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INOVATIVE DESIGN OF WHEELCHAIR BY USING USER CENTERED DESIGN APPROACH

Hartomo Soewardi[1], Bagus Tri Ajie[2], R.Abdul Jalal[3]

Department of Industrial Engineering, Industrial Technology Faculty
Islamic University Of Indonesia Yogyakarta, Indonesia
hartomo@uii.ac.id[1], bagus_triajie@yahoo.com[2], 835220103@staf.uii.ac.id

ABSTRACT

Wheelchair is one of the tools for disabilities feet. Some existing wheelchair is still simple because it has the limited functionality and is also less comfortable in use. However wheelchair is still required by them even though it has not satisfied what they need. The purpose of this research is to develop a multifunctional and ergonomic wheelchair design which can meet user's requirement. User Centred Design concept is used in this research to specify design parameter of wheel chair. The survey was conducted to identify the user criteria and the statistical analysis was utilized to test the hypothesis developed. The results of this study are the design parameters of wheelchair that can satisfy the disable require in ergonomics and multifunctional criteria.

Keywords*: Wheelchairs, Multifunction, User Centred Design, ergonomics*

1. INTRODUCTION

According to data from National Socioeconomic Survey in 2000, disabilities in Indonesia reached 1.46 million people (0.74% of the total population) which is about 0.83% live in rural area and 0.63% live in urban. Meanwhile, the World Health Organization (WHO) predicted that one in 10 people suffer disabilities and it has an increasing trend compared to the results of a quick survey in 1979 which means the disabled in Indonesia reached 3.11 percent [a]. Therefore, most of them who suffer from disabilities require tools to facilitate in performing their activities in daily life.

Wheelchair is one of the tools for disabilities feet to move from one to another place, whether a flat or a slope road. But some existing wheelchair design is still simple and has the limited functionality as well as uncomfortable. Thus it is important to re-design a special wheel chair to improve mobility and comfort.

User centre design (UCD) concept is one of a method that can be used in design. This method has been successfully applied in most field for example, the development of online gaming technology [b], commercial product development [c], advanced wireless sensor networks [d], the design of the tablet case made from coconut husk [e], and design of web-based student administration system [f]. This paper presents a study on designing the wheelchair for meeting the disable user's criteria by using this concept such that it will be more comfortable and useful.

2. THEORETICAL BACKGROUND

The quality of human-product interaction can be improved by following a user-centred design process [g, h]. Most design processes involve the basic design cycle as presented [i].

User-centered design consist of five phases [i]. The first is analysis of customer need where designers try to understand Sin a product. Synthesis is the next phase that it is performed to unify the user's criteria and designer's concept by mapping process to determine the design parameters. The third phase is the simulation. In this stage, its activities carried out are to test alternatives design made based on design parameters. Evaluation phase is performed to re-examine whether the design is already made which represent user desires. The last phase is decision making. It is to decide the best designs that ready to make a real prototyping. Figure 1 describes these phases.

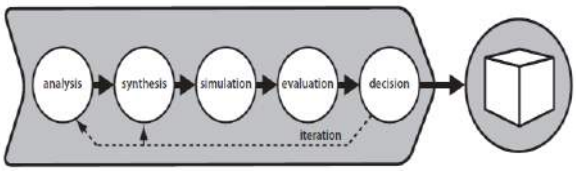

Figure 1. The basic design cycle of UCD [i]

3. RESEARCH METHOD

3.1 Survey

Survey was conducted to identify the user criteria of wheel chair, the design parameter, and to validate the purposed design. Questionnaire were developed and distributed to more than 30 respondents (disable user). Their ages ranged from 17 to 60 years old.

3.2 Mapping Process Method

Mapping process was conducted to determine the design parameter for satisfying customer criteria [j]. The method used in this process is axiomatic design method (AD). Axiomatic design is a theory which has the function to determine criteria for the best design and minimize the complexity of a system [k]. A process of the method is started from determine the functional requirement (FR) and the design parameter (DP) that satisfying FR [l]. See in Figure 2.

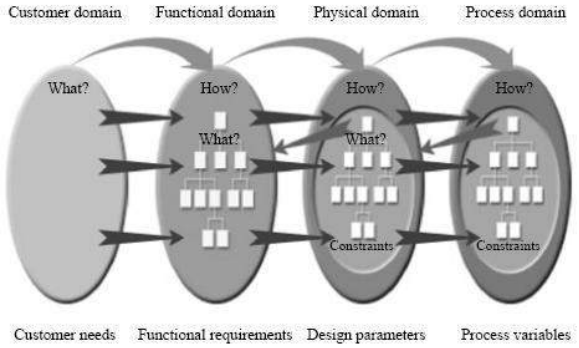

Figure 2. Four Domains in Axiomatic [m]

3.3 Statistical Analysis Method

In this study, a non-parametric statistical method is used. Test validity is the degree of ability to show the extent to which a measuring instrument measures what it is supposed to measure [n]. Validity of customer attribute testing can be done by the method of Spearman's Rank Correlation test [0]. The method used in determine the level of reliability is Cronbach alpha coefficient. Descriptive non parametric statistical analysis was used to map the customer attribute to physical design parameters. The test is performed to determine whether there are differences or similarities between the two groups of responses related data. Stuart Maxwell test It is Marginal homogeneity to validate of wheelchair and differentiate an existing design as well as developed design [p].

