Product design of post-stroke static bicycle

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Abstract. This research was conducted to design a standard static bicycle for post-stroke patients using Quality Function Deployment method combined Analytic Hierarchy Process, Value Engineering, and Brainstorming model. The product was designed from strong metal material, portable, by considering the strength to withstand the load, ergonomic aspects, and the stability. Quality Function Deployment was used to determine the characteristics of the product. Pair wise comparison in Analytic Hierarchy Process model was chosen to obtain and identify the optimum attributes alternative. Meanwhile, Brainstorming applied to collect and generate various ideas of characteristic products. Open and closed questionnaire were used as a survey tool. The results showed that optimum weight is on the backrest material, while the smallest weight is the color of the additional function.

1. Introduction

Humans in their lives use various designs as a facility to support their activities. Humans wish the design as a product that fits the trend and needs. This raises human awareness about the importance of an exclusive and representative design. Design is the result of human cultivation creativity that embodies to meet human needs, which requires planning, design and development of design. Design and development of design or commonly called product design is a set of product development that becomes a process in the work of the marketing department and business vision, which includes improving the vision or purpose of the product into technical specifications, new development concepts, and embodiment of product engineering.

The ability to provide product designs or services that meet customer needs but at competitive prices is a great advantage for companies to compete in the market. For that, companies need to adopt a number of methods and tools to effectively capturing customer needs to achieve higher customer satisfaction. Quality Function Deployment (QFD) is a well-known method for customer-oriented design and product development reviews [1].

Combining QFD with other techniques helps to address these drawbacks and can form the basis of future research. The integrated and innovative method, which combines QFD with another technique tool, can precisely solve main contradictory problems in the process from the product demand analysis to the product design, production and application [2].

The purpose of this research is to design a new concept of post-stroke static bicycle using Quality Function Deployment method combined Analytic Hierarchy Process, Brainstorming model, and Value engineering technique.

Post-stroke static bicycle is a bicycle-shaped tool without wheels that can be used easily for post-stroke sufferers in doing light exercise and functional organ therapy. Post-stroke static bicycle is made...
of lightweight and strong material so it is safe to use for post-stroke sufferers. Post – stroke stationary bicycle is also equipped with a heart rate sensor and timer that is able to control the heart condition and time of the user. Therefore, the presence of static bicycle tools can afford facilitate the process of therapy and recovery of post-stroke patients.

2. Theoretical Background

2.1. Quality Function Deployment (QFD)

QFD is the way to improve the quality of goods or services by understanding the needs of consumers and then linking them with technical characteristics to produce goods or services at each stage of making the goods or services produced. QFD is used to help businesses focus on the needs of their customers when developing design and manufacturing specifications. QFD method is a quality engineering method by identifying consumer voices, determining consumer desires and involving them in the product or service development stage. QFD uses a questionnaire that contains customer needs or an investigation of customer satisfaction with products that are related to technical characteristics [3].

QFD was developed in 1996 by Yoji Akao in Japan, and has been recognized as an effective method for integrated products and process development. QFD is a structured approach to integrating customer voices into product design / development. This is applied in many industries such as the automotive, electronics, construction and service sectors. QFD is implemented as a multi-process process, offering the greatest potential to realize significant benefits [4].

QFD is used to help businesses focus on the needs of customers when developing design and fabrication specifications. Quality Function Deployment is a technique utilizing to guarantee the quality in each creating items stages, beginning by the plan quality itself [11]. QFD is divided into four phases that are used to connect consumer needs with product design characteristics, and then translate them into part characteristics, manufacturing operations, and production characteristics. QFD identification stage of consumer needs, and the characteristics of the parts are applied at the product design stage. The QFD approach may likewise be extremely useful for scholastics intending to approve recuperation viability in the administration business [12]. The main purpose of QFD is to determine the priority design criteria which are the main focus in product design and development. The main planning tool used in QFD is the House of Quality. House of Quality translates the customer's voice into design requirements that meet certain value targets and matches them to the organization or company that will design those design requirements [5].

The application of the QFD methodology in the product / service design process begins with the formation of a product / service planning matrix or called the house of quality.

Part A : The first room HOQ is the needs or desires of customers (customer needs and benefits). This phase uses the affinity diagram process and then is arranged in a hierarchy with the lowest level of need to the highest level. Most development teams collect customer votes by interview and then arrange in a hierarchy.

