Product Design of a Multifunctional Wheelchair Using Nigel Cross Approach

Rosnani Ginting¹, Aulia Ishak² and Lani Diyana Etania³

¹,²,³Department of Industrial Engineering, Universitas Sumatera Utara, Medan, Indonesia, 20155
Email: etaniyaetaniya@gmail.com rosnani@usu.ac.id aulia.ishak@usu.ac.id

Abstract. A wheelchair is a tool used by people who have difficulty walking due to illness, injury or disability. In general, wheelchairs can only be used for sitting and as a tool that helps users move from one place to another. The multifunctional wheelchair that will be designed aims to make it easy for wheelchair users to carry out their activities. This multifunctional wheelchair has an additional function in the form of a toilet as a place to defecate and is equipped with a table and basket. In the process of making this multifunctional wheelchair product design, first a brainstorming technique is used to determine the characteristics of the product to be made, then draw conclusions from the brainstorming that has been collected. Furthermore, the sampling technique was carried out by distributing open and closed questionnaires to determine the type of product. Then conducted a market survey using sampling techniques, and determine the validity and reliability of the main product with competitor I, competitor II and III competitors. The step of the problem to the sub-problem is determined in order to classify the objectives to be made in designing a multifunctional wheelchair product.

1. Introduction
Product Design or commonly referred to as product design is a set of product development that becomes a process in the work of marketing and business vision, which includes improving the vision or objectives of the product into technical specifications, new development concepts, and the embodiment of new product engineering [1].

The product development process certainly starts from the manufacturer's understanding of consumers' perceptions and expectations of the product itself. Customer satisfaction assessment methods are used to assess consumer desires for existing products. The concept of customer satisfaction according to Parasuraman, et al. used to measure the level of customer satisfaction in the SERVQUAL method. The attributes of a product are basically very closely related to customer satisfaction, where the higher the customer assessment of a product attribute, the higher the customer satisfaction is felt. A development product can be said to be successful if it gets a positive response from consumers followed by the desire and actions to buy the product [2].

2. Background
A wheelchair is a tool used by people who have difficulty walking due to illness, injury or disability. When some individuals with limited mobility can be helped with a standard wheelchair, or with other
limited mobility, it is difficult or impossible to operate a standard wheelchair. This multifunctional wheelchair is designed to facilitate the activities of people with disabilities and the elderly in carrying out their activities. This wheelchair has several additional functions that will facilitate its users [3]. One technique that can be applied in general and can be used in various fields is brainstorming techniques. Brainstorming techniques were first developed by Alex F. Osborn in the 1930s. Brainstorming means the invasion of as many ideas as possible about a problem held in a meeting. Brainstorming is one of the ways in health education methods to increase one's knowledge [4]. Brainstorming is intended so that students are able to produce as many good initiatives (ideas) and are weighted through discussion and criticism [5].

2.1. Research purposes
The development of the era, of course many consumers desire to have products that have many functions [6]. This study aims to demonstrate the usefulness of multifunctional wheelchairs. This wheelchair aims to facilitate the activities of persons with disabilities and the elderly in carrying out daily activities. According to WHO (World Health Organization), people with disabilities are a definition that covers the weakening, limitations of activities, and barriers to participation [7]. Research data is obtained from distributing open questionnaires, closed questionnaires and market surveys to find the information needed related to manufacturing multifunctional wheelchair product design.

3 Research methodology

3.1. Approach Nigel Cross
The method used in the design of wheelchair products is based on the 7 steps of product design according to Nigel Cross. The seven steps include:

- Clarification of Purpose
  Purpose clarification is done to determine the purpose of product design. The method used is the destination tree
- Defining Functions
  With the objective tree method it can be seen by focusing on problems that have many levels of difference in general or in detail
- Determination of Needs
  Aims to make manufacturing specifications that are accurate enough for product design
- Determination of Characteristics
  QFD (Quality Function Deployment) is a planning tool to improve the quality of goods and services by understanding the needs of consumers and linking to the technical provisions for producing or producing an item or service.
- Alternative Generations
  A design step which aims to generate alternatives obtained to solve a problem in the design stage
- Alternative Evaluation
  A process in selecting the best alternative that can be applied from a variety of alternative choices that have been obtained
- Repair Details
  The details of repairs are one modification in developing a product, improving its appearance, reducing weight, cutting costs and increasing attractiveness[8].
3.2. **Sampling Method**
Sampling (sampling) is a systematic method for selecting subjects to be studied. The following outlines some general terms that need to be understood in sampling, including observation unit (unit of analysis), population, sample, and representative sample [9].

