Innovative Design of Ergonomic Wheelchair For Disabled People

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Innovative Design of Ergonomic Wheelchair For Disabled People

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Abstract. For disabled people, difficulties in daily activities still become a major problem, especially for those who do not have normal legs. This condition requires an appliance to ease them in moving that is wheelchair. However, the use of the existing wheelchair still gives problems such as pain in buttock (90%), waist (93%), hands (86%), thigh (90%), and back (93%). Furthermore, the chair is easily damaged (83%), difficult to manoeuvre and move (83%), as well as expensive (67%). Thus, it is crucial to improve wheelchair. The objective of this study was to propose an ergonomic and innovative redesign of wheelchair in order to be able to satisfy users' need. The QFD method was used to determine the design specification of the wheelchair. Survey was done to identify user requirements of the design. Statistical analysis was implemented to test hypothesis. The result of this study showed that the proposed design of the wheelchair is valid to satisfy user criteria at 5% significance level since it is more comfortable, stronger, affordable, easier to use, easier to repair and easier to move.

1. Introduction

As a normal person needs a good daily life, so do disabled people. In doing daily activities, many disabled are facing obstacles in moving such as walking. Therefore, these disabled require aids to ease their activities especially for those who do not have normal legs due to hemiplegic, amputation, polio and cerebrovascular accident (VCA). A study found that an increase number in disabled people is not followed by the availability of adequate facilities because it does not meet user expectations [1]. According to [8] the facilities should be able to help them. Reference [5] expresses that a person who has physical or mental disorders will be hampered in carrying out activities. Based on data from [6] the number of disabled people in Indonesia is 11,580,117 with 3,010,830 of them have physical disabilities. Therefore, this fact has encouraged to make some improvement by redesigning better appliance i.e wheelchair. Reference [4] had developed an ergonomic wheelchair in his study but the design requires further modification to be more innovative and able to overcome complaints.

Based on the preliminary study, it was found that there are still some user complaints in the use of the wheelchair, namely buttock (90%), waist (93%), hands (86%), thigh (90%), and back (93%). In addition, the chair is also easily damaged (83%), difficult to maneuver and move (83%), as well as expensive (67%). Thus, it is crucial to improve or redesign the existing wheelchair. The objective of this study was to propose an ergonomic and innovative redesign of wheelchair that can satisfy user requirements.

2. Method of the Research

2.1. Survey

Survey was conducted to identify the user criteria of wheelchair, design parameter and validate the proposed design. The first two questionnaire were distributed to 30 respondents who did not have normal legs. Their age ranged from 15 to 60 years old. They consist of 23 males and 7 females. While the last questionnaire, Nordic Body Map questionnaire, is used to validate the proposed design where this measurements was done after respondens operated the wheelchair for three hours per participant in a day directly without rest.This test use three respondents.

2.2. Instrument

Some tools were used to support the study as follows:
Questionnaire was developed into three parts. The first was to identify customers' needs. The second was to determine the design specification. The last was to validate the proposed design. Anthropometer was used to measure the body dimensions. Nordic Body Map questionnaire was to determine some complaints before and after using a wheelchair. IBM SPSS software version 22.0 was used to process statistical data. Solid work software 2015 was used to design a virtual prototype of the wheelchair.

2.3. Anthropometry

Anthropometry is the study of the body dimensions and certain other physical characteristics [9]. The determination of body part in this study was done after the voice of customers was defined. The dimension of body part measured consisted of sitting shoulder height, shoulder width, hip width, forearm length, sitting elbow height, popliteal height and maximum grip width.

2.4. Quality Function Deployment Method

Quality Function Deployment (QFD) is a method used to develop a product based on the need of customers [3]. A process of the method starts by determining "what's" (customer needs or voice of customers) and "how" (technical requirements) that can satisfy customers as shown in Figure 1.[2]

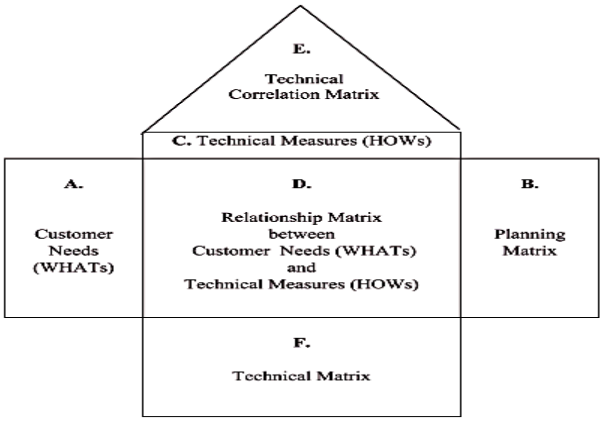

Figure 1. Conceptual map of house of quality [2]

The mapping procces using House of Quality consisted of the following steps 2:

1. Identify customer's needs (What's).
2. Evaluate customer criteria.
3. Determine technical measures (How's).
4. Determine relationship matrix between customer need and technical requirements.
5. Determine technical correlation.
6. Determine target specification of design.