Part B : The Planning Matrix is the second part of HOQ and is referred to as a place to determine product goals or objectives, based on the team's interpretation of market research. Goal setting is a combination of customer needs priorities.

Part C : The part when HOQ is a technical response, is a description of the product or service to be developed. Usually the picture is derived from customer needs in the first section of HOQ.

Part D : The fourth part of HOQ is relationships, is the biggest part of the matrix and becomes the biggest part of the work. In this phase the priority matrix method is used.

Part E : The fifth part of HOQ is technical correlations, matrices that look like roofs. This matrix is used to help the QFD team determine which designs are experiencing bottlenecks and determine the key communication between the designers.

Part F : This section contains three types of data namely:
Planning and defining the role (blueprint of the information in the list of needs): Markets, firms, and the economy are noted for creating and selecting a suitable product idea. Later, needs and constraints will be arranged into a list of needs.

- Technical response priorities, ranking order of importance (ranking) technical requirements.
- Competitive technical benchmark, information on the results of comparison of the performance of the technical requirements of products produced by the company against the performance of competitors' products.
- Technical targets, performance targets technical requirements for new products or services to be developed [6].

The House of Quality shows the structure to design and form a cycle, and its shape resembles a house [7]. There are several advantages to using QFD, namely:

- QFD helps companies to make product design decisions based on what customers want with the company's ability to carry out the production process.
- QFD enhances effective communication between various company divisions and teamwork.
- Improve product quality.
- QFD increases consumer satisfaction through convincing consumers of the products produced [8].

3. Research Methods
This product is based on literature studies from credible national and international journals and other sources related to stroke problems, post-stroke medical devices and heart detection sensors.

Data collection research was carried out by distributing open questionnaires, closed questionnaires and market surveys conducted in order to find accurate and credible information to be used as information in the development of bicycle health aids post-stroke.

Brainstorming is done as a first step to explore ideas and ideas before determining the product to be designed. Brainstorming is a method used to spawn ideas and ideas in a simple and efficient manner. There are 8 main rules for brainstorming: groups must be non-hierarchical, group leaders act as facilitators, groups are expected to generate as many ideas as possible, not allowed to criticize each idea, ideas that seem strange are still accepted, try all ideas stated briefly and clearly, the atmosphere during brainstorming takes place relaxed and free, activities should take place in no more than 20-30 minutes.

Purpose of use of the method brainstorm is draining everything something students think about inside respond to the problems raised teacher to him. Order purpose in application of the brainstorming method can achieved then the need for rules is watch out for [9].

Sampling is a method of data collection that is very popular because of its huge benefits in saving time and cost resources in data collection activities. Sampling is the process of drawing samples from the population through certain mechanisms through the meaning of population characteristics can be known or approached. Broadly speaking the sampling method can be classified into two parts, namely probability sampling (sampling that is related to probability factors) and non-probability sampling (sampling that is not related to probability factors). The basic difference from the two types of sampling is that in addition to technical / implementation mechanisms, also from the main goal, namely probability sampling, it looks at the possibility of new areas to be examined while non-probability sampling emphasizes exploration and feasibility in applying an idea. The sampling method used is the nonprobability sampling method. The sampling technique used is simple random sampling. Simple random sampling (simple random sample) is the way random sampling by truly providing opportunities the same one [10].

Through this sampling method, the number of samples is then determined, then an open questionnaire, closed questionnaire, and AHP questionnaire are made. The questionnaire was made to determine what tools and designs are expected by wheelchair users to be made in the product design
process. Then after the questionnaire was recapitulated, validity and reliability tests were used to determine the design of a multifunctional wheelchair. Then QFD is used to determine the characteristics of the product to be made. QFD is a structured methodology used in product planning and development processes to determine specifications of needs and desires consumers, as well as systematically evaluating the capabilities of a product or service in meeting the needs and desires of consumers.

Then in order to find a solution to every problem that arises from making a product, steps are determined to generate alternatives, evaluate, and improve details. From all these steps, it can be determined the characteristics of making the product at the appropriate cost.

4. Results and Discussion
The results of the design of this product are health aids, namely a post-stroke stationary bicycle based on the heart rate sensor as a tool to control the user's condition. Post-stroke static bicycle is designed with the easy for user concept (easy for users) because they can be adjusted in size according to user needs. This bicycle is also designed using a lightweight iron frame that can withstand loads of up to 100 kg.

