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Abstract. This paper aims at establishing improvement process of prosthetic hand product design using Quality Function Deployment (QDF). Since the prototype of the well-functioned prosthetic hand is launched, the early life cycle checking of the product design is undefined. Brainstorming and QFD are utilized to gain improvements of the product usability. Besides, usability test is designed both qualitative and quantitative test to assess the usability concept of a custom product. The research finding show the improvement of product based on easiness factors while Voice of Customer calculate the highest absolute value for technical responses is regulation of the motion mechanism (53.4%).

INTRODUCTION

In the field of product development, industrial success is determined based on two things: design phase and the suitability of the product with consumer desires and the speed of the industry in adapting/responding to situation changes [1]. Product innovation is developed to get customers from various sectors. In the field of medical devices, innovation products are dominated by the development of assistive devices. Assistive devices in the health sector can be said as an instrument, apparatus, machine and/or implant that does not contain drugs used to prevent, diagnose, cure and alleviate diseases, treat sick people, restore health to humans and/or form structures and improve function the body [2]. Aids are used to help and alleviate complaints of patients who have physical deficiencies due to various things that have happened such as accidents, illnesses, and heredity [3,4].

Recently, research related to assistive devices for people with disabilities especially for the hands in Indonesia has not been developed. Most products must be imported like Michaelangelo, Steeper, i-limb, Naked, bebionic, Mert's hand, TRS prosthetic, etc. Prosthetic hands in Indonesia are dominated by home industries with limited production quantities and only passive-aesthetic product types. The most important reason is the very high price of sensor assistive devices for resembling hands. Ongoing research is developed to achieve the goal of obtaining low-cost products with a number of restrictions related to previously designed movements. The products developed are in the form of active artificial hands that help people with disabilities to carry out daily activities at a lower cost compared to other countries. The artificial hand is custom designed and prototype based to accommodate the need for active functions in assistive devices in the form of sensors to capture input signals from muscle contractions of patients [5]. Recently, the researches is focusing the study in usability studies [6-12]

The prototype development that has been carried out basically only refers to the functional aspects of the product without regard to the customer's voice. In fact, according to [13], to support the creation of products that are in accordance with the wishes of the customer, it is necessary to test and evaluate the product to the needs of users/patients. Because the prototype has been completed and technically functional, then the product design and development approach will be different from the basic product life cycle theories such as QFD [14-17]. This study

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aims to redefine the Quality Function Deployment (QFD) function in the prototype phase of product designs and implement the generated models in case studies of the development of prosthetic hand products.

METHODS

Product Specification

Anthropomorphic Prosthetic Hand is one assistive device that specifically designed for people with hand disabilities. This tool is designed according to the dimensions of a patient's arm amputation at the one of public hospital Semarang. It can be controlled for several movements that have been predetermined by the designer. The development of Anthropomorphic Prosthetic Hand as one of the active aids for people with disabilities is certainly very supportive for the creation of products that are in accordance with the wishes of the user both in terms of dimensions and economic. This product has 5 gesture modes that can be changed according to user needs. These modes can be changed by pressing the button on the artificial hand. Each mode provides a combination of colors on the LED so that the user knows the mode used. There are five hand functions that can be done by Anthropomorphic Prosthetic Hand. This function can be done to do some activities that are usually done by hand. Power grip is a function of hand movement that is expected to replace the holding function marked with a red LED. The second mode with a green LED indicator can make a tripod movement which is expected to replace the function of pinching small objects or writing on the hand, while the third method with a blue color indicator LED can perform the precision closed movement which is expected to replace the function of taking the flash disk and necklace. The fourth mode with the green and red LED indicators can perform the hook movement which is expected to perform the function of carrying items such as a lightweight tote bag. The fifth mode with a blue and green light color indicator LED can perform active index movements that are expected to replace the function of pressing the keyboard on the computer [5].