2.5. Statistical Analysis

Non-parametric statistical analysis was conducted to test the hypothesis by using the Stuart-Maxwell method. The hypothesis was there is no difference between specification of the developed design and customer requirements. In addition, the Wilcoxon method was to test the difference between the proposed wheelchair and the existing wheelchair [10].

3. Result and Discussion

3.1. Result of Survey

Table 1 is presenting the result of the survey conducted in the preliminary study. This survey identified the six valid attributes on 5% significance level.

Table 1. Customers attribute.

No	Attribute	Validity Score	Reliability Score
1	Comfortable	0.717	0.633
2	Strong	0.856	0.586
3	More economic	0.553	0.687
4	Easy to use	0.594	0.697
5	Easy to repair	0.593	0.702
6	Easy to user move	0.451	0.715

Comfortable attribute means that user requires the design not cause any pain on the whole body parts. Strong attribute shows that the design is not easily damaged thus reducing the risk of accident for user. More affordable attribute declares that the price is not expensive thus being affordable for user. Easy to use attribute means that the design is easy to use by users. Easy to repair attribute means that the design can provide a complete information about the standard operation procedure, while easy to move is that it is easy for users to maneuver.

3.2. Result of Design of Spesification

Figure **2**. presents House of Quality of the design developed. It contains customer requirements, technical requirements, important rating, customer competitive evaluation and target spesification. This study found the target spesifications or design parameters of the wheelchair design that satisfy the technical requirements and customer attribute.

The design specification of the seat is 51 cm in depth, 52 cm in width, 7.5 cm in thickness, the backrest is 64.5 cm in height, 52 cm in width, 7.5 cm in depth, the grip diameter of steer is 20 cm and the height of footrest ranges from 40 cm to 49 cm. This dimension is applied in design referring to user requirements in order to make user sit comfortably. Moreover the material used for the seat and backrest is platinum foam D-26 and composite. The characteristics of this material are pillow and soft so it is comfortable to support the upper body of the user. In addition, the material is quite strong and easy to repair if it is broken, meeting the standard operation procedure.

Furthermore, the material used for the frame of the wheelchair is duplex stainless steel. This type of material is proven to be light, not easily broken, corrosion resistant and durable, making the frame very strong to support the user's body. In addition, the price of the material is affordable for customers. Therefore, the wheelchair developed is more affordable (IDR 3,005,000 per unit). Another advantage is the use of a steer system and 3 wheels for maneuvering, allowing users to more easily operate and move it. Besides, the design of the footrest is adjustable so it can increase the comfort in use. In fact, it is also supported with arm rest

