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Wheelchair's Design Development for Disabled People in Yogyakarta, Using Quality Function Deployment Method

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Abstract. A wheelchair is one of the most common tools for disabled people to mobilize. Using a proper and correct wheelchair will help the disabled to improve their life's quality and also their social condition. Unfortunately, most of the wheelchairs are not correctly built or in a proper condition to be used, even worse, the disabled are usually not using the correct wheelchair type for their diseases. This research shows 7 parameters that were used to develop a new wheelchair's design the customers want. The 7 parameters namely: wheelchair's aesthetic, weight, safety, wheelchair's mechanism, ergonomics, usability, and economic factors will then be used in the QFD process in order to find the customer's need. This paper is implementing the QFD in order to create a better wheelchair for the disabled. The output of this research is a new kind of wheelchair that the users, in this case, is disabled, want according to the questionnaire they filled in. The final specifications of the wheelchair will be having 3 wheels, and the dimensions will be 39 cm X 39 cm on the seat and 64 cm X 15 cm on the wheel. The seat will be a sir filled the seat and will also have 5-6 cm thickness. The Final design of the wheelchair will be returned back to the users to undergone a validation process.

Introduction

There are a lot of types of healthcare device that can be used as an assistive mobility device, one of the most commonly used healthcare devices for mobility purpose is a wheelchair. Using a wheelchair, the disabled could gain some benefits such as the increasing level of health over time, better quality in their life and a better economic condition [1]. Using a proper and right wheelchair could really improve the disabled life's condition and also could prevent the condition of their body getting worse. The Disabled could travel freely and do many kinds of activity and even chores without having to cling and depends on another family member.

Unfortunately, wheelchairs are being developed and design unproperly, they are still being developed with *one fit for all* concept [2], creating one types of a wheelchair for all-purpose and any kinds of disease, thus we often see some wheelchairs users are not comfortable with the wheelchair they use and have.

According to SUPAS (Intercensal Population Survey) that being held in 2015, shows that there are at least 31.825 persons in Yogyakarta that having a problem with mobility, whilst 25.322 persons are not having any methods or tools of mobility. Without having any tools or devices for mobility, the disabled will become more isolated in their life, even worse, they will become the burden of society.

One of the most commonly used methods of product design and development is *Quality Function Deployment* (QFD). This method emphasizing on finding what the customers want, over the product they will buy. The customer needs in QFD are being used in order to provide the product that the customer truly desired. In this paper, the customer's needs are being used to develop the design of the new wheelchairs in order to provide what the customers want.

This paper emphasizes on finding what the disabled *needs* in a wheelchair by using the QFD method and then creating and developing a new type of wheelchair based on the needs found in QFD.

Research Methodology

The paper, emphasizing on finding the customers needs on a proper and good wheelchair. Customers voice identification processes in this paper are found by using questionnaire. The disabled in this paper acted as the main users for the expected wheelchair design. There are several parameters of a good and proper wheelchair [3,4], namely: materials, ergonomic factors, functionality, usability, weight, safety, economics factors, ease of use, ease of mobility, comfortability of the cushion.

Based on the requirement, this paper provides seven points of expected parameters such as:

1. Wheelchair's Aesthetic
2. Weight
3. Safety
4. Wheelchair's mechanism
5. Ergonomics
6. Usability
7. Economic factor

The seven parameters being used in this research are based on previous research related to wheelchairs such as ergonomics factors and usability. Using the seven parameters that being pointed out, the QFD questionnaire is being made and distributed to the disabled. The questionnaires are then being distributed to 45 disabled all around Yogyakarta.

The Parameters then could be used in the designing process, they are used as a need statement in the Quality Function Deployment (QFD) process. The final specification of the wheelchair created by the needs vs metric process is the final wheelchair design that will be brought back to the users as a validation process.

Results and Discussion

Questionnaire Analysis. The questionnaire contains the required parameters for the expected wheelchairs, the parameters are then being translated as 17 points of questions. In this section, the questionnaires are being analyzed with *Principal Component Analysis* (PCA) in order to classify the questions into smaller groups. The first step of the PCA process is the *Kaiser Meyer Olkin* (KMO) test and *Bartlett's Test of Sphericity* shown in Table 1. Based on Table 1, it is known that the KMO point is 0.742, which means the variable that is determined in this paper can be predicted correctly. Eigenvalues are being used in the following analysis process in Table 2. Using Eigenvalues methods shows that there are 4 main components that can be used to group the questions that were used in the questionnaire, in order to do so, the 4 components need to be rotated with the *Varimax* method, shown in Table 3. These 4 components will also be used as the needs in the Quality Function Deployment method.

