Design of Multifunction Wheelchair with Nigel Cross Method

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Abstract. Product design can be done with the initial steps of a systematic approach that is making concept ideas and evaluating them. With the concept, the product design is required to have a concept development, as well as testing of the concept. This research aims to add a multifunctional design to an existing product, a lever for an adjustable chair, and a place for drinking bottles. The design attributes are obtained from the designer's brainstorm. The size of the design is obtained from a direct field survey of market desires for Multifunctional Wheelchair Products. This Multifunction Wheelchair was created because Manual wheelchairs have the disadvantage of requiring a lot of energy for their users. The specifications of the Multifunctional Wheelchair are obtained from distributing questionnaires to the elderly and disability in hospitals. QFD method discusses a comparison between Multifunctional Wheelchair Products, with 3 other competitors with the same attributes. Solving each problem, resulting in sub-solutions from Nigel Cross's steps to maintain product excellence. Pairwise Comparison and AHP calculate the weights of each attribute then rank them. The final step is value engineering to increase the value product for consumers and reduce the cost of producing.

1. Introduction
Aging is a process of slowly disappearing the ability of body tissues to repair themselves. In the elderly, decreased in the musculoskeletal system [1]. The more a person gets older than the person will be vulnerable to a disease because of a decrease in his body system. The elderly tends to experience a decrease in the musculoskeletal system. A decrease in the musculoskeletal system can affect physical mobility in the elderly and can even cause disruption to the physical mobility of the elderly. A wheelchair is a mobility aid for people who have limited movement in carrying out daily activities [2]. Limitations of this movement can be physical disability, injury, or caused by diseases that affect human motor.

The aim of this research is to help the elderly who are already vulnerable to musculoskeletal/spinal diseases in order to assist them in carrying out activities [3]. This QFD method has the benefit of having efficiency with time, customer focus, teamwork and documentation oriented. This method is used to identify the desires and needs of the elderly in making a wheelchair, so as to facilitate the elderly in their activities [4].
2. Theoritical Background

2.1. Brainstorming
The first step in product design is brainstorming. Brainstorming is a well-known method of generating ideas. There are six stages: forming a group and establishing leaders, informing the rules of brainstorming, group leaders making statements of initial problems, each member exploring ideas for 30 minutes, each member writing ideas and responding to each other, and collecting evaluation papers from brainstorming [5].

This brainstorming method is used to practice activeness in asking and processing questions so students can participate in the process of giving ideas. This method aims to collect ideas or opinions to determine and choose various ideas in making a product. The application of this method is expected to make students more active with ideas or ideas that emerge [6]. This method requires members to achieve quantity, postpone judgments, open up broad ideas, and filter. Although this method is accepted and used, sometimes it will get into trouble, such as strong voices in the room, members have an understanding of evaluations, and members who are closing themselves, etc [7].

The sampling technique that will be used is random sampling because the population that will be sampled are the elderly and the disabled. After determining the number of samples, an open questionnaire, closed questionnaire, and AHP questionnaire were made. All types of questionnaires are used to determine what people expect from the design of the tools carried out. With all the answers on the questionnaire, then the validity and reliability of the answers were tested about the design of the Multifunctional Wheelchairs.

Product design using Nigel Cross can be seen as follows.

- Clarification of Purpose
- Defining Functions
- Determination of Needs
- Determination of Characteristics
- Alternative generation
- Alternative Evaluation
- Repair Details

The purpose of this brainstorm is to make it easier to gather ideas or ideas from each group member whose attributes will be included in the questionnaire to be distributed to respondents.

2.2. Quality Function Deployment (QFD)
In addition, in determining the characteristics of the product using the QFD method. QFD is a method for adding quality products or services by knowing the needs of customers and connecting them with technical provisions to produce products or services at every step of the process of making a product or service[8]. Quality Function Deployment is a technique utilizing to guarantee the quality in each creating items stages, beginning by the plan quality itself [14]. QFD can explain the gap in the quality of products and services with the facts obtained by the customer so that technical measures must be taken to add HR and management [9]. QFD output is a criterion for the customer's desire for the product, along with all the attributes that need to be seen, so that the issued product quality level is met and can make the customer satisfied [10].

Through the use of QFD, marketing staff and product design teams easily answer questions about what attributes are needed by customers. The characteristics of a product design that will be developed are not based on the tastes, opinions and desires of individuals from the company, but also judged by the "voice" of prospective customers or customers are very many and varied [11]. The stages of the QFD method are as follows [12].
The first stage (Voice of Customer Collection), in this phase the customer's wishes are collected in determining the required attributes and these data are obtained from interviews and direct observation.

Second Stage (Preparation of Quality Houses / House of Quality) stages in making quality homes, namely creating a matrix of customer desires, making technical parameters, determining technical parameters related to consumer desires, technical correlations, steps in making quality homes include manufacturing consumer desire matrix, creation of technical parameters, measurement and targeting.

