Quality Function Deployment for the Improvement of the Attributes from a Hybrid Micro Hydro-Solar Generator

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Abstract

The research conducted by the research team finds that Langkat Regency in Indonesia has sufficient potential for the development and application of alternative energy to strengthen the energy security of the community, one of which is micro-hydro and solar power. To support this, it is necessary to make resolutions to enhance the quality of generator tools, especially in the scale of home use and rural areas that are difficult to reach by the state electricity network. The tool used to help this increase is Quality Function Deployment. Determination of product technical characteristics is carried out by discussing and conducting interviews with related parties, in this case, interviews are conducted with local residents who are familiar with the Utilization of Alternative Electrical Energy Sources. According to the Phase I results of the Quality Function Deployment (QFD) Hybrid Micro Hydro-Solar Generator, the most critical aspects to improve right away are Production Costs, Technological Sophistication, and Types of Materials, in order of relevance, anticipated cost, and difficulty level. Production Costs, Technological Sophistication, Material Types, Generator Capacity, and Product Mechanism are the technical features with the highest to lowest relevance.

Keywords
Quality Function Deployment, Micro Hydro, Solar Power, Generator and Consumers' Needs.

1. Introduction

Over the years, what is literally meant by alternative energy has switched due to the hefty amount of energy options to choose from with different purposes for use. In the condition of this paper, the intended alternative energy is renewable energy. Renewable energy is energy derived from natural sources that are renewable or can naturally recur after usages, such as wind, sunlight, geothermal heat, tidal currents, and rain. When compared to the energy production process, there is a principal difference between fossil fuels and renewable energy. The process of creating fossil fuels is difficult and requires a process with sophisticated equipment, chemical, and physical processes. Meanwhile, alternative energy can be created with simple equipment and very simple natural processes.

The application of alternative energy is still not fully implemented in Indonesia. In developed countries themselves, alternative energy has been widely applied to household life. There are many instances of alternative energy that we can use to take over the primary energy source. Between them is the energy of the sun, wind, rivers, and ocean waves. All of them are owned or exist in Indonesia.

The use of energy itself has been found in various applications. Among them of concern are power plants based on a combination of solar and micro-hydropower. To further improve the quality of the application tool, the QFD tool is used. QFD is a mechanism for incorporating client feedback into product design and development. Quality Function Deployment (QFD) is a mechanism for combining product and process development that has been proven to be effective (N. Mendoza et al 2003).

In 1983, QFD was first presented to the United States and Europe. QFD continues to pique academic and industrial attention throughout the world today. Automobiles, electronics, construction, and services are just a few of the

businesses that employ them. QFD is implemented as a multi-process method, giving it the best chance of yielding reliable findings (N.K. Naseri, 2014).

The House of Quality is one of the most common names for the QFD approach. The QFD chart's data is organized to emphasize the link between customer wants and product quality features. Cross-links between client want and design changes, as well as between design variables themselves, are introduced by the quality house. Each customer's needs are translated into one or more technical requirements at each level of a structured project with a linked matrix through the use of high-quality housing.

1.1 Objectives

This research was conducted with the aim of determining which attributes of a Hybrid Micro Hydro-Solar Generator can be used as a focus or starting point in quality improvement or improvement activities. The tool used itself is Phase 1 of Quality Function Deployment.

2. Literature Review

Design is the process of turning ideas or concepts into tangible data. This is not the same as manufacturing or building. The design process is the process of developing a notion before it is translated into a physical form or implemented. Caldecote (1989) defines design as the transformation of ideas into information on how to produce a thing.

Design, from the perspective of an engineer, is the application of scientific, mathematical, and creative principles that are imagined as structures, machines, and systems to demonstrate technical functionality. Engineering science and industrial design are also very significant in the development of consumer items, in addition to product form and function. Engineers and industrial designers are responsible for consumer items. Engineers determine the functionalities of a product, whereas industrial designers add aesthetic value to the design.