Table 1 Kaiser Meyer Olkin's and Bartlett's Sphericity Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.742
Bartlett's Test of Sphericity	Approx.Chi-Square	580.102
	Df	136
	Sig.	0.000

Wheelchair Designing Process. Components found on the varimax process are then being used in the needs vs matrix process, which is the main point of the QFD process. Using the customer's voice that is captured based on the questionnaire, those components shown in Table 3 are being converted into several needs for the making of the House of Quality namely: *utility factors, esthetic & safety factors, flexibility factors,* and *social & psychological factors*. While the needs are already being stated, the next step that should be done is choosing the technical responses of the needs. Some needs will be intertwined with other technical responses, this happened because some of the technical responses can be connected into several needs. Another main point of the HOQ process is the weighting for each needs statement. The weighting processes in this paper is done by the *Pairwise*

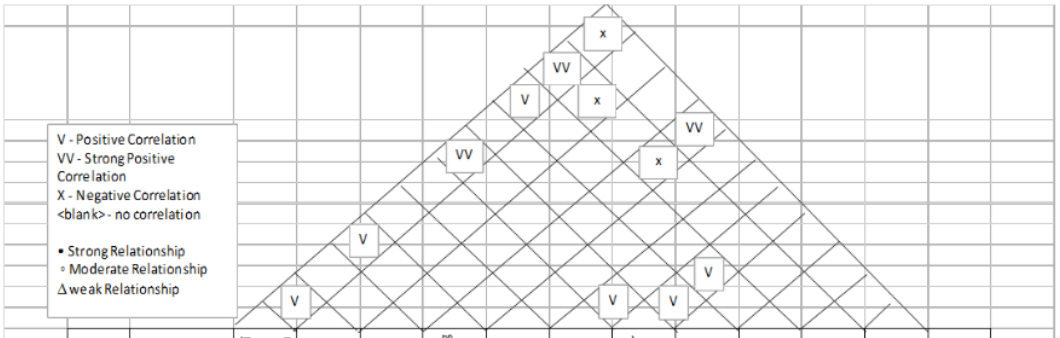
comparison process. Based on the weighting process, thus both technical responses and needs statements will be translated into some measurable values in the HOQ process shown in Fig. 1.

Table 2 Eigenvalue Result

2 Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8,212	48,305	48,305	8,212	48,305	48,305	3,911	23,009	23,009
2	1,607	9,451	57,755	1,607	9,451	57,755	3,094	18,202	41,211
3	1,336	7,860	65,615	1,336	7,860	65,615	2,669	15,701	56,912
4	1,098	6,459	72,075	1,098	6,459	72,075	2,578	15,163	72,075
5	,984	5,790	77,864						
6	,900	5,294	83,159						
7	,649	3,815	86,974						
8	,535	3,149	90,123						
9	,406	2,391	92,513						
10	,299	1,757	94,270						
11	,270	1,585	95,855						
12	,211	1,240	97,095						
13	,193	1,137	98,232						
14	,106	,621	98,853						
15	,091	,534	99,387						
16	,066	,389	99,776						
17	,038	,224	100,000						

Table 3 Varimax Result

	Component			
	1	2	3	4
Question_Numbers_7	,832	,177	-,017	,292
Question_Numbers_11	,801	,172	,265	,066
Question_Numbers_8	,666	-,138	,433	,179
Question_Numbers_14	,651	,373	,151	,377
Question_ Numbers_12	,650	,395	,029	,274
Question_ Numbers_3	,586	,486	,266	,136
Question_ Numbers_2	,132	,883	,020	,140
Question_ Numbers_5	,382	,765	,117	,216
Question_ Numbers_4	,120	,630	,271	,191
Question_ Numbers_15	,474	,487	,280	,442
Question_ Numbers_10	,174	,095	,856	,303
Question_ Numbers_9	,094	,128	,809	,048
Question_ Numbers_6	,470	,230	,657	,104
Question_ Numbers_1	,043	,401	,432	,109
Question_ Numbers_13	,298	,169	,065	,865
Question_ Numbers_17	,159	,213	,262	,839
Question_ Numbers_16	,408	,414	,269	,595



		Wheelchair's dimension	numbers of part	material	supporting parts	couch's material	couch's thickness	wheelchair's weight	wheel's type	numbers of wheel	assembling time	extra slot	weight
No.	Needs												
1	Utility	▪ 396		◦ 132	◦ 132	Δ 44	◦ 132	▪ 396	▪ 396	◦ 132	◦ 132	◦ 132	44%
2	Esthetic	◦ 51	▪ 153	◦ 51	◦ 51	◦ 51	◦ 51			▪ 153		◦ 51	17%
3	Flexibility	▪ 252	▪ 252					◦ 84	◦ 84		▪ 252	◦ 84	28%
4	Socio & Phsycological		◦ 33	Δ 11	◦ 31			▪ 99			◦ 31		11%
	Total Score	699	438	194	214	95	183	579	480	285	415	267	3849
	Priority	18.16	11.38	5.04	55.56	2.47	4.75	15.04	12.47	7.4	10.78	6.94	
	Ranking	1	4	9	8	11	10	2	3	6	5	7	
	Measurement Units	m2	pieces	list	pieces	list	cm	kg	list	pieces	seconds	list	

Fig 1. House of Quality

Concept Screening and Designing Process. Fig 1, shows that the *wheelchair's dimension* gets the highest score in the HOQ process followed by the *wheelchair's weight* as the second important criteria. Based on the 11 criteria of the wheelchair's design, the next steps that should be done is the *Concept Screening* process. Screening is done in 5 wheelchair's product that already been in the market namely: *standard wheelchair, active wheelchair, complex rehab wheelchair, recliner wheelchair,* and *travel wheelchair*. In this paper, the standard wheelchair is used as the main reference of the wheelchair's design development, the screening process is shown in Table 4. Using Table 4 as a reference, it can be drawn to create the final specification of the wheelchair as shown in Table 5.