Quality Function Deployment (QFD)

QFD is a structured method used in the product planning and development process to determine specifications and needs and to evaluate products according to what consumers want [15,16]. The main focus of this method is to directly involve the customer in the product development process. The philosophy underlying this focus is that the customer will never be satisfied with the performance of a product even though the product that has been produced is perfectly designed by the developer. QFD serves a translation customer needs into something that can be produced by the organization by not only meeting as many customer expectations as possible, but also trying to exceed what is expected by the customer, it aims to increase customer satisfaction, so that the products produced can compete well with competing products.

There are several main activities in implementing the QFD concept, namely:

1. Voice of customer
   At this stage, a survey of customers is carried out directly to obtain information about what is needed by consumers when using a product. Data on consumer needs is then generated into a list to be proceed to the next stage. In the first stage, a survey was conducted by performing direct interviews shortly after the product was tested on respondents. Respondents were given a USE questionnaire to obtain qualitative data. The low-scale aspects will be recorded later to be clarified with respondents about the causes. Giving open questions outside the questionnaire is also conducted to obtain deeper information related to what is felt and what is needed by consumers to make the product more leverage when used to do daily activities.
2. House of Quality (HoQ)
   House of quality is a matrix of the results of a series of parts previously made in the QFD method. Some parts that must be made beforehand are:
   - Matrix of consumer needs
   - Planning matrix
   - Technical response matrix
   - Targeting
   - Determine the improvement ratio

The improvement ratio shows the amount of changes or improvements that must be made. Determination of the value of improvement is to use a formula.

- Determine sales point
  The selling point value is obtained by holding discussions with the respondent. Later this value will be determined based on how far these needs provide added value if realized. There are three sales point values as shown in Table 1.

Tabel 1 Sales point [15]

Value	Categories
1	*Week*
1.2	*Medium*
1.5	*Strong*

- Raw weight and Norm raw weight
- Matrix of the relationship of technical responses to consumer needs
  Determination of the level of technical response relationships and customer needs is determined by providing numerical assessments and will later be symbolized in accordance with the value of the relationship. In the matrix, the form of the assessment is symbolized by the symbol described earlier in Table 2.

Table 2. Relationship value

Symbol	Numeric value	Definition
△	1	Maybe there is a relationship
○	3	Moderate relationship
◎	9	Very strong connection

- Determination of priorities

3. Analysis and Interpretation
   From the house of quality matrix, the next step taken is to analyze and interpret the matrix. This was performed to provide an explanation of the results of using the QFD method. The proposing improvements of the Anthropomorphic Prosthetic Hand product provide a design in accordance with the needs of consumers in terms of usability.

Respondents

There are 2 respondents in this study. The first one is Mr. SA, a newspaper deliveryman. While doing his work as a builder in 2002 Mr. SA had a work accident that caused his hands to be amputated immediately to save other limbs. The second respondent who did the Bionic hand testing was Mr. ES. He is an employee at the Semarang City private hospital. Mr. ES is 53 years old and has experienced disability at birth. He was diagnosed with cognitive impairment which is a disorder in the growth of the structure of the baby that arises since the baby is still in the fetus [18].

RESULT AND DISCUSSION

Voice of Customer (VoC)

VoC is obtained when discussions and questionnaires are filled with respondents and when the discussion is open to find out other things that the respondents think need to be improved. Table 3 is the result of discussions with each respondent for each activity carried out.

Table 3. The recapitulation of VoC

Activities	Voice of Customer	
	Respondent 1	Respondent 2
Open the door	- Respondents did not feel any difficulty when using the product to open the door - These activities do not require high accuracy so that they can be done easily easily	- Easy enough to open the door - Large door handles, it makes it easy for respondents to open them
Take a coin	- Respondents have a little difficulty in positioning themselves when taking coins - Respondents find it difficult to take small objects such as coins. - Density of fingers to flank small / thin objects feels less strong - Joints on stiff wrists so respondents need a little effort to position themselves when taking coins	- Coin is an object that needs concentration to be taken and hands feel stiff. - The fingers are not tight when carrying coins into the glass - Need adjustments to get used to hand movements when moved
Unzip	- Slippery fingers when used to clamp small objects - The density of fingers to flank small/thin objects is felt to be less strong, because when he pull a zipper several times the zipper is detached	- Finger intermittent regardless of zipper when pulled - The surface of the fingers used to flank the coin feels less tight
Move objects	- The palms are slippery when used to hold objects - The bumps that are too thick and stiff on the lower palm make the respondent a little difficulty holding objects - Thumbs that do not fit the shape and size - When used to hold objects, the respondent feels that the grip strength is lacking, so the respondent feels that this needs to be improved	- When gripping an object the hand does not catch the object tightly - It needs to be positioned because the thumb is a little obstructing when positioning the object - The lower part of the palm is not flat so it is a bit annoying when taking objects