The selection of sampling techniques is a research effort to get a representative sample (representing), which can describe the population. The sampling technique is divided into 2 large groups, namely Probability Sampling (Random Sample) and Non-Probability Sampling (Non-Random Sample) [10]. This study uses judgment sampling is a sampling technique based on the assessment of researchers that he is the best party to be used as research samples [11]. Respondents in this study are people who use wheelchairs and understand wheelchairs.

3.3. **QFD Method**

*Quality Function Deployment (QFD)* is a methodology in the process of designing and developing products or services that are able to integrate the voices of consumers into the design process [12]. Quality Function Deployment is a technique utilizing to guarantee the quality in each creating items stages, beginning by the plan quality itself [15]. QFD will translate what customers need into what the company must produce [13]. 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. The main purpose of QFD is to determine the priority design criteria which are the main focus [14]. The QFD approach may likewise be extremely useful for scholastics intending to approve recuperation viability in the administration business [16].

4. **Results**

4.1. **Product Specifications**
Before doing product design. Then an assessment was made to find out the specifications of the wheelchair products. The results of the data collected are as follows:

- **Brand**: GEA
- **Type**: FS871
- **Types of products**: Road Aid
- **Framework Construction**: Chrome Plated Steel
- **Wheel Type**: Solid Rubber (Dead Tires)
- **Maximum Load**: 100kg
- **Wheelchair Weight**: 19.6kg
- **Chair Dimension**: 40x41x50cm
- **Folded Dimensions**: 93x24x88 cm
- **Drive Wheel Diameter**: 59cm

4.2. **Classification of Purpose & Function and Determination of Needs**
To find solutions to the problems above, there are 3 steps needed so that the problem will be divided into sub-problems, namely the classification of goals & functions, and determination of needs. The conclusions of the 3 steps in designing a multifunctional wheelchair product are:

The purpose of designing a multifunctional wheelchair such as multifunctional wheelchair material, seating width, seat and back seat material, long foam seating and backrest, chair arm length, the location of the bell, basket shape, table shape, portable toilet coating and has a feature wc that can be pulled forward.

The Destination Tree diagram can be seen in Figure 1 below.
The division of functions into essential sub-functions such as wheelchair designing function, wheelchair seating design functions, wheelchair footrest design sub-function and wheelchair toilet design sub-function. Determine the level of generality to operate such as the product has a fashionable, comfortable and ergonomic design, the product makes it easy for users to go to the toilet and the product has additional functions such as tables, bells and baskets.

4.3. Determination of Characteristics
In this section, sub problems of multifunctional wheelchair specifications will be found sub solutions with the steps of the Nigel Cross design, to determine the product characteristics. House of Quality multifunctional wheelchairs can be seen in Figure 2 to Figure 5 below.

Figure 1. Destination tree diagram
**Figure 2.** Matrix of resistance between product attributes and technical characteristics

| Product Composition | Assembly Time | Service Life | Strength of Materials | Machine Quality | Measurement Time | Multifunctional Wheelchair Weight |
|---------------------|---------------|--------------|-----------------------|-----------------|-----------------|----------------------------------|
| Thick Foam Seating  : 3.5 cm | v v V V v V V | | | | | |
| Seating Width : 50 cm | v v X x X x V V | | | | | |
| Sleeve Length : 50 cm | v v X x x V V | | | | | |
| Table and Basket Layout : Right Side | X X X x v X X | | | | | |
| The location of the bell : Right Side | X X X x v x x | | | | | |
| Basket Shape : Round | X X X X X V X | | | | | |
| Types of Dirt Container Coatings : Plastic | V V V v v x X | | | | | |
| Seating Upholstery Material : Synthetic skin | V V V v v x y | | | | | |
| Framework Material : Aluminum | V V V v V V V | | | | | |
| Additional Features : WC | V v v v v V V | | | | | |