4. RESULT AND DISCUSSION

4.1. Customer Voice

Customer voice identified from a wheelchair user which four attributes valid and reliable customer.

Table 1. Customer Attribute

No	Atribut
1	Forceful
2	Multifunction
3	Flexible
4	Ergonomics

Based on Table 1, forceful described as wheelchairs that are capable of prop the weight of the wheelchair users. Interpreted multifunctional design that has more than one main function that can be used. The flexible design that can provide balance in a wheelchair when used. Ergonomic design attributes can be interpreted into design that has a comfort for wheelchair users.

4.2. Proposed design of Wheelchair

Table 2, Table 3, Table 4 and Table 5 present result of mapping process to determine the design parameter of wheelchair. Table 2 shows the result of design parameter satisfying customer attribute: "forceful". While Table 3 shows the result of design parameter satisfying customer attribute: "multifunctional". And table 4 shows the result of design parameter satisfying customer attribute: "flexible". Table 5 shows the result of design parameter satisfying customer attribute: "ergonomics".

Figure 3 shows virtual design of wheelchair based on the identified design parameter.

Table 2. Forceful of wheelchair

Code	**Customer Attribute**	**Code**	**Functional Requirement**	**Code**	**Design Parameter**
CA1	Forceful	FR1	Have the ability to prop the human body mass	DP1	Sturdy design
		FR 1.1	Designing appropriate construction	DP1.1	Durable material
		FR1.1.1	Do welding	DP 1.1.1	electric welding
		FR 1.2	Using a hard material	DP 1.2	Materials iron plate, iron pipe
		FR 1.3	Determining the supporting material	DP 1.3	endurance of material
		FR 1.3.1	combining of material	DP 1.3.1	sponge, Synthetic Leather

Table 3. Multifunction of wheelchair

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA2	Multifunctional	FR 2	Have functions in addition to the main function	DP 2	Multiple attributes
		FR 2.1	Provides functions to rest	DP 2.1	Sleeping position
		FR 2.1.1	Using the back of the chair	DP 2.1.1	The seats can recline
		FR 2.2	Provides functionality to transfer or move	DP 2.2	Moving on to the bed and toilet
		FR 2.2.1	Using armrests	DP 2.2.1	Can be separated pairs
		FR 2.3	Providing sanitation functions	DP 2.3	Bedpans
		FR 2.3.1	Using the seating section	DP 2.3.1	Seat cover can be pulled

Table 4. Flexible of wheelchair

Code	**Customer Attribute**	**Code**	**Functional Requirement**	**Code**	**Design Parameter**
CA3	Flexible	FR3	Having balance	DP3	easily turn
		FR 3.1	Having a complete wheel components	DP 3.1	axle good

Table 5. Ergonomics of wheelchair

Code	Customer Attribute	Code	Functional Requirement	Code	Design Parameter
CA4	Ergonomics	FR 4	Provide wheelchair design that is comfortable to use	DP 4	wheelchair according anthropometry, has a padded pedestal, Convenient walk, painless,
		FR 4.1	Determining the size of the wheelchair	DP 4.1	Size according to ISO, measure dimensions
		FR 4.1.1	Using the appropriate dimensions wheelchair design	DP 4.1.1	Anthropometry high body parts in a sitting position, popliteal length, shoulder width, high popliteal, width calf
		FR 4.1.1.1	measured in a sitting position	DP 4.1.1.1	Dimension of P95 is 83.23 cm
		FR 4.1.1.2	Measure the length of the popliteal	DP 4.1.1.2	Dimension of P50 is 38.98 cm
		FR 4.1.1.3	Measure the width of the shoulder	DP 4.1.1.3	Dimension of P95 45.51 cm
		FR 4.1.1.4	Measure the height of the popliteal	DP 4.1.1.4	Dimension of P50 is 43.09 cm
		FR 4.1.1.5	Measure the width of the calf	DP 4.1.1.5	Dimension of P95 is 12.7 cm
		FR 4.2	Determining the seat cover	DP 4.2	sponge coated synthetic leather
		FR 4.3	Determining the type of wheel	DP 4.3	Front wheel, rear wheel
		FR 4.3.1	Determining the front wheel	DP 4.3.1	Rubber wheels with a diameter of 9 cm
		FR 4.3.2	Determining the rear wheel	DP 4.3.2	Bicycle wheel with a diameter of 67 cm
		FR 4.4	Determine the position of the wheels so easy to reach	DP 4.4	Not far from the reach of the hand 60 degrees

