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# DESIGN OF WHEELCHAIRS FOR PEOPLE WITH DISABILITIES

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## ABSTRACT

Persons with disabilities, referred to as disabled people, are often regarded as unproductive citizens, unable to carry out their duties and responsibilities. About 15 percent of the world's population are people with disabilities - more than one billion people. They are considered the largest minority group in the world. In reality, there are not many public facilities or special services provided to persons with disabilities. One of them is in the aspect of education. In public facilities of the education sector, not many education buildings or educational providers with facilities and infrastructure that can support people with disabilities are available. As for mobility equipment that can help people with disabilities on both legs, namely crutches, walking sticks, walkers, and wheelchairs, aim to help and facilitate their mobility.However, the wheelchair that is available in the market today only has a limited function of moving left, right, and spinning. Other activities require help from others, such as reaching higher objects and moving the body from a wheelchair to another seat through the stairs/steps. Therefore we need a product design that starts from preparing product concepts from old products into a new product to meet the needs of the market/people with disabilities.

**Keywords: ( Product Design, Wheelchair, Diffable, Ergonomics)**

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## 1. Introduction

According to Law Number 4 of 1997, Article 1 Paragraph 1 of the Disabled, Persons with Disabilities is any person who has physical or mental disorders that interfere with and are obstacles and obstacles for him to perform correctly. Data from the Central Statistics Agency (BPS) of the Republic of Indonesia, in 2015 shows that, the number of people with disabilities who have difficulty walking or climbing stairs (handicapped) with an age range of 10 years and over is 7,808,385, out of a population of 258.2 million people or about 3%. Winarsih (2014) mentions that disability is under the classification of:

1) Have Severe Disorder (Disability) ( 332,069 people )
2) Severe Impairment Seeing Despite wearing glasses (97,767 Persons)
3) Severe Hearing Impairment Despite Using Hearing Aids (72,283 Persons with Persons)
4) Severe Communication Disorders (80,955 Persons)
5) Severe Impaired Memory/Concentration (46,762 Persons)
6) Severe Impaired Walking or Climbing Stairs (145,500 Persons)
7) Severe Disorders of Taking Care of Self (114,337 Persons)

Many things can influence the causes of disability in Indonesia. Some of them include the struggle for land, work, or certain customary violations, the various regions throughout Indonesia, various natural disasters that repeatedly come in multiple places. There are still incidents of polio and leprosy, vitamin A deficiency, high incidence of stroke, and poor patient safety in medical practice. Hypertension which can lead to stroke affects 31.7% of the population aged 18 years and over (Sugeng, Tarigan, & Sari, 2019). This situation is exacerbated by the low level of traffic safety and work safety.

Indonesia itself already has a special law regarding persons with disabilities. For example, Law no. 4/1997 concerning Persons with Disabilities and Government Regulation 43/1998 concerning Efforts to Improve the Social Welfare of Persons with Disabilities (1997/1998). Article 5 states that "every person with a disability has equal rights and opportunities in all aspects of life." Article 6 lists various rights for persons with disabilities such as education, employment, equal treatment, accessibility, rehabilitation. As well as Law No.25/2009 concerning Public Services (2009): Article 29 states that public service providers must provide exceptional services to persons with disabilities by regulations, Law No.28/2002 concerning Building Construction (2002) regulates that the facilities must be accessible to persons with disabilities. Article 27 states that facilities must be accessible, safe, and enjoyable, especially for persons with disabilities. However, in reality, not many public facilities or special services are provided to persons with disabilities. Accessibility to achieve equality in the use of public buildings and government offices is still rarely implemented. Public transportations are not friendly to people with disabilities,and there is an absence of supportive sidewalks for people with disabilities. Vehicle parking spaces are not suitable for people with disabilities. The elevators are too narrow. Sanitation facilities that do not support, and slippery roads and uneven roads that persons with disabilities cannot pass. Some provisions allow persons with disabilities to file claims for their rights in various regulations, but these provisions are not widely known. Observations by (Sudibyo, 2002) evaluated the rights of persons with disabilities to work for the ILO. They stated that Indonesia already has legal instruments, but their implementation is fragile.

The disability experienced by the individual and the unsupportive reaction of the social environment usually makes the efforts of the quadriplegic individual disappear, so that the quadriplegic individual is less able to develop their potential (Rodas, Zeedyk, & Baker, 2016). People with disabilities (handicapped) face many obstacles, such as limited access in the educational environment as accessing objects that are higher up, difficulty moving from one chair to another, difficulty climbing stairs or steps, and others. Park, Chowdhury, and health (2018) said that in the United States, there is a lack of data on the population with disabilities, as a result of which designers find it difficult to make products for people with disabilities. The data were available in the data of American soldiers from the second world war.

