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THE PRODUCT DESIGN OF WATER BOTTLED FOR ADULTS ACCORDING TO CUSTOMER NEEDS USING QUALITY FUNCTION DEPLOYMENT (QFD) METHOD

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Abstract— Manufacturing of 'refilled' water bottled is an effort to help active adults in fulfilling the daily drinking water needs, and reduce the use of un-eco-friendly disposable water bottled. In order to reduce the errors that occur in the production process and to ensure that the product design has 'good' selling power and 'great' quality value, accordingly necessary to execute the product development planning that focuses on customer satisfaction needs. The research aims to design the water bottled product that meets the customer needs using Quality Function Deployment (QFD) method. The results of QFD and House of Quality (HOQ) translate customer needs in the form of technical characteristics with the calculated value of absolute importance. Based on the QFD results, the level of importance of the costumer needs is the affordable price (11%), portable (10.9%), light weight (10.8%), easy to use (10.8%), safety (10.7%), thermostat (9.98%), large capacity (9.93%), simple design (9.11%), elegant appearance (9.02%), glass storage (7.69%). In addition, based on the overall QFD calculation results, the specification target in design and development of adult water bottled from the greatest technical importance value are: Bottle dimension (15.8%), bottle shape (13.6%), bottle material (12.8%), bottle cap / cover shape (9.71%), temperature control system (8.91%), bottle cap / cover mechanism system (7.47%), bottle color (6.12%), additional for storage space (5.12%).

Keywords— Bottled Water, QFD, Product Design, Customer Needs, Technical Importance

I. INTRODUCTION

Drinking water bottle is a tool used to help adults to fulfil their daily drinking water needs, which can usually be taken away.In the General Guidelines of Balanced Nutrition, Indonesian adults are advised to consume 2 Litres or 8 glasses water per day to maintain their health and optimize their physical ability [9].In addition, the National Food and Nutrition Widyakarya recommend Indonesian people to drink 0.8 to 2.8 Litres water per day, depending on age, gender, activity, and environmental temperature. It indicates an increase in the use of water bottled by people, especially in tropical regions such as Indonesia.

The consumption of bottled drinking water in Indonesia reached 23.1 billion Litres in 2014 [10]. The demand for drinking will increase over time. Moreover, people who bring water bottle reflect healthy lifestyle. This opportunity has been captured by several companies in the field of drinking water. According to references [11][9], available bottled water packaging uses a type of plastic that is not heat resistant, and has the potential to release harmful compounds derived from monomer residues from polymers and plastics. This plastic bottle is made for once-time use, or cannot be used for refills. In addition, the impact of the use of bottled drinking water, where the plastic is a material that is difficult for biodegradation so that it can pollute the environment. Therefore, we should use a drinkable bottle that can be refilled, so as to reduce the percentage of environmental pollution and avoid the potential that can harm the health of our body. The habit of carrying drinking bottles is a great way to start a healthy life. It can also help reduce the use of disposable plastic bottles. Furthermore, the opportunities in the field of drinking water have been captured by several companies. They provide drinking water in a various packaging to attract the customer's attention. In order to maintain the product life cycle, its necessary to develop product. The product development is important because it provides variations, and as business strategy to maintain and to attract customers. References [7][14] also confirmed that the new product development literature emphasizes the importance of introducing new products on the market for continuing business success, and important source of competitive advantage. Therefore, a study of product development is needed to design water bottled. In product development, the design must be understood as a word that describes both a process and an outcome [1], and also suits with the customer needs. The first phase of product development and a base of product design is customer needs analysis. Research on the analysis of the needs of adult drink bottles has been done by Solihin, et al [9]. In their study, it was found that the design of drinking bottle products should pay attention to the safety and price of the bottle [9]. However, in their research, there is no user characteristics and design of the drinking bottles. The purpose of this research is to complete the previous research which is to find the characteristics of the users of adult drinking bottles and how to design the drinking water bottle in accordance with the needs of the customer.

II. LITERATURE STUDY

A. Product Design and Development

References [16] explained that the new design can be interpreted as the development of product that has been marketed. The engineering design described as follows the development of a product from its technical conception through detail design, and the design of the related manufacturing process and tooling [Angela Dumas]. Product planning and design is a set activities starting from encouraging perception of market opportunities, and ends with the production, sale