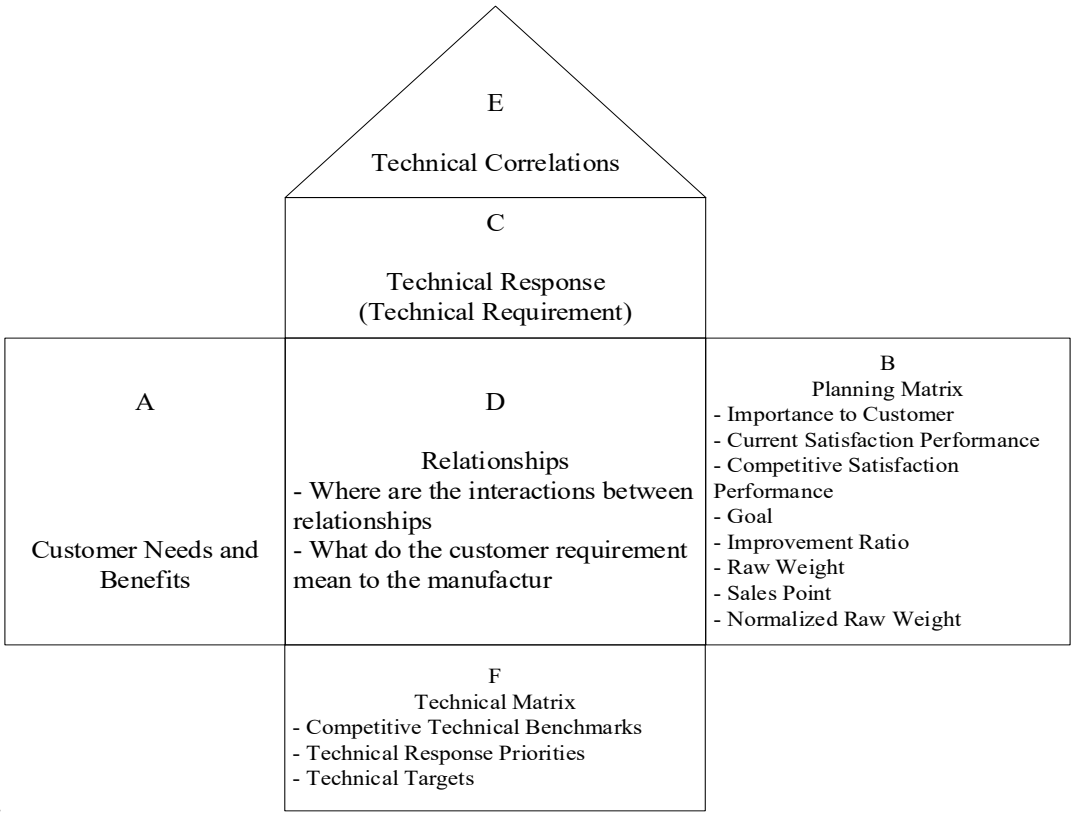

Figure 1. House of Quality (Lou Cohen 1995)

Design is the application of technology and scientific principles to organize the components of a device. When a device is adjusted and implemented to achieve a specific result, it must meet the six requirements outlined by Pye (1989). These requirements are as follows.

- Components must be realized using the basics of device adjustment
- Device components must be symmetrically related to each other and to the object.
- Components must be powerful enough to transmit and withstand the forces required for the expected result.
- Availability of access to the device.

The need for convenience and economy is the charge of the result must be accepted. Appearance needs mean the appearance of the device must be accepted. QFD (Quality Function Deployment) is a structured method for the development and planning of the product that allows a team of developers to clearly identify customer needs and wants. The House of Quality is a framework for the Quality Function Deployment method to management design.

The House of Quality is shaped like a house and depicts the structure for developing and shaping a cycle. The key to creating a HOQ is to focus on consumer demands, rather than technological innovation so that the design and development process is more in line with what the client wants. The House of Quality is shown in Figure 1.

The description of each part is as follows:

- Customer need
  Customers need to incorporate a list of all customer needs and expectations which are usually determined by qualitative research.
- Planning matrix
  A planning matrix is a product planning matrix that contains quantitative data on consumer needs and performance goals to be achieved.
- Technical response
  The technical response is a technical parameter that provides an overview of how the product/service development team responds to consumer needs and desires.
- Relationship
  The relationship shows the relationship between technical parameters and consumer needs and desires that have been modeled in QFD.
- Technical correlation
  Technical correlation describes the relationship that occurs between technical responses which can be divided into very strong positive correlation, strong positive enough, very strong negative, and no relationship.
- Technical matrix
  The Technical Matrix contains information in the form of priorities from the technical aspects of the product as well as the planned technical targets based on competitive benchmarks for the purpose of developing product quality.