Due to the large number of cases that occur in people with disabilities, especially physically disabled people, a mobility device is

needed to help and facilitate people with disabilities in carrying out their activities. The current mobility equipment that can help the disabled/paralyzed in both legs are crutches, tri-leg canes, walkers, and wheelchairs to assist and facilitate their movement activities. But the wheelchairs available in the market today only have functions limited to moving left, right, and rotating. These functions have not been able to help quadriplegic motion activities optimally. Some activities need help from other people, such as reaching higher objects, moving the body from a wheelchair to a wheelchair—another seat, past the stairs/steps. So we need a product design that starts from preparing product concepts, both new products, and old products that will be modified into a new product in the form of engineering and industrial design to meet the market's needs/(the disabled).

(Doré, Pailhes, Fischer, & Nadeau, 2007; Nagamachi, 2002; Olive & Thouvenin, 2008) Considers that during product development should focus on the product itself and not the end-user. However, they highlight that some of the existing products still have little consideration for the ergonomic relationship between human, object, and spatial factors throughout the product design process (Norman, 2002; Rubin & Chisnell, 2008). Rubin and Chisnell (2008) said the designer must include an integrated ergonomics vision in the design process to avoid segmentation between these three factors.

## 2. Method

In general, the product development process is divided into six stages (phases). These six phases are (Ulrich-Eppinger, 2001):

1. Phase 0. Planning

In this phase, planning activities are called the 'zero phase, namely preliminary activities that include project approval and the actual product development launch process.

2. Phase 1. Concept Development

In this phase, the target market's needs are identified, alternative product concepts generated and evaluated, and one or more concepts selected for development and experimentation in subsequent phases.

3. Phase 2. System-Level Design

This phase includes the definition of the product architecture and the description of subsystems and components. The final assembly description for the production system is defined in this phase. The output of phase 2 includes the layout of the product form, functional specifications of each product subsystem, as well as a preliminary process flow diagram for the final assembly process.

4. Phase 3. Detailed Design

This phase includes a complete specification of all unique components' shape, material, and tolerances in the product and identifying all standard features purchased from suppliers. Process plans are stated and production equipment is designed for each component made in the production system. The output of this phase is the recording of controls for the product, specifications of purchased components, and process plans for manufacturing and assembling the product.

5. Phase 4. Testing and Repair

This phase involves the construction and evaluation of various initial production versions of the product. The initial prototype (alpha) is made using components with the shape and type of material in actual production but does not require a manufacturing process with the same process as in the actual manufacturing process. The alpha prototype is tested to determine whether the product will work as planned and whether the product meets the main customer satisfaction (specification/quality) needs. The next prototype (beta) is made with the components needed in production but is not assembled using the final assembly process as in the actual assembly. Beta prototypes are evaluated internally and also tested by consumers using them directly. The goal of the beta prototype is to answer performance and reliability questions in order to identify the need for technical changes to the final product

6. Phase 5. Product Launch

This phase is also known as the initial production phase. In this phase, the product is made using a real production system. The purpose of this initial production is to train the workforce in solving problems that may arise in the actual production process. The products produced during the initial production will be tailored to the customer's wishes and carefully evaluated to identify any deficiencies that arise. The transition from initial production to actual production goes through stages. At some point in this transition, products are launched and begin to be made available for distribution.

## 3. Result

The mission statement that has been made is used as a reference for the next product development phases. The mission statement for the repair of disability aids, namely wheelchairs, is described in Table 1.

**Table 1. Mission Statement**

| **Wheelchairs** | |
|---|---|
| 1. Description | The product is used for students with disabilities to carry out their studies well |
| 2. Main Business Goals | - Disabled Students<br>- Environmentally friendly<br>- Modify existing products |
| 3. Main Market | Disabled students who are currently undergoing school or other education |
| 4. Second Market | All disabled in education and other government agencies |
| 5. Limitation Assumption | - New product innovation<br>- The design used considers anthropometry<br>- Made in Indonesia |
| 6. Stake Holder | - Buyers and Users<br>- Manufacturing operations<br>- Service operations<br>- distributors |

Identification of user needs is carried out in two stages, namely Phase I and Phase II). Each stage consists of several steps that need to be done. Explanation of data processing at each of these stages, among others:

Stage I

Phase I is the stage carried out to identify the functional requirements that need to be in the tool/product to be repaired. Three steps were carried out in Phase I, among others:

a. Determination of customer functional requirements

The identification of functional needs was carried out by conducting structured interviews with ten respondents who were disabled in the legs and used a wheelchair in their daily activities. Data collection needs is done by using interview techniques to implement it. The answer or statement given by the respondent is written in a customer statement form. The following are customer statements and interpretations of their needs. From the results of interviews conducted, several functional requirements variables were obtained which can be seen in Table 3.