Third Stage (Analysis and Interpretation) is the analysis of all stages from the first stage to the third stage. The stages are as follows:

- Preparation of organizational encouragement
- Determination of objectives and desirable benefits of QFD
- Determination of customers / consumers
- Determination of adequate products
- Complementary facilities and materials that support QFD activities

![QFD flow chart](image)

The purpose of the implementation of the QFD method as a measurement tool for researchers to more easily know the wants and needs of customers. In order to find a solution to every problem from manufacturing a product, steps that evoke alternatives, evaluate, and improve detail. From all of these steps, it can be concluded that the product can be made with the right attributes and costs. The QFD approach may likewise be extremely useful for scholastics intending to approve recuperation viability in the administration business [15].

3. Research Methodology
In this study, the researcher first conducted a brainstorming. Brainstorming is done to generate ideas for products to be made. Then the results of this brainstorming will be made in the form of a
questionnaire which will be distributed to several respondents. Samples taken by researchers were 30 respondents. The questionnaire is taken by using two types of questionnaires, namely open questionnaires and closed questionnaires to get a wheelchair product design in accordance with consumer demand.

The next step is to test the validity and reliability of the respondents' answers to the product under study, competitor 1, competitor 2, and competitor 3. Then determine the classification of product objectives and functions. Furthermore, determining the product characteristics using QFD based on the results of the questionnaire. In the search for sub-solutions to be a solution for every problem of product manufacturing, it has steps, namely, generating alternatives, evaluating alternatives, and communication. All of the steps above are ways of determining the characteristics of the product the researcher wants to make at the right cost.

This paper uses primary data, which the data is taken directly by researchers by distributing questionnaires to the elderly. The sampling technique used in this study was cluster sampling, which was aimed specifically at the elderly.

4. Result
The results of this study are the design of multifunctional wheelchair using the Nigel Cross approach.

4.1. Brainstorming
To find solutions to these problems, there are 3 steps so that the problem will be divided into sub-problems, namely the classification of goals and functions, and the determination of needs. The conclusions of the 3 steps in designing a Multifunctional Wheelchair product are:

- Classification of Purpose
  A list of the overall design goals of the Multifunction Wheelchairs, including:
  - The color of the Multifunction Wheelchair is black.
  - The motive of the Multifunction Wheelchair is plain.
  - The number of Multifunction Wheelchairs is 4 pieces.
  - The seat material for the Multifunction Wheelchair is foam.
  - The Material of the Multifunction Wheelchair framework is Stainless Steel.
  - The shape of a multifunction wheelchair is a cylinder (tube).
  - The seat dimensions of the Multifunction Wheelchair are 50 cm x 45 cm x 45 cm.
  - The type of wheelchair lever is a pull.
  - The position of the multifunction wheelchair is right.
  - The Material of the Multifunction Wheelchair armrest is foam.
  - The Destination Tree diagram can be seen in Figure 2. below.
Designation of functions
Function assignment aims to determine the essential functions required and the system limitations of the new design. These essential functions are:
- The main design sub-function of a multifunctional wheelchair
- Multifunctional wheelchair auxiliary functions
- The sub-function of the multifunctional wheelchair

Determination of Needs
Based on the results obtained on the determination of needs, Wish > Demand was found, which means that the basic design of the Multifunction and Herbal Wheelchairs products is in accordance with the desires of consumers in the market. So, the sub-problems resulting from these three steps are:
- The product has an ergonomic and efficient design
- The product has a sufficiently long service life or durability
- The product has a frame that is quite strong

4.2. Quality Function Deployment (QFD)
The use of Quality Functions (QFD) has been recognized as an effective method for developing integrated products and processes. The QFD chart is a good asset for the product development process because it helps engineers identify key features in considering product design [13]. In this section, a sub-problem of the Multifunctional Wheelchairs specification will be found a sub-solution with the steps of the Nigel Cross design, to determine the product characteristics. The sub-problem of product specifications for multifunctional wheelchairs will be sought for sub solutions with the Nigel Cross
design step, namely determining the characteristics of the product. House of Quality Multifunctional Wheelchairs can be seen in Figure 3. below.

4.3. The Integration of Brainstorming and QFD

- Multifunctional Wheelchair Attributes based on the results of the questionnaire in accordance with the wishes of consumers are as follows:
  - The color of the Multifunctional Wheelchair is Black
  - The motive of the Multifunctional Wheelchair is Plain
  - The number of wheels (pieces) of a Multifunctional Wheelchair is 4 units
  - The seat material of the Multifunctional Wheelchair is Foam
  - The skeleton material of the Multifunctional Wheelchair is Stainless Steel
  - The shape of the drinking place of the Multifunctional Wheelchair is a Cylinder
  - Seating Dimensions (cm) of Multifunctional Wheelchairs are 50x45x45
  - The type of Push Lever of a Multifunctional Wheelchair is Pull

Figure 3. Wheelchair quality function deployment (QFD)
• Drinking Position of the Multifunctional Wheelchair is Right
• The Material of the Armrest from a Multifunctional Wheelchair is Foam