Inputs and suggestions for improvement from respondents were translated into attributes that would later be used as inputs for making HoQ. The following are attributes made based on the VoC obtained and collected. From the VoC it is also obtained the level of consumer interest that measured using a Likert scale from 1 to 5. The level of importance illustrates how important an attribute is to be improved. Another criterion assessed by respondents is Sales Points. It is obtained by calculating the average answers from respondents. There are 3 scales, namely 1, 1.2 and 1.5. The meaning of the scale that 1 indicates that these attributes do not help product sales. Scale 1.2 shows that the attribute is quite helpful in selling products. The last scale of 1.5 shows that the attribute helps product sales. Table 4 is a recapitulation of the level of importance and Sales Points according to respondents.

Table 4. Recapitulation of Interests and Sales Points

Attributes based on VoC	Importance	Sales Point
Grip accuracy for small objects	4,5	1,50
Conformity of form	4,5	1,50
Product weight	4,5	1,35
Finger density	4,0	1,35
Gripping ability	4,0	1,35
Variations in hand function	3,5	1,20
Hand width adjustment (thumb)	3,5	1,50
Flexibility of the wrist joint	3,5	1,20

From the results of determining the level of importance, the most important attribute to be repaired according to respondents is the accuracy of the handle for small objects with a value of 4.5. The results of the Sales point calculation show there are 3 attributes that have the highest value, namely the accuracy of the handle for small objects, the suitability of the shape and the width of the hand. This shows that the above attributes will greatly influence the increase in product sales according to respondents.

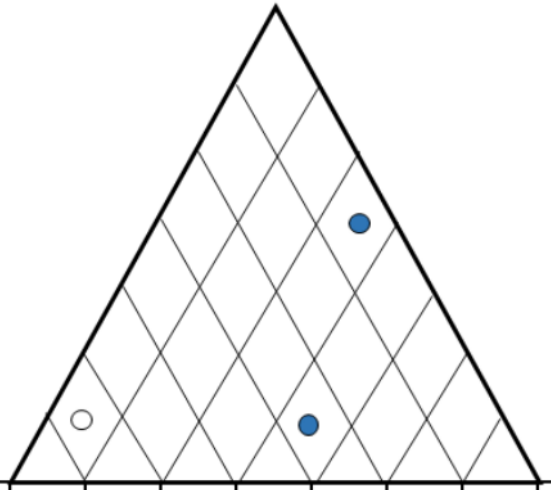
House of Quality (HoQ)

The second stage is preparing the House of Quality (HoQ). At this stage, a brainstorming is conducted with the developer to get a technical response from the input of respondents. Importance is also obtained at this stage to get product development priorities. From the results of brainstorming, the technical responses based on the attributes is considered as shown in Table 5.

Table 5. Recapitulation of technical responses

Attributes	Technical Responses
Grip accuracy for small objects	Material adjustment Setting the mechanism of motion
Conformity of form	Modification of the shape of the palm
Product weight	Material adjustment Hand Anthropometry Adjustment Hand morphology adjustment
Finger density	Material adjustment Setting the mechanism of motion
Gripping ability	Modification of the shape of the palm Hand Anthropometry Adjustment
Variations in hand function	Added coding mode
Hand width adjustment (thumb)	Hand morphology adjustment
Flexibility of the wrist joint	Exercise users

Brainstorming results target values for each attribute. These values are combined with the assessment of respondents to produce NRW (Normalization raw weight). An assessment of the relationship between customer needs and technical responses was also obtained during brainstorming with the developer. Some of the data is then used as input in making the HoQ matrix, so that the results of calculations can be used to determine the technical response that has the greatest influence on customer satisfaction. The results of the input processing can be seen in HoQ (Figure 1).