**Table 2. List of Hierarchy**

| **Wheelchairs ease the activity for people with disability** | **Wheelchairs with additional equipment** |
|---|---|
| **Wheelchairs can reach higher objects<br>*Wheelchairs ease the use of a joystick<br>***Wheelchairs are easy to move left and right | **Wheelchairs with folding table<br>*Foldable wheelchairs |
| | **Safe material to use** |
| **Durable/not easily damaged wheelchairs** | **Safe wheelchairs to use** |
| ***Wheelchairs can last a long time (years)<br>***Wheelchairs are not easy to rust<br>**Wheelchairs can withstand heavy loads<br>**Wheelchairs are made of lightweight material | ***Has properly functioned brakes<br>***Does not hurt the user when pedaled by hand |
| | |
| | **Affordable wheelchairs** |

| | |
|---|---|
| **The wheelchairs are comfortable to use** | **Design affects comfort** |
| ***The wheelchairs are comfortable when the user moves them by hand<br>**The seat and backrest of wheelchairs are comfortable to use | ***The wheelchairs are the right size for the users' body<br>*Wheelchairs with a simple design<br>*Bigger seat design looks good |
| **Wheelchairs are easy to use/operate**<br>*****how to use | **Use hydraulic pressure** |
| **Multifunctional wheelchairs**<br>*** can transfer from wheelchair to bed | |

In the process of sorting these needs, several steps are carried out. An explanation of each step includes:

1. Counting respondents' answers according to the needs group

The table above describes the number of respondents' interpretations of a need. It should be noted that a respondent can provide more than one interpretation for a variable of need.

2. Divide the number of interpretations of each need variable into each level of importance

The results of calculating the number of interpretations for each need that has been calculated in the previous step are then broken down or divided into each level of importance. The distribution of the number of interpretations is carried out according to the answers given by the respondents at the time of the interview. The result of dividing the number of interpretations of each need variable into each level of importance

3. Sorting needs by the level of importance

After calculating the number of interpretations of needs for each level of importance, the next step is sorting/sorting needs. The sorting or sorting of the variable needs is done based on the assessment of the level of importance given by the respondent.

From the results of the grouping of needs above, it can be seen that the most important degree of importance is the highest number of needs, namely wheelchairs that are durable / not easily damaged, wheelchairs that are safe to use, and wheelchairs with economical prices.

Phase II is the stage that aims to identify the type of user that needs to be based on the characteristics inherent in the user.

Phase II consists of two steps, namely determining user characteristics, which are then followed by determining user requirements.

The results of the needs that have been obtained from Phase II will then be combined with the results of identifying functional requirements that have been identified at the beginning of the needs identification phase.

## 3.4 Combining Variables of Needs

The needs variables that have been identified in Phase II are then combined with functional requirements which are the results in Phase I. The results of combining functional requirements and user requirements are based on user characteristics (Phase II). From table 5 it can be seen that the solution to customer needs, the level of relevance of the solution, and the importance of the solution in order to know the customer's wishes.

The list of metrics describes the technical characteristics that can help to achieve a required variable. The list of metrics that have been created will then be made into a metric-needs matrix. This matrix describes the relationship

between requirements and their metrics. The complete requirement-metric matrix is shown in the table below.

From the table, we can know the level of relationship between customer desires and our own solutions. From the results above, there are similarities between the customer needs metric "Can reach objects that are higher up" which is number 1, the customer needs metric "Materials are made of Stainless Steel with the best quality. " i.e. numbers 2 and 6, customer needs metrics "Ergonomic design" i.e. numbers 1,3 and 10, customer needs metrics "Equipped in operation" i.e. 4, customer needs metrics "Having additional features can help move to a regular chair or to a bed " ie numbers 1,3,5,7 and 8, customer needs metrics "Using pure Stainless Steel that does not contain harmful chemicals" namely number 6, customer needs metrics "There is a table that can be folded, and the chair can be raised and lowered" namely number 5,7, and 8, the customer needs metric "Included with additional brakes" which is number 8, the customer needs metric "Affordable price" is number 9, the metric k customer needs "Design and dimensions of the wheelchair according to the user's body size" namely numbers 3 and 10, the metric of customer needs "The system used for the function

The list of metrics and metric-needs matrices that have been made previously is then continued to the next step, which is to determine the target value based on the specifications of the tool (Zulfahmi, 2009)

The collection of information about similar products is carried out based on the variables of needs that have been determined further. The information results are entered into a table.