The comparison of Multifunctional Wheelchair products with competitors for the same attributes based on customer perception is as follows:
• For tool colors: authors products are superior to competitors 1 and competitors 2, and competitors
• For tool motives: authors products and competitors 2 are in the same position, superior to competitors 1.
• For the number of tool wheels: product authors is in the same position as competitor 1, superior to competitor 2.
• For seating materials: authors products are in the same position as competitors 1, superior to competitors 2
• For authors product framework materials, competitors 1 and competitors 2 are in the same position.
• For the form of drinking places: authors products are in a position superior to competitors 1 and competitors 2.
• For the seating dimension: Authors products are in a position superior to competitors 1 and competitors 2.
• For the type of push lever: authors products are in a position superior to competitors 1 and competitors 2.
• For drinking positions: Authors and competitors 1 products are in the same position, superior to competitors 2.
• For armrest material: Authors and competitors 1 products are in the same position, superior to competitors 2

The sub-solution stems from the resolution of each problem that occurs, including the selection of attributes for the Multifunctional Wheelchairs carried out by the use of Nigel Cross steps, while maintaining the superiority that is already owned and improving the quality of the product. In this section, there are 3 steps undertaken so that the sub-solution becomes a solution, namely alternative generation, alternative evaluation, and communication (improving details). Following are the conclusions of the three steps in the process of designing a Multifunctional Wheelchair.

• Alternative Generations
  At this stage, a number of design solutions are implemented as an alternative choice for the Multifunction Wheelchair product and the area for finding solutions will be expanded using the Morphological Chart.

**Table 1.** Combination of design solutions for Multifunctional Wheelchair products

| No | Characteristics                | How To Achieve Function |
|----|--------------------------------|-------------------------|
| 1  | Machine Shape                  | Cylinder                |
| 2  | Machine Dimension              | 22x20x4                |
| 3  | The inclusion part of the material | Side          |
| 4  | Constituent Materials          | Iron                   |
| 5  | Intake Lock                    | No                     |
| 6  | Engine Capacity                | 0.4                    |
| 7  | Number of blades               | 2                      |
| 8  | Energy Sources                 | Battery                |
| 9  | Timer                          | No Need                |
| 10 | Light Indicator                | No Need                |

Alternative 1

Alternative 2

Alternative 3
2. Alternative Evaluation
Alternative evaluations are carried out with the aim of comparing utility values from alternative tool designs that are made or made on the basis of performance on the basis of weighting objectives. In doing so, first a list of goals for product design is made, then determine ranking and all alternatives with Pair Wise Comparison and AHP scale.

Table 2. Performance parameters of each attribute

| Wheelchair Characteristics       | Parameter | 5 | 4 | 3 | 2 | 1 |
|----------------------------------|-----------|---|---|---|---|---|
| Wheelchair Seating Material      | Quality   |   |   |   |   |   |
| Wheel Chair Frame Material       | Quality   |   |   |   |   |   |
| The shape of a Wheelchair Drinking Place | Quality   |   |   |   |   |   |
| Wheelchair Seating Dimensions    | Quality   |   |   |   |   |   |
| Plunger lever type               | Quality   |   |   |   |   |   |
| The position of the wheelchair drinking place | Quality   |   |   |   |   |   |
| Wheelchair armrest material      | Quality   |   |   |   |   |   |

The results of each weighting for each multiplication are:
Authors: 4,694
Alternative 1: 3,068
Alternative 2: 2,944

So, the alternative chosen is the alternative with the highest weight, alternative 1 because it has the closest value to authors.

5. Discussion
Value engineering is the final stage of the design process that aims to increase the value of products for consumers and reduce costs that must be incurred by producers. The steps are to make a list of product components and identify the function of each component, determine the value of the dominant function, calculate the cost of each component, find ways to reduce costs without reducing its value, and finally evaluate the alternative. The cost required to make a Multifunctional Wheelchair is IDR 743,200.00.

6. Conclusion
The conclusions for the design of Authors Multifunctional Wheelchair products are as follows: Multifunction Wheelchairs color is black, additional function pattern is plain, additional function wheels is 4, additional function seating material is foam, additional function frame material is Stainless Steel, additional function shape is cylindrical, additional function seating dimension is 50x45x45 cm, additional function type lever is pull-push, additional function drinking position is right, additional function armrest material is foam.

For the attributes of the product Multifunctional Wheelchairs can be divided into several sections. The primary attribute of the Multifunctional Wheelchair product is the main design and additional functions. The main design attributes are divided into secondary attributes namely color, motive, number of wheels, seating material, frame material, shape of the drinking area, dimensions.

The process of designing a Multifunctional Wheelchair product uses the Nigel Cross seven steps where the results of the seven steps are as follows: Classification of objectives by the objective tree method with 3 different levels. The function determination stage using the analysis function method and black box methods produces sub-functions. The third stage is the preparation of needs that produce Wish > Demand (W > D), namely Wish = 8 and Demand = 2. The characteristic determination stage shows that there are 7 technical characteristics with 6 characteristics with difficult difficulty level and 1 characteristic with difficulty level is quite easy. Alternative generation stage produces 3 alternative products. The alternative generation stage using the morphological chart method shows that authors is more stable compared to alternative 1. The improving details stage shows a decrease in the value of product manufacture from the price of IDR 1,500,000.00 to IDR 743,200.00.
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