*Degree of Relationship:*

- V = Strong Positive Relationships : 4
- v = Medium Positive Relationships : 3
- x = Medium Negative Relationships : 2
- X = Strong Negative Relationships : 1

**Figure 3.** Matrix of relationships between product attributes and technical characteristics
Figure 4. Relationships among fellow technical characteristics

Figure 5. Quality function of a multifunctional wheelchair deployment
4.4. Alternative Generations

The alternative generation stage aims to gather as many alternatives as possible that can be used to solve problems in the design of Multifunction Wheelchair products, to then find the best solution or alternative. This is done using the morphological map method (Morphological Charts) with the steps including:

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

Morphological Chart shows all the possible relationships of solutions or alternatives that can be used in the design of Multifunctional Wheelchairs as in Morphological Chart Multifunctional Wheelchairs products are displayed in the form of a matrix of 10 x 3, where there are 10 functions that must be achieved and there are 3 possible alternatives applied. The combination formula used is:

\[ 3^{10} = 59,049 \]

So the total possible combination of achieving these alternatives is 59,049 ways.

Table 1. Combination of multifunctional wheelchair product design solutions

| No | Characteristics          | How To Achieve Function |
|----|--------------------------|-------------------------|
| 1  | Thick Foam Seating       | 3 cm                    |
|    |                          | 3.5 cm                  |
|    |                          | 5 cm                    |
| 2  | Seating Width            | 50 cm                   |
|    |                          | 45 cm                   |
|    |                          | 40 cm                   |
| 3  | Sleeve Length            | 40                       |
|    |                          | 45                       |
|    |                          | 50                       |
| 4  | Table and Basket Layout  | Right side              |
|    |                          | Left side               |
|    |                          | Right side              |
| 5  | The location of the bell | Left side               |
|    |                          | Right side              |
|    |                          | Left side               |
| 6  | Basket Shape             | Round                   |
|    |                          | Rectangular             |
|    |                          | Square                  |
| 7  | Types of Dirt Container  | Plastic                 |
|    | Coatings                 | Plastic                 |
|    |                          | Synthetic Skin          |
| 8  | Seating Upholstery Material | Foam               |
|    | Framework Material       | Iron                    |
|    |                          | Aluminum                |
|    |                          | Stainless               |
| 9  | Additional Features      | An additional toilet    |
|    |                          | Can be assembled        |
|    |                          | Automatic               |

4.5. Alternative Evaluation

Alternative evaluation aims to compare the utility values of alternative product designs made or made on the basis of performance on the basis of weighting objectives, where the results of the alternative generation step will be evaluated by re-examining the alternative to be selected so that the best alternative is produced. The method used is the Weighted Objectives method with AHP scale. Weighting for each attribute is needed to know how the influence of these attributes in product design. Weighting is done by dividing the ranking value of each attribute to the total rating value itself. The results of the weighting of each comparison matrix can be seen in the table below.

Table 2. Weighting of pairwise comparative matrices between level I primary attributes

| Element              | Design | Material | Additional Functions | Weight |
|----------------------|--------|----------|----------------------|--------|
| Design               | 0.3806 | 0.3103   | 0.4561               | 0.3823 |
| Material             | 0.3398 | 0.2770   | 0.2184               | 0.2784 |
| Additional Functions | 0.2796 | 0.4128   | 0.3255               | 0.393  |
| Total                | 1.0000 | 1.0000   | 1.0000               | 3.0000 |
improving details are as follows:

- Make a list of product components and identify the functions of each component
- Determine the value of the function identified
  Based on the functions that have been identified, the values are determined based on consumer perception. The values of each function are assessed based on the suitability of the design to the consumer’s desire
- Calculate the cost of each component