3. Methods

The data for the study was gathered through literature reviews, observations, interviews, and questionnaires. The questionnaire was employed as the technical characteristics questionnaire. The sampling approach utilized is total sampling, which is a sort of non-probability sampling.

The procedure for using the HOQ matrix is:

- Determination of Customer Requirements
- Determining the level of consumer requirement
- Determination of the technical characteristics of the product
- Determination of the relationship between each technical characteristic
- Arranging the Relation Matrix
- Determination of Planning Matrix
- Determination of Technical Matrix
- HOQ matrix creation

4. Results and Discussion

Determination of Customer Requirements is done through a survey using a questionnaire that is distributed online using a google form. The results can be seen in Table 1.

Table 1. Customer Requirements (CR) regarding utilization of alternative electrical energy sources

Customer Requirements
Price
Cost of Operation and Maintenance
Security factor
Ease of Operation and Maintenance
Durability
Environmental Effect
Energy Output
Aesthetics

The extent to which consumers provide an appraisal or expectation of existing consumer demands is determined by determining the level of consumer interest. The value of the mode on the questionnaire is used to determine the level of importance for the variable of consumer needs. The value of the mode that becomes the level of importance is obtained based on the frequency of respondents' answers to the most respondents to each variable. The result can be seen in Table 2.

Table 2. Customer Importance(CI) terhadap Kategori Kano

Customer Requirements	Questionairre Result					CI
	Measurement Scale					
	1	2	3	4	5	
Price	0	0	0	0	1	5
Cost of Operation and Maintenance	0	0	0	0	1	5
Security factor	0	0	1	0	0	3
Ease of Operation and Maintenance	0	0	0	0	1	5
Durability	0	0	1	0	0	3
Environmental Effect	0	0	0	0	1	5
Energy Output	0	0	0	0	1	5
Aesthetics	0	0	0	0	1	5

Table 3. Technical characteristics of utilizing alternative electrical energy sources

No	Technical Characteristics
1	Sophisticated Technology
2	Generator Capacity
3	Material Type
4	Production cost
5	Product Mechanism

Determination of the technical characteristics of the product is done by discussing and conducting interviews with related parties, in this case, interviews with local residents who understand the Utilization of Alternative Electrical Energy Sources. The technical characteristics of the product can be seen in Table 3.

The association between each of the existing technical qualities is determined by determining if there is a mutually supporting (positive) or conflicting (negative) relationship between these technical characteristics. The assessment given will be based on the following rules:

- Value 9 denotes a strong relationship;
- Value 3 denotes a moderate relationship;
- Value 1 denotes a weak relationship.
- Value 0 denotes the absence of any relationship.

To determine the amount of links between customer demands and product technical features, the Relation Matrix was used. Strong, moderate, weak, and not connected at all are the relationship levels. The following rules will be used to make the assessment:

- Value 9 denotes a strong relationship;
- Value 3 denotes a moderate relationship;
- Value 1 denotes a weak relationship.
- Value 0 denotes the absence of any relationship.

The value of customer satisfaction with Alternative Power Plants on the qualities of the services supplied is used to determine the Planning Matrix. The Planning Matrix is created in order to determine the priority of the customer requirements variables that will be attempted to be met by the business. Because this planning matrix is the result of computations based on many types of data, it must be assembled in phases.

Measurement of the level of consumer satisfaction using the formula:

$$\text{Weighted Average Performance} = \frac{\sum \text{Number of Respondents at Performance Value i}}{\text{Total Number of Respondent S}}$$

The method that can be used in calculating the value of this improvement ratio is by comparing the target value of product quality to be achieved in the future with the level of quality of consumer assessment (satisfaction) with the product. The target value is obtained from the level of interest (expectations) of consumers towards each variable of need.

$$\text{Improvement Ratio} = \frac{\text{Goal}}{\text{Current Satisfaction Performance}}$$

In this stage, sales points (sales value) will be obtained from the Alternative Power Plant variable for the future which is expected to increase consumer satisfaction to become a factor in the competition. At this stage, the company is faced with a decision to choose the most influential and non-influential needs variables for increasing profits. For this reason, a priority scale is needed which usually uses 3 scale values, namely:

1.0 : given to a variable of need if the variable is considered not too influential for increasing company profits so that it gets less attention from the company.
1.2 : given to a variable of need if the management thinks that if the variable can be obtained it will affect the increase in company profits.
1.5 : given to a need variable if the management thinks that if this variable can be fulfilled it will greatly affect the increase in company profits.

