0,4415, shows that the maximum satisfaction level that can be achieved using the fuzzy QFD method is 44,15% from the total maximum satisfaction level of 100% that can be achieved.

After the engineering characteristics are obtained, it is to be decided the direction of the towing tractor product development in consideration of the company's capabilities. This capability level information is obtained from the company minding the cost, fabrication capabilities, design complexity level, and development time for each engineering characteristics. The development direction that is being proposed is to improve horsepower, tire size, grade ability and a decrease in wheelbase, tread rear, and towing tractor dimension.

Table 1.
Importance and Satisfaction Level of The Customer Attributes For The Towing Tower Product

No	Customer Attribute	Importance Rating	Satisfaction Level	
			Patria	Toyota
1	Speed stability	5.00	4.00	4.00
2	Propellability	5.00	4.00	4.00
3	Engine durability	5.00	4.00	4.00
4	Transmission performance	5.00	4.00	4.00
5	Cooling system	4.00	4.00	4.00
6	Tire type	4.00	3.00	3.00
7	Steering weight	4.00	4.00	4.00
8	View	5.00	4.00	4.00
9	Footstep	4.00	3.00	3.00
10	Fore and rear plate thickness	5.00	3.00	4.00
11	Canopy availability	4.00	2.00	3.00
12	Front rear window availability	4.00	4.00	3.00
13	Reasonability of price compared to product quality	5.00	3.00	3.00
14	Product operating ease	5.00	4.00	4.00
15	Usage comfortability	5.00	4.00	4.00
16	Passenger's seat availability	4.00	3.00	3.00
17	Spare tire's availability	4.00	1.00	4.00

Table 2.
Optimal Engineering Characteristics Values

No	Engineering Characteristics	Optimal Value	Dimension
1	*Drawbar pull*	6267,63	kg
2	*Piston displacement*	7235,71	cc
3	*Horse power*	117,94	kw
4	*Torque*	436,86	Nm
5	*Height*	3071,22	mm
6	*Length*	4150	mm
7	*Width*	1862,40	mm
8	*Turning radius*	6223,10	mm
9	*Underclearence*	200	mm
10	*Centerheight of drawbar*	400	mm
11	*Tire size*	13,89	PR
12	*Wheelbase*	2100	mm
13	*Tread front*	1218	mm
14	*Tread rear*	1610,88	mm
15	*Speed*	40,32	km/h
16	*Gradeability*	36,28	%
17	*Service weight*	7122,51	kg

4. Conclusion

This study aims to obtain the importance, satisfaction levels and optimal engineering specification values for the towing tractor product produced by PT United Tractors Pandu Engineering by using the fuzzy QFD method. From the questionnaire, the customer attribute that has the highest importance rating is the speed stability, propellability, engine durability, transmission performance, view, fore and rear plate thickness, reasonability of price compared to product quality, product operating easiness, usage comfortability and radiator checking easiness. Beside that, the attributes which need special attention by the company because their satisfaction levels were lower that that of Toyota's are the thickness of material for front and rear plate, canopy availability, radiator check easiness, etc.

By using fuzzy linear regression method and multiobjective decision-making, ways to determine the optimal engineering characteristics target value and the direction of development are the improvement of the propellability and climbing ability of the towing tractor with slimmer or smaller body dimension.

For further study, the number of competitors being used as comparisons ought better be added so that the results can be more optimized and computational model software, which simplifies computation, especially using fuzzy QFD method should be developed.

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