4.6. Solution

The final stage of the design process aims to increase the value of the product for consumers and reduce costs incurred by producers. The solution that has been obtained from the alternatives that are compared to similar competitors' products, this can be done using the Value Engineering method. The steps in improving details are as follows:

| Table 3. Weighting of pairwise comparative matrices between level II design secondary attributes |
|-----------------------------------------------|
| Element                          | Thick foam seating | Seating Width | Sleeve length | Table and Basket Layout | Location of the Bell | Basket Shape | Types of Manure Container Coatings | Seat Upholstery Materials | Framework Material | Additional Features | Weight |
| Thick foam seating               | 0.078              | 0.028         | 0.080         | 0.051              | 0.042               | 0.061        | 0.195                       | 0.160              | 0.050           | 0.117               | 0.086 |
| Seating width                    | 0.161              | 0.057         | 0.013         | 0.075              | 0.062               | 0.071        | 0.032                       | 0.153              | 0.064           | 0.071               | 0.075 |
| Sleeve length                    | 0.072              | 0.327         | 0.074         | 0.026              | 0.030               | 0.098        | 0.048                       | 0.125              | 0.085           | 0.184               | 0.107 |
| Table and Basket Layout          | 0.148              | 0.074         | 0.278         | 0.097              | 0.045               | 0.064        | 0.092                       | 0.063              | 0.083           | 0.082               | 0.103 |
| Location of the Bell             | 0.140              | 0.069         | 0.182         | 0.162              | 0.074               | 0.020        | 0.044                       | 0.240              | 0.088           | 0.061               | 0.108 |
| Basket Shape                     | 0.112              | 0.071         | 0.067         | 0.133              | 0.335               | 0.088        | 0.061                       | 0.049              | 0.119           | 0.041               | 0.108 |
| Types of Manure Container Coatings| 0.036             | 0.170         | 0.145         | 0.100              | 0.161               | 0.137        | 0.095                       | 0.040              | 0.093           | 0.066               | 0.104 |
| Seat Upholstery Materials        | 0.032              | 0.024         | 0.038         | 0.101              | 0.020               | 0.118        | 0.156                       | 0.065              | 0.089           | 0.200               | 0.084 |
| Additional Features              | 0.132              | 0.074         | 0.070         | 0.098              | 0.071               | 0.062        | 0.086                       | 0.061              | 0.084           | 0.045               | 0.079 |
| Total                            | 1,000              | 1,000         | 1,000         | 1,000              | 1,000               | 1,000        | 1,000                       | 1,000              | 1,000           | 1,000               | 1,000 |

| Table 4. Performance parameters of each attribute |
|-----------------------------------------------|
| Characteristic                          | Parameter | Score |
| Seat Thick Foam                         | Size      | 5 cm  | 3.5 cm | 3 cm  | 4 cm  | 2 cm |
| Seating Width                           | Size      | 50 cm | 45 cm | 60 cm | 80 cm | 70 cm |
| Sleeve length                           | Size      | 40 cm | 45 cm | 50 cm | 36 cm | It is not in accordance with |
| Table and Basket Layout                | Conformity| Perfectly fit | Corresponding | Suitable | Not quite | right |
| Location of the Bell                    | Conformity| Perfectly fit | Corresponding | Quite | Not quite | right |
| Basket Shape                            | Conformity| Perfectly fit | Corresponding | Quite | Not quite | right |
| Types of Manure Container Coatings     | Conformity| Perfectly fit | Corresponding | Quite | Not quite | right |
| Seat Upholstery Materials               | Quality   | Very good | Well | Pretty good | Not good | Not good |
| Framework Material                      | Quality   | Very good | Well | Pretty good | Not good | Not good |
| Additional Features                     | Conformity| Perfectly fit | Corresponding | Quite | Not quite | right |

4.6. Solution

The final stage of the design process aims to increase the value of the product for consumers and reduce costs incurred by producers. The solution that has been obtained from the alternatives that are compared to similar competitors' 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
- Determine the value of the function identified
  Based on the functions that have been identified, the values are determined based on consumer perception. The values of each function are assessed based on the suitability of the design to the consumer’s desire
- Calculate the cost of each component
The price of the main raw material, supplementary material, and supporting material for the manufacture of the product has been estimated in advance to determine the selling price of the product produced.

- Look for ways to reduce costs without reducing value.
  From the results of the evaluation, value engineering can only be done by finding replacement components whose prices are relatively cheaper than before. After the survey, a replacement component is obtained with the price
- Evaluate alternatives and select change.
  The way to reduce costs is through wheel replacement and reducing foam, plastic, bolts and nuts, as well as dynamos and on-off buttons that can be searched for at a lower price than the estimated price, so the initial price is estimated at around IDR 931,000.00 to IDR 532,000.00.