The absolute weight value is calculated by the formula:

$$\text{Absolute weight} = \text{customer importance x improvement ratio x sales point}$$

The value of the relative planning weight is calculated by the formula:

$$\text{relative weight} = \frac{\text{absolute weight requirement}}{\text{total absolute weight requirement}} \text{ x } 100\ \%$$

The Technical Matrix is calculated using the HoQ's performance metric, which includes three aspects: difficulty, importance, and the expected cost. The relationship between technical characteristics determines the amount of difficulty. The weights of the relationship values are first translated, and then the weight of each technical characteristic is divided by the overall weight. Furthermore, the percentage range obtained is used to determine the level of difficulty.

The overall weight for each association between companion qualities may be used to compute the difficulty level's value. The overall weight for each link between product qualities and technical features may be used to compute the value of the degree of significance. The formula for determining the degree of significance of product features with technical characteristics is:

$$\text{level of importance} = \frac{\text{technical characteristics weight}}{\text{sum of technical characteristic weight}} \text{ x } 100\%$$

Because the more complex a technical feature is to create, the more expensive the cost allocation will be, the level of difficulty factor is utilized as the foundation for cost estimations. Estimated expenses are stated in percents and are affected by the designer's own preferences.

Customer Requirement	*Customer Importance*	**Karakteristik Teknik**	Sophisticated Technology	Material Type	Product Mechanism	Generator Capacity	Production cost	*Improvement Ratio*	*Sales Point*	Bobot Absolut	Bobot Relatif
			9	3	9	3	9	***Planning Matrix***			
			9	9	3	9					
			9	9	9						
Price	5		3	3	1	0	9	1,2	1.5	9,6	15,6
Cost of Operation and Maintenance	5		1	1	0	0	9	1,2	1,2	7,6	12,5
Security factor	3		1	3	3	1	1	1,7	1	5,1	8,3
Ease of Operation and Maintenance	5		9	1	3	1	1	1,2	1,2	7,6	12,5
Durability	3		1	3	1	9	3	1,7	1,5	7,7	12,5
Enviromental Effect	5		1	0	0	0	0	1,2	1	6,4	10,4
Energy Output	5		3	1	3	3	1	1,2	1,5	9,6	15,6
Aesthetics	5		3	3	1	0	1	1,2	1,5	7,6	12,5
Level of Difficuties			4	4	3	3	5				
Level of Importance			25	17	14	16	28				
Cost Estimation			21	21	16	16	26				

Figure 2. HOQ Matrix

The HOQ matrix is created using the data acquired in the preceding phases. The HOQ can be seen in Figure 2.

5. Conclusions

Through the use of QFD, the main attributes of a micro-hydro hybrid solar power plant are found that be considered the most crucial. The results of QFD Phase I of Utilization of Alternative Electrical Energy Sources show that the most important characteristics to be improved immediately are Production Costs, Sophistication of Technology and Types of Materials with the highest importance, level of difficulty, and estimated costs. From the planning matrix, product attributes in the form of Power Generation Price and Energy Output are prioritized for improvement because they have the greatest weight.

The technical characteristics that have the highest to the lowest level of importance are Production Costs, Technological Sophistication, Material Types, Generator Capacity, and Product Mechanisms. By focusing on these selected attributes, manufacturers can save a lot of time, cost, and effort while still meeting consumer desires.

Acknowledgements

This study was funded by Directorate of Research and Community Service, Directorate General for Research and Development at the Ministry of Research, Technology and Higher Education of Indonesia.

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Biographies

Rosnani Ginting received P.hD degree from Universiti Sains Malaysia. The areas of her specialization are Production System, Product Design and Planning, Machine Scheduling, Manufacturing System Plan, Decision Support System and Enterprise Resource Planning. She is active as a Head of Postgraduate Study Program Department of Industrial Engineering at Universitas Sumatera Utara. Her published books Production Systems, Machine Scheduling, Product Planning, Industrial Engineering Plan, Decision Support System, Questionnaire, and QFD. She has published numerous international papers. Her papers with title “TRIZ or DFMA Combined with QFD as Product Design Methodology: A Review”, and also title "Integration of quality function deployment and value engineering: A case study of designing a Texon cutting tool" indexed on SCOPUS. Her bookchapter has also published in Intechopen Publisher with title "Integrated Model of Product Design Methods".

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