Problems in the design process contained in post-stroke stationary bicycle include the selection of product composition, length of assembly process, material strength level, and sensor design process.

4.1. Clarifying Object, Establishing Functions, and Setting Requirement
To find a solution to the above problems, there are 3 steps needed so that the problem will be divided into sub-problems, namely the classification of goals & functions, and the determination of needs. List of post-stroke static bicycle design goals is:

- Standard static bicycle frame.
- Using hollow mixed iron material.
- Use silver as the frame color.
- Has a frame length of 120 cm.
- Have hand and foot pedals.
- Has a heart rate sensor.
- Has a foot pedal for rheumatoid therapy.
- It has a hand pedal for user nerve therapy.

The objective tree diagram can be seen in Figure 1.

![Figure 1. Tree diagram](image-url)
• Division of functions into essential sub-functions
  • Sub function of static bicycle design after stroke.
  • Sub function of designing heart rate sensors.
• Determine the level of generality to operate
  • The product has a standard design, simple and ergonomic.
  • Products make it easier for the exercise and therapeutic tools for post-stroke sufferers.
  • The product has additional functions in the form of a timer sensor and heart rate.

4.2. Determination of Characteristics
In this section, the sub-problem of the multifunctional wheelchair specification will be found in the sub-solution with the steps from Nigel Cross’s design, to determine the characteristics of the product. Post-stroke static bicycle house of quality after stroke can be seen in Figure 2 to Figure 5 below.

| Material Diameter | Density of Material | Loss Thickness | Loss Optical Size | Color Spay Distance | Drying Time | Print Volume |
|-------------------|---------------------|----------------|------------------|---------------------|-------------|--------------|
| Tool Shape        | 5                   |                |                  |                     |             |              |
| Tool Color        | 4                   |                |                  |                     |             |              |
| Tool Size         | 5                   |                |                  |                     |             |              |
| Motive Tool       | 4                   |                |                  |                     |             |              |
| Camera Pixel Size | 5                   |                |                  |                     |             |              |
| Lamp Location     | 5                   |                |                  |                     |             |              |
| Tool Features     | 3                   |                |                  |                     |             |              |
| Tool Feature Adjust Location | 4 | | | | | |
| Tool materials    | 4                   |                |                  |                     |             |              |
| Additional Tools Functions | 4 | | | | | |

**Figure 2.** Resistance matrix between product attributes and technical characteristics

**Figure 3.** Matrix of relationship between product attributes and technical characteristics

**Figure 4.** Relationship between fellow technical characteristics
Characteristics of a post–stroke stationary bicycle products obtained from design goals are:

- **Product Material**: Iron
- **Product Application**: Sit
- **Storage Method**: Folded
- **Product Size**: 75x30x150
- **Product Model**: Standard
- **Foot Pedal Design**: Rheumatic Slippers
- **Additional Features**: Hand Pedal
- **Additional Function Attributes**: Aroma Therapy
- **Additional Function 1**: Heart Rate Sensor
- **Additional Function 2**: Training Hands

**Figure 5.** Quality function deployment a post–stroke stationary bicycle

- **Consumer Preceptions**
  - 5 = Very Good
  - 4 = Good
  - 3 = Enough
  - 2 = Not Good
  - 1 = Very Not Good

- **Level of Difficulty**
  - 1 = Not Difficult
  - 2 = Medium
  - 3 = Difficult
  - 4 = Very Hard
  - 5 = Absolute Very Hard

- **Degree of Interest (%)**
  - 1 - 10 = Less important
  - 11 - 20 = Important
  - 21 - 30 = Very important

- **Cost Estimation (%)**
  - 0-10 = Cheap
  - 10-20 = Moderate
  - 20-30 = Expensive
5. Discussion
Sub solution is a solution every problem that occurs, including among others the selection of attributes for post-stroke static bicycle carried out by the use of Nigel Cross's steps, while maintaining the advantages that have been owned and improving the quality of these products.

In this section, there are 3 steps to be taken so that sub-solutions become a solution, namely Generating Alternatives, Evaluating Alternatives, and Improving Details. The following are the conclusions from the three steps in the process of designing Stroke Post Stroke.