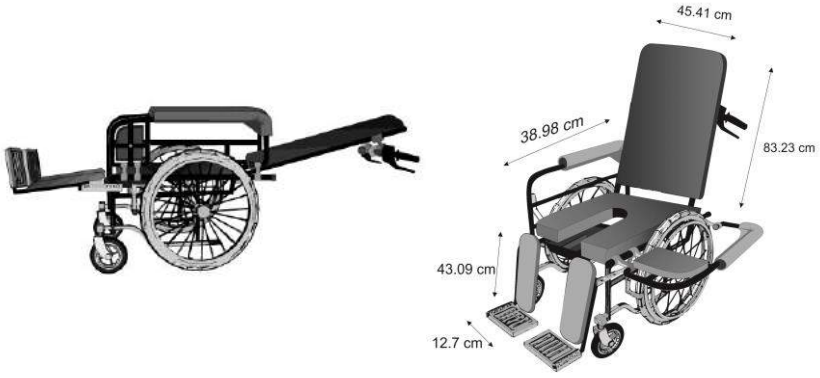

Figure 3. Design of wheelchair

The forceful design (Table 2) have 6 design parameters: user resistant to body weight, durable materials, using electric welding, material steel plate and steel pipe, durability, synthetic leather. It explains that the wheelchair has a resistance to load user. Multifunctional design (Table 3) have wide variety of additional design functionality with design parameters: the position of sleep, a chair can recline, go into bed or toilet, and bedpan. It identifies that the wheelchair design provides functions to rest, can move to bed, also provide bedpan in wheelchair, it's mean that wheelchair is more useful. Flexibility in design (Table 4) includes the design parameters such as easy to turn aside and have the right to part laker wheelchair. This shows that the wheelchair is easy to use and has a balance at the time used by the user. Ergonomic design in (Table 5) includes the design parameters such as the size of the corresponding dimension of high body sitting upright 83.23 cm in size, dimension size 38.98 cm popliteal buttocks, shoulder width dimensions of 45.51 cm, height dimension popliteal 43.09 cm, 12.7 cm calf width dimension, providing a base sitting foam coated synthetic leather, the front wheels using a bicycle wheel diameter 67cm, rear wheel using a rubber wheel diameter of 9 cm, hand reach 600. This means that the wheelchair design provides comfort for the user.

4.3. Result of Validation

To test the hypothesis whether there is a significant difference between the needs of wheelchair users and design. Then tested Stuart Maxwell Marginal homogeneity implemented to validate wheelchair. Here is a hypothesis developed.

H_0 : There is no a significant difference between the user's requirements and wheelchair design

H_1 : There is a significant difference between the user's requirements and wheelchair design

Table 5 Stuart Maxwell test of Marginal Homogeneity results

User's requirements	z values
Forceful	0.450
Multifunctional	0.631
Flexible	0.117
Ergonomics	0.670

Table 5 present result of this test which the value of z ranges from 0.117 to 0.631. it means the null hypothesis can be accepted because z> 0.05. Thus the design parameters of wheelchair is valid to made customer criteria.

5. CONCLUSION

It can conclude as follow.

1. Design of wheelchair which is developed based on customer attribute needs are forceful design, multifunctional, flexible, and ergonomics.
2. The design parameters of forceful design attributes are solid design, durable material, electric welding, material steel plate and steel pipe, sponge and synthetic leather. The design parameters of multifunctional attributes are sleeping posture, the seat can recline, moved into bed and toilet, armrests separated pairs, bedpan, cushion bias pulled open. The design parameters of flexible attributes are easy to turn and use the bicycle wheel axle. The design parameters of ergonomics attributes are size according to ISO, anthropometry body sitting position the size of 83.23 cm, anthropometry length popliteal dimensions 38.98 cm, anthropometry shoulder width, measure the dimensions of 45.51 cm, height anthropometric popliteal measure the dimensions of 43.09 cm, width anthropometric calf size 12.7 cm, sponge coated synthetic leather, rear wheel diameter of 670 bicycle wheel, rear wheel diameter Karet 9.cm. calf in the recline position
3. According to validation test, a design of wheelchair valid to satisfied customer criteria at 5% significant level.

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AUTHOR BIOGRAPHIES

Hartomo Soewardi is a senior lecturer of Industrial Engineering Department, Faculty of Industrial Technology, Islamic University of Indonesia, Yogyakarta. Currently he is Ph.D in Engineering Design and Manufacture. His teaching and research interest are industrial ergonomic design, product design, management and quality design. His email address is hartomo@uii.ac.id

Bagus Tri Ajie is a final student of Industrial Engineering Department, Faculty of Industrial Technology, Islamic University of Indonesia, Yogyakarta. His email address is bagus_triajie@yahoo.com

R. Abdul Djalal is a lecture in Department of Industrial Engineering, Faculty of Industrial Technology, Islamic University of Indonesia