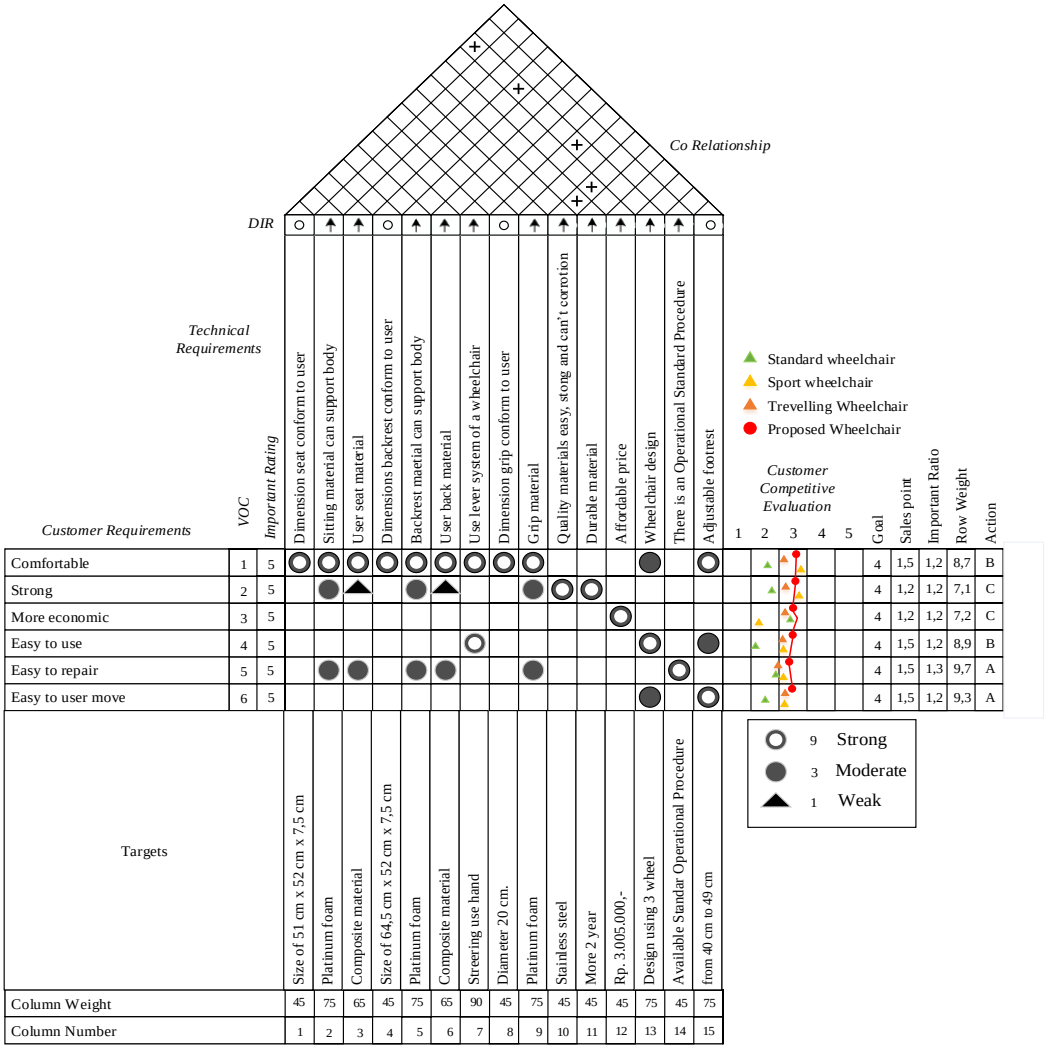

Figure 2. House of quality wheelchair.

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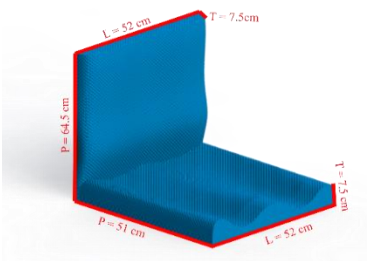

Figure 3. Seat and backrest design.

Figure 4. Steer design.

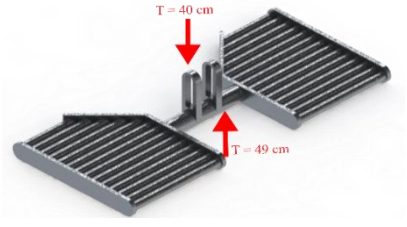

Figure 5. Footrest design.

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Figure 6. Three-wheel design.

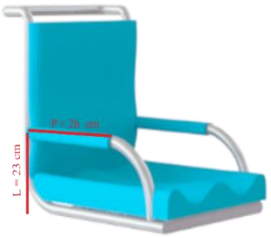

Figure 7. Arm rest design.

3.3. Result Conceptual Design

Right view Top view Isometric view Front view Back view

Figure 8. Design of wheelchair.

Figure **8**. describes the conceptual design of the wheelchair developed.

3.4. Statistical Analysis

3.4.1 Homogeneity Test. Stuart Maxwell method was implemented to validate the proposed wheelchair design to test the hypothesis below:

H_0: There is no significant difference between the proposed design and user requirements.
H_1: There is significant difference between the proposed design and user requirements.

Table 2. Results of Stuart Maxwell of marginal homogeneity test

Attribute	Asymp.sig. (2-tailed)
Comfortable	0.782
Strong	0.763
More economic	0.715
Easy to use	0.131
Easy to repair	0.123
Easy to user move	0.683

Table 2. presents the result of this test where the value of z ranges from 0.123 to 0.782. This means that H_0 is accepted because $z > 0.05$. Thus, the design parameter of the wheelchair is valid to meet the attributes that users require.

3.4.2 Different Test. The Wilcoxon method was to test the hypotheses below:

H_0: There is no significant difference between the developed design and the existing design.
H_1: There is significant difference between the developed design and the existing design.

Table 3. Result of Wilcoxon test

Attribute	Score	Asymp.sig. (2-tailed)
Comfortable	4	0.000
Strong	4	0.003
More economic	4	0.000
Easy to use	4	0.002
Easy to repair	4	0.006
Easy to user move	4	0.004

Table 3. presents the result of this test where the value of z ranges from 0.000 to 0.006. This means that the null hypothesis is not accepted because $z < 0.05$. Thus, the design has difference with the existing wheelchair; this design is more comfortable with score 4, stronger with score 4, affordable with score 4, easier to use with score 4, easier to repair and easier to move with score 4 in five scale.

4. Conclusion

It is concluded as follows:

1. The identified customer attributes of the wheelchair design are comfortable, strong, more affordable, easy to use, easy to repair and easy to move.
2. The design specification or parameters of the wheelchair developed are: frame using stainless steel material with a seat of 64.5 cm in depth, 52 cm in width, 7.5 cm in thickness and a backrest of 64.5 cm in height, 52 cm in width, 7.5 cm in depth; using a foam platinum D-26 as the seat and backrest; using composite as support material; using lever system as steering wheel with grip diameter of 20 cm and 26 cm in length, arm rest of 23 cm in width and footrest height ranging from 40 cm to 49 cm.
3. The proposed design is valid to satisfy customer requirements at 5% significance level where it is proven to be more comfortable (score 4), stronger, affordable (score 4), easier to use (score 4), easier to repair and easier to move (score 4).

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