5.1. Generating Alternatives

Table 1. Combination of post-stroke static bicycle product design solutions

| Functions                        | How To Achieve Function |
|----------------------------------|-------------------------|
| Product Material                 | Iron                    |
| Storage Method                   | Folded                  |
| Method of Application            | Stand Up                |
| Product Size                     | 75cmx30cmx150cm         |
| Additional Features              | Handle Therapy          |
| Additional Attribute             | Aroma Therapy           |
| Foot Pedal Design                | Rheumatic Sandals       |
| Product Model                    | Standard                |
| Additional Functions 1           | Stopwatch               |
| Additional Functions 2           | Uric-Acid Detector      |
| 1                                |                         |
| 2                                |                         |
| 3                                |                         |

Alternative generation stage aims to collect as many alternatives as possible that can be used to solve problems in the design of post-stroke static bicycle, then find the best solution or alternative. This is done using the Morphological Charts method with steps including:

- Make a list of important functions or goals for the product.
- Make ways to achieve essential functions.
- Identify combinations of design solutions that can be applied.
- Identify the feasibility of a combination of sub-solutions.

Morphological Chart shows all possibilities. Post-stroke static bicycle as in Table 1. Morphological Chart of post-stroke static bicycle is displayed in the form of a 10 x 3 matrix, where there are 10 functions that must be achieved and there are 3 alternatives that might be applied. The combination formula used is: 10C3 = 120 unit. So the total possible combinations to reach these alternatives are 120 ways.

5.2. Evaluating Alternatives
Alternative evaluation aims to compare utility values from alternative product designs that are made or based on performance on the basis of weighting objectives, where the results of alternative generation
steps will be evaluated by re-examining alternatives to be chosen so that the best alternatives are produced. The method used is the Weighted Objectives method with the AHP scale. Ranking of ratings is done using Pair Wise Comparison and AHP scale, with data obtained from importance values for each attribute in QFD. Level I is the Pairing Appeal Matrix between Primary Attributes, Level II is the Pairing Appeal Matrix between Secondary Attributes of Design, and after the comparative matrix paired with the AHP scale is then weighted for each level. Weighting for each attribute is needed to find out how the attributes affect it. In product design, weighting is done by dividing the ranking value of each attribute against the total rating value itself. The results of weighting each comparison matrix can be seen in the table below.

Table 2. Weighting the pairing appeal matrix between primary level II attributes

| Element             | Applications | Storage | Product Size | Foot Pedal Design | Product Model | Additional Features | Additional Function | Additional Functions 1 | Additional Functions 2 | total |
|---------------------|--------------|---------|--------------|-------------------|--------------|---------------------|----------------------|------------------------|------------------------|-------|
| Applications        | 0.083        | 0.036   | 0.076        | 0.063             | 0.039        | 0.088               | 0.237                | 0.190                  | 0.064                  | 0.097 |
| Storage             | 0.149        | 0.065   | 0.013        | 0.074             | 0.070        | 0.095               | 0.034                | 0.136                  | 0.097                  | 0.082 |
| Product Size        | 0.077        | 0.344   | 0.071        | 0.029             | 0.032        | 0.096               | 0.062                | 0.106                  | 0.110                  | 0.103 |
| Foot Pedal Design   | 0.167        | 0.110   | 0.306        | 0.126             | 0.056        | 0.093               | 0.100                | 0.088                  | 0.157                  | 0.134 |
| Product Model       | 0.195        | 0.085   | 0.197        | 0.207             | 0.092        | 0.027               | 0.053                | 0.240                  | 0.122                  | 0.135 |
| Additional Features | 0.114        | 0.084   | 0.091        | 0.167             | 0.418        | 0.123               | 0.069                | 0.051                  | 0.135                  | 0.139 |
| Additional Function Attributes | 0.039 | 0.172 | 0.129 | 0.144 | 0.183 | 0.205 | 0.114 | 0.037 | 0.111 | 0.126 |
| Additional Functions 1 | 0.031 | 0.032 | 0.047 | 0.101 | 0.027 | 0.172 | 0.218 | 0.071 | 0.095 | 0.088 |
| Additional Functions 2 | 0.144 | 0.071 | 0.070 | 0.088 | 0.083 | 0.101 | 0.113 | 0.082 | 0.110 | 0.096 |
| **Total**           | **1.000**    | **1.000** | **1.000**   | **1.000**         | **1.000**    | **1.000**           | **1.000**             | **1.000**               | **1.000**               | **1.000** |