The final specification of the wheelchair is then being used to draw the newly designed and developed wheelchair shown in Fig 2. The newly designed wheelchair is then being validated by the customers, whom in this paper are the disabled who fill in the questionnaire that being handed down to them.

Validation Process. Validation process needs to be done after the final design of the newly developed wheelchair has been made, thus the final design of the wheelchair is actually the design that the respondents need or not. The validation process is done by showing back the final design, and respondents are free to give any comment, using the comments, author then re-creating the new design based on the comments and evaluation given by respondents. Some evaluations given by the respondents are:

1. No handbrake on the new wheelchair, it could be dangerous for the users.
2. A three-wheeled chair is prone to flip up when being used, thus it can be dangerous for the user when it is going to be used.
3. Make sure the footrests are safe, judging by the look of it, there are possibilities that the user's feet are thrown away from the footrests.
4. Maybe the headrest can be removed.
5. Make sure we can fold the wheelchair; it could be big trouble if we carry the wheelchair that can be folded.

Table 4. Concept Screening

No	Criteria	Existing Product				
		Standard Wheel Chair (Reference)	Active Wheel Chair	Complex Rehab Wheel Chair	Recliner Wheel Chair	Travel Wheel Chair
1	Wheelchair's Dimension	0	+	0	0	0
2	Number's of part	0	0	0	+	0
3	Wheelchair's Material	0	+	0	0	0
4	Supporting Parts	0	+	+	+	0
5	Couch's Material	0	0	0	0	-
6	Couch's Thickness	0	0	0	0	-
7	Wheelchair's Weight	0	0	0	0	0
8	Wheel's Type	0	+	0	-	-
9	Number's of wheel	0	+	0	0	0
10	Assembling Time	0	0	-	-	+
11	Extra Slot	0	-	+	0	-
	Sum +'s	0	5	2	2	1
	Sum 0's	11	5	8	7	6
	Sum -'s	0	1	1	2	4
	Net Score	0	4	1	0	-3
	Rank	4	1	2	3	5
	Continue	NO	YES	YES	YES	NO

Based on the comments given by the respondents, it is imperative to recreating and redesigning the newly developed wheelchair that being shown in Fig 3 and Fig 4. There are also several responses based on the validation process written by the author such as:

1. Handbrake is a crucial part; it will be given in the newest design.
2. The front part of the wheelchair will be more stretched in order to prevent the flip-up accident.
3. Several improvements will be made for the footrest to prevent the user's leg to be thrown away, such as giving a piece of cloth placed on the chassis and there will be some extra depth on the footrest to prevent any possibility of the user's feet to be thrown away.
4. The headrest is an extra part for this newly designed wheelchair, if the users are not fond of the wheelchair, they can easily take it down and removed it.
5. The wheelchair will be created to be easily folded, thus answering what the customer's needs.

Table 5 Final Specification

No	Techinical Respond	Unit	Final Specification
1	Wheelchair's Dimension	Cm	
a	*wheelchair's seating size*		39 cm X 39 cm
b	*back rest's size*		39 cm X 39 cm
c	*wheel's diameter*		64 cm & 15 cm
2	Number's of part	Pieces	8 pcs
3	Wheelchair's Material	List	aluminum & composites
4	Supporting Parts	Pieces	3
5	Couch's Material	List	air
6	Couch's Thickness	Cm	± 5 - 6 cm
7	Wheelchair's Weight	Kg	± 15 kg
8	Wheel's Type	List	Pneumatic
9	Number's of wheel	Pieces	3
10	Assembling Time	Second	900 second
11	Extra Slot	List	Available

Fig 2. Wheelchair Design Based on Final Specification

Fig 3. Front View and Side View of the Revised Wheelchair

Fig 4. Folding Process of the Newly Revised Wheelchair

Conclusions

Wheelchair users are usually having a hard time finding the right wheelchair for them to use, this paper is trying to close the gap by creating the proper wheelchair based on the customer's needs using the Quality Function Deployment as a customer's identification tool. The final design of the newly developed wheelchair shows that the wheelchair the customers want is a three-wheeled wheelchair, with a safe and proper footrest in order to prevent the feet and leg being thrown away and it also can be folded to help and ease both the users and their family to bring the wheelchair.

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