From the specifications of the target product above, it can be seen about the specifications of the target product from competitors, and from the competitor's product it can assume the ideal value of the product to be made. From the competitor's marginal value, it can be seen that metric 1 has an ideal value of 5, metric 2 has an ideal value of 4, a metric 3 has an ideal value of 4, a metric 4 has an ideal value of 3, a metric 5 has an ideal value of 4, a metric 6 has an ideal value of 4, a metric 7 has an ideal value of 3, a metric of 8 The ideal value is 4, the ideal value for metric 9 is 5, the ideal value for metric 10 is 4, and the ideal value for metric 11 is 4.

**Table 4 Customers' Needs and Degree of Importance**

| No | Customers' Needs | Importance |
|---|---|---|
| 1. | Wheelchairs ease the activities | 4 |
| 2. | Wheelchairs are durable/not easily damaged | 5 |
| 3. | Wheelchairs are comfortable to use | 4 |
| 4. | Wheelchairs are easy to use/operate | 4 |
| 5. | Multifunctional wheelchairs | 4 |
| 6. | Wheelchairs with additional equipment | 3 |
| 7. | Safe materials to use | 4 |
| 8. | Wheelchairs are safe to use | 5 |
| 9. | Affordable wheelchairs | 5 |
| 10. | Wheelchairs design affects comfort | 3 |
| 11. | Using hydraulic pressure | 4 |

From the list of model requirements from the list of customer needs and analyzing the physical, dynamic, and static models of the wheelchairs to be made, 12 components of wheelchairs requirements list, namely 1 component of the dynamic model (hydraulic pump), 1 component of the physical model (ergonomic), and 1 component of the static model (table addition).


Figure 1 Function Tree Chart

The chart above shows that overall, the function tree consists of four levels. The first level or the top level is the main function of a versatile wheelchair, which is that it can be raised and lowered. The second level is the answer to the "how" question from the above level, which is that the wheelchair can be raised and lowered using hydraulics. The third level is the answer to the above level of how to operate the hydraulic, which is manually. The next level answers the question on the third level, which is how to operate the hydraulic in a wheelchair, which is by equipping a control device in the form of a stick located on the side of the wheelchair.

:

**Table 5. List of a matrix for Multipurpose Wheelchair Products**

| No | Needs | Matrix | Importance | Unit |
|---|---|---|---|---|
| 1. | 1 | Can reach higher objects | 5 | Subj |
| 2. | 2,6 | Made of the best quality Stainless Steel | 5 | Subj |
| 3. | 1,3,10 | Ergonomic design | 4 | Subj |
| 4. | 4 | Equipped with operation manual | 4 | Subj |
| 5. | 1,3,5,7,8 | Have additional features to help to move to regular chair/bed | 4 | Subj |
| 6. | 6 | Use pure Stainless Steel that does not contain harmful chemicals | 4 | List |
| 7. | 5,7,8 | There is a foldable table, and chair that can be raised and lowered | 3 | Subj |
| 8. | 8 | Equipped with additional brakes | 4 | Subj |
| 9. | 9 | Affordable prices | 4 | Subj |
| 10. | 3,10 | Wheelchairs design and dimensions suit the users' body size | 5 | Subj |
| 11. | 4,11 | The system used as the main function of the wheelchair | 3 | Subj |

Table 6 Concept of Product Decomposition

| No | Concept Name | Note |
|---|---|---|
| 1 | A | Wheelchair material (stainless steel, synthetic leather), Chair color (brown and gray), Table material (plywood). |
| 2 | B | Wheelchair material (steel, synthetic leather), Chair color (black), Table material (wood). |
| 3 | C | Wheelchair material (aluminum, rubber), Chair color (brown and black), Table material (Iron). |

Interpretation:

The table above shows 3 concepts that will be used for comparison of prototyping.

Figure 2 shows the first rank of alternative design, which is the 2nd alternative, a multipurpose wheelchair. The alternative design that is ranked first will be directly selected and then improved and product tested. The selected alternative design is shown in Figure 2.