The final stage of the design process aims to increase product value for consumers and reduce costs that must be incurred by producers. Solutions that have been obtained from the alternatives that are then communicated to consumers through the product with all the attributes that it has compared to similar competitor products. This can be done using the value engineering method. The steps in improving details are as follows:

- Make a list of product components and identify the functions of each component as shown in Table 4 below.
- Determines the value of the identified function
  Based on the functions that have been identified, their values are determined based on consumer perceptions. The values of each function are reviewed based on the suitability of the design for the consumer's desires as shown in Table 5.
Table 3. Data on post-stroke static bicycle

| Component       | Function                                      |
|-----------------|-----------------------------------------------|
| Bicycle         | As a static bicycle frame                     |
| Safety Cover    | As a protective material for each end of a static bicycle part |
| Silica Gel      | As a hand pedal bearing material              |
| Sensor Device   | As an additional function material            |
| Las             | As additional function adhesives and parts to static bicycle |
| Paint           | As a coating for static bicycle               |

Table 4. Value of each function

| Function          | Score | Information                                                                 |
|-------------------|-------|-----------------------------------------------------------------------------|
| Additional Functions | Good  | An additional function is the heart rate sensor as a tool for stroke therapy / recovery |
| Main Design             | Good  | Static bicycle has an ergonomically design for size and shape that is tailored to the wearer, namely the elderly |

- Calculate the costs of each component.
  Prices of the main raw materials, additional materials, and auxiliary materials for the manufacture of products have been previously estimated to determine the selling price of the products produced. Component prices are assumed as found in Table 6.
- Look for ways to reduce costs without reducing value.

Table 5. Cost of post-stroke static bicycle per Product Unit

| Component | Component Price (IDR) | Number of Components Required | Total Price (IDR) |
|-----------|-----------------------|-------------------------------|-------------------|
| Bicycle   | 500.000               | 1 set                         | 500.000           |
| Safety Cover | 13.500               | 8 pcs                         | 108.000           |
| Silica Gel   | 27.418                | 4 pcs                         | 109.672           |
| Sensor Device | 445.000              | 1 pc                          | 445.000           |
| Welding     | 125.000               | 1                             | 125.000           |
| Paint       | 19.000                | 1                             | 19.000            |
| Total       |                       |                               | IDR 1.306.672    |

From the results of evaluations carried out, value engineering can only be done by finding a replacement component that is relatively cheaper than before. After the survey, the replacement component is obtained with the price as found in Table 7.

Table 6. The results of cost evaluation for each component of post-stroke static bicycle product

| Component   | Component Price (IDR) | Number of Components Required | Total Price (IDR) |
|-------------|-----------------------|-------------------------------|-------------------|
| Bicycle     | 394.000               | 1 set                         | 394.000           |
| Safety Cover | 13.500                | 8 pcs                         | 108.000           |
| Silica Gel  | 27.418                | 4 pcs                         | 109.672           |
| Sensor Device | 184.500              | 1 pc                          | 184.500           |
| Welding     | 125.000               | 1                             | 125.000           |
| Paint       | 19.000                | 1                             | 19.000            |
| Total       |                       |                               | IDR 940.172      |
• Evaluate alternatives and select change
  The method of reducing costs is through replacing materials from fiberglass to aluminum which can be searched for at a price that is cheaper than the estimated price, so the price initially estimated is around IDR 1,306,672 to IDR 940,172.

![Design post-stroke static bicycle](image)

**Figure 6.** Design post-stroke static bicycle

6. Conclusion

The conclusions obtained in the manufacture of Post-stroke stationary bicycle products are as follows: The main material used in making static bicycles is iron, which can be used only by placing the product in front of any chair in your home, then using it by pedaling. This product can also be folded and carried anywhere you want. There are hand pedals and foot pedals that are designed using rheumatic slippers. This product is also equipped with a heart rate sensor and aromatherapy to relax the user's mind. The optimum weight is on the backrest material, while the smallest weight is the color of the additional functions. Then, the hand and foot pedals are designed using rheumatic slippers, and the alternative of the inexpensive material to design a post-stroke static bicycle is aluminium, with total cost production of nine hundred then using fiberglass as one million rupiahs.

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