Technical Response / Customer Requirements	Importance	modification of the shape of the palm	material adjustment on the distal	mechanism of motion regulation	anthropometric adjustments of the hands	morphological adjustment hand	coding mode addition	exercise for users	Target	IR	SP	RW	NRW	Rank
Grip accuracy for small objects	4.5		●						5	1.11	1.50	7.50	17.3%	1
Conformity of form	4.5	●							5	1.11	1.50	7.50	16.8%	2
Product weight	4.5		○		▲	▲			1	0.22	1.35	1.35	3.0%	7
Finger density	4.0		○	●					5	1.25	1.35	6.75	15.1%	4
Gripping ability	4.0	○			●				5	1.25	1.35	6.75	15.1%	5
Variations in hand function	3.5						●		5	1.43	1.20	6.00	13.5%	6
Hand width adjustment (thumb)	3.5					●			5	1.43	1.50	7.50	16.8%	3
Flexibility of the wrist joint	3.5							●	1	0.29	1.20	1.20	2.7%	8
Technical Importance: Absolute		1.965	2.055	9.655	1.389	1.542	1.215	0.243						
Technical Importance: Relative		10.87%	11.40%	53.40%	7.70%	8.50%	15.10%	1.30%						
Priority		4	3	1	6	5	2	7						

Figure 1. House of Quality in prosthetic hand product

Based on the HoQ matrix, several conclusions can be drawn about the proposed improvements. The first is the relationship matrix which is a compiled matrix to describe the relationship between consumer interests with technical parameters. This phase is important because consumer interests can affect one or more technical requirements or vice versa. The relationship between the level of importance and technical response is divided into 3 namely strong, moderate, weak and there is no relationship at all. There are 7 correlations, 4 moderate correlations and 2 strong weak correlations between technical responses and consumer interest attributes. On the roof of the HoQ, there is information about the relationship between technical responses whether there is a strong relationship or there is a contradiction between technical responses. The brainstorming phase results information if there is no contradiction that affects the technical response and also relationship of technical responses, both positive and negative.

From Figure 2, the various relationships between parts of the matrix combines the input from respondents and responses from developers. The first attribute is the accuracy of the handle for small objects. This attribute is taken from the input of respondents who find it difficult when taking coins. The developer determine that this is possible because the surface of the hand uses PLA material, and when used to take small objects the respondent feels slippery to be able to take coins. The technical response of the developer is to add a rubber-like material to the distal part of the Prosthetic Hand's finger. In general, there are indeed 2 types of components that can be used to liken Bionic hands to real hands, namely by adding silicone or glove [19]. Silicone is usually used on several parts of the hand, while the glove is used as a glove on the prosthetic hand.

The second attribute is the suitability of the form. Referring to the input of respondents, there is inconveniences when using of Bionic's hand, especially on the palm of the hand. When performing the task of taking light objects, the respondents felt the bottom of the palm slightly protruding and disturbing when taking objects. From this input the developer responded by providing a solution to modify the part by giving a little cavity when the hand was printed with 3D print, and later the cavity will be given a rubber-like material with the aim that when used there are still a few bumps on the hand because normal hands do have bumps. However, rubber-like material is used with the intention that when it is used to hold something the part can adjust to the object being held and make the grip against the object stronger.

Product weight is input given by the respondent to the developer during an open discussion after testing is done. However, the developer only gives a scale of 1 to the target on this attribute. This is because the developers consider the products created are much lighter compared to other products circulating in the market. Bionic hand weight is around 450gr and socket around 400gr. When compared to other products, the developer considers that number to be light enough to use.