5. Conclusion
The conclusions obtained in the manufacture of Multifunction Wheelchair products are the design of this multifunctional wheelchair product suits its purpose of having several additional features that help people with disabilities and the elderly. Additional features include a WC and a bell. The characteristics of multifunctional wheelchair products obtained from the design goal is to have 3.5 cm thick foam seat, seat width of 50 cm, 50 cm long arms, position the table and basket are located on the rightlaying position bel is on the top right, the shape of the basket is round, the type of coating is a plastic container of dirt, seating upholstery in the form of synthetic leather, the skeleton material is aluminum and the additional feature is toilet. The attributes of the Multifunction Wheelchairs product can be divided into several sections. The primary attributes of the Multi-Function Wheelchair product are design, materials and additional functions. The secondary attributes of the Multifunction Wheelchairs product are thick foam seating, seat width, arm length, table and basket position, bell location, basket shape, type of dirt container liner, seat coating material, frame material and WC. For QFD it is found that all the characteristics of the technique are quite easy to do, for the degree of importance product composition, assembly time, service life, material strength, assembly strength, length of measurement and weight of multifunctional wheelchairs are quite important and estimated costs in quite expensive category. Based on the value engineering step through improving details, it was found that from the alternatives available there were the best alternatives with a total cost of IDR 532,000.00.

References
[1] Ginting R 2013 Perancangan Produk (Yogyakarta: Graha Ilmu)
[2] Hariastuti NLP and Lukmandono L 2017 Analysis of the Design of Product Designs to Increase Small and Medium Industry Competitiveness. Industrial Engineering Scientific Journal 16(1) pp 13-21
[3] Syam R and Mustari M 2011 Design of Electric Wheelchairs to Ride Down Mechanical Journal 2 (2)
[4] Hartati B, Sarfika R and Putri DE 2019 Implementation of Health Education with Brainstorming Methods for Adolescent Knowledge About Growth and Development in Pauh Padang City IPTEKS Downstream Journal 2 (1) pp 14-23
[5] Situmeang DM 2020 Collaboration on Geniur Learning Strategy and Brainstorming Methods to Increase Motivation and Student Learning Outcomes PIONIR Journal 6 (1)
[6] Ady W A G 2011 The Development of Wheelchair Designs Especially in The Elderly is Based on Product Images using The Kansei Engineering Method
[7] Hadi S 2018 Universal Kitchen Cabinet Design (Case Study for Wheelchair Users and Normal Users) Intra 6 (1) pp 1-8
[8] Sulaiman F 2017 Product Design: Multifunctional Candle Holder Design with Nigel Cross 7 Step Approach Journal of Innovation: Journal of Engineering and Innovation 4 (1) pp 32-41
[9] Nurdiani N 2014 Snowball Sampling Techniques in Field Research *ComTech: Computer, Mathematics and Engineering Applications* 5(2) pp 1110-1118

[10] Nasution R S K M 2003 *Teknik Sampling* (Medan: USU Press)

[11] Pratama R 2013 The Effect of Budgetary Participation on Budgetary Slack with Organizational Commitment and Motivation as A Moderator (Empirical Study on the Regional Work Unit in Padang) *Journal of Accounting* 1(1)

[12] Yuliarty P, Permana T and Pratama A 2008 Development of Chalkboard Product Design Using the Quality Function Deployment (QFD) Method *PASTI Scientific Journal* 6

[13] Ginting R 2005 Improving the Quality of Library Services Using the Servqual Method and the Quality Function Deployment Method at the USU Medan Library *Journal of Communication Research* 17(1) pp 15-24

[14] Ardani F, Ginting R and Ishak A 2014 Design of Spring Bed Product Design Using the Quality Function Deployment Method *USU Industrial Engineering Journal* 5(1) p 219632

[15] Wurjaningrum F 2008 Design of education service quality improvement of Airlangga university by applying Quality Function Deployment (QFD) model *International Conference on Service Systems and Service Management* pp 1-6

[16] Wu W Y, Qomariyah, A, Sa, N T T and Liao, Y 2018 The integration between service value and service recovery in the hospitality industry: An application of QFD and ANP *International Journal of Hospitality Management*, 75 48-57