Figure 2 selected alternative design

The chosen alternative design still has some disadvantages. The emerged disadvantages are later improved. The purpose is that the design made is based on the user's needs. The image of the product concept design is shown in Figure 3.

Figure 3 product concept

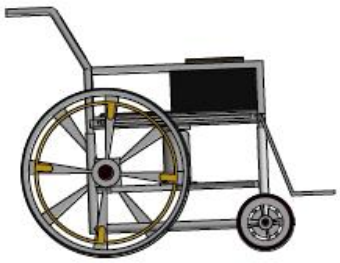
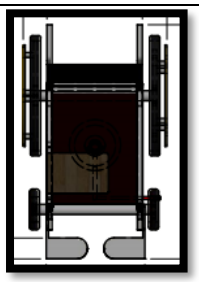
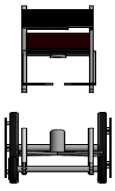
From the product design, several disadvantages emerged, and the suggestions for improvement include:

1. The hydraulic control device is placed slightly tilted instead of horizontally, making it easier for users to operate it.
2. The triangular-shaped hydraulics used to make the wheelchair unable to be folded perfectly, but it is light to carry anywhere.

The disadvantages and suggestions are used as inputs in making improvements. All suggestions are implemented so that the improvements can be seen in the design drawings in the Table below:

Table 7 Improved design concept

| **Figure** | **Note** |
|---|---|
|  | *The material used is stainless steel. |

| | |
|---|---|
|  | Side view of the wheelchair with a rear tire diameter of 59 cm and front tire diameter of 20 cm. |
| | Side view using triangular hydraulic with control device on the side of the wheelchair. |
|  | Top view of the wheelchair with a length of 140 cm and width of 70 cm. |
| | *the rectangular handle is more comfortable to handle and the rounded finishing on the sides makes it more comfortable. |
|  | The back view of the wheelchair in the picture has a backrest width of 44 cm. The backrest is covered with a sponge or foam for comfortable usage. |

Choosing the design to be selected.

In the previous step, the first ranked alternative design has been determined. The alternative design that occupies the first position will be directly selected and further improved and product tested. The selected alternative design is shown in Figure 4.

Figure 4 Selected Alternative Design

Improve the selected product concept

The alternative design that has been chosen still has some disadvantages. To help the improvement process, a design model is made from a prototype of inventor design. This aims to help in visualizing the real form of the product design that has been selected. The emerged disadvantages are later improved. It is intended that the design will be made according to user needs. A photo of the product concept design is shown in Figure 5.

Figure 5 Product Concept Photos

From the product design, several disadvantages and improvement suggestions emerged, including:

1. The hydraulic control device is placed in the middle instead of horizontally, making it easier for users to operate it.
2. The triangular hydraulics are changed into bottled hydraulics because triangular hydraulics made the wheelchair unable to be folded perfectly and it cannot be applied properly to the wheelchair.

The advantages and suggestions are used as input in making improvements. All suggestions are implemented so that the improvements can be seen in the design drawings in Figure 6.

Figure 6. Wheelchair using hydraulic/triangle jack (left) and wheelchair-using hydraulic/bottle jack (right)

The image above shows the difference between a wheelchair using a triangular jack and a wheelchair using a bottle jack (improvement). Seen on the side, the bottle jack is able to withstand a 3-ton load. The difference itself lies in the hydraulic/jack model. The triangular jack when applied to a wheelchair is not suitable since it makes the wheelchair cannot be folded and has a heavier load than using a bottle jack. The following is a picture of the finished product of a versatile horse according to the chosen alternative design.

Figure 5 Product Photo

## 4. Conclusion

The purpose of this research is to make an improvement design of the wheelchair. Improvements were made to the design of the existing tool. The conclusions generated in this study are described through explanations. The design of the wheelchair repair tool is to use the addition of hydraulics and a table, the materials used are steel and wood for the jack and a table that is used to raise and lower the wheelchair so that users can carry out activities more easily. The addition of a table function is a new concept presented in the design of the multipurpose wheelchair improvement. From the results of product concept testing, there are significant differences between the types of wheelchairs used. The type of wheelchair in question is a wheelchair in general. The type of tool has an influence on aspects of ease of use of tools, comfort when reaching goods, ease of activity. Further research can continue the development of the wheelchair concept up to the implementation phase. In the product concept generation phase, an analysis is carried out for each material that will be used as an alternative solution.

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