Prosthetic hand finger density level is considered important enough to be corrected by respondents. At the time of the task of taking coins, respondents felt they had given a strong enough contraction in the hand, but respondents felt the fingers were not strong enough/tight to clamp the coin. The response from the developer to respond to these inputs with a target value of 5 which means it will be prioritized for improvement. The technical solution provided is to adjust the finger movement mechanism in Bionic hands for the precision closed mode. If it is adjusted with existing competing products, the process of moving the fingers is the little finger, ring finger and middle finger fully folded first, then the thumb moves half closed towards the index finger, and the last index finger moves towards the thumb independently and close fully 20].

The next attribute is the ability to hold. This attribute is obtained based on the response of respondents who feel the Bionic's hands are not tight enough to hold light objects. Meanwhile, according to the developer the hand is equipped with a motor that has a large enough torque. However, the developer gives a target value of 5 on this attribute, because the developer feels that it can be improved by adjusting the size of the hand and modifying the shape of the palm. Adjusting palm size can be done on the basis of Anthropometric theory. In general, the size of making Prosthetic Hand cannot be made in one size. It refers to competitors who make 2 types of sizes for prosthetic hands produced, namely Large and Medium. If using anthropometry as a reference for making measurements, then for large size developers can use 95% of men with a length of 189 mm and a width of 88 mm. Whereas for medium size, 95% of women with 181 mm hand length and 78 mm width can be used. By adjusting the size of prosthetic hand based on the body size of Indonesian people, it is expected that users are more comfortable and easier to get used to using prosthetic hands [20].

Inputs on the addition of hand function variations were obtained when open discussions with respondents after the research was conducted. Respondents felt that it was necessary to add hand functions to accommodate other activities. From this input the developer responds by giving a target value of 5. The value indicates if the developer is capable and has the potential to realize that input. At present the prosthetic hand that was created has 5 hand

functions namely Power grip, Hook, Precision closed, Active index and Tripod. The function is actually able to do quite a lot of daily activities. However, when compared to competitors, some hand functions that might be added when referring to competitors are Key grip, Finger abduction and Precision open.

When conducting an experiment of taking light objects that use the Power grip function, respondents need a little time to position the width of the hand with the object to be taken. This is because the width of the hand when opening is felt to be less than optimal. Engineering can be done by changing the morphology of the thumb of the prosthetic hand. When compared with existing competitors, Bionic hands are made capable of opening with widths between 105-120 mm [9].

The last input given by the respondent was about the flexibility of the wrist joint. Respondents felt that it is needed to make it easier when use prosthetic hands. From this attribute the developer gives a target value of 1. The developer does not prioritize these attributes because the developer feels that if a joint is given to the wrist it will make it more difficult to use the hand for other hand functions. The developer provides another technical solution to respond to these inputs, namely by better training respondents on the use of prosthetic hands so that later by continuing to practice using the product the respondent will be easier and accustomed to solving the problem without the developer adding joints to the wrist.

CONCLUSION

Brainstorming is conducted to identify the factors that influence the ease of use of anthropomorphic prosthetic hand in accordance with respondents' perceptions. The results of the identification of these factors such as products that are felt slippery when used to pick up small objects, lack of strength grip when used to hold objects, Fingers are not tight enough to clamp small / thin objects, lack of suitability of the width of the hand to hold, the incompatible shape of the palm which is too stiff, lacks flexibility in the wrist joint, products are too heavy and the features / modes used are less varied. The results of the brainstorming are then used as input in making the proposed improvements using the QFD (Quality Function Deployment) method. In designing the proposed improvements using the QFD (Quality Function Deployment) method, 8 attributes from VoC (Voice of Customer) and 7 technical responses for the 8 attribute solutions are obtained. From the calculation based on input data obtained, it is known that the technical response which has the highest absolute weight value is the regulation of the motion mechanism that is equal to 9,655. This value if presented with the total value of the weight loss for all technical responses is 53.4%. This percentage shows that if improvements were made to the mechanism of motion, it would meet the needs of customers as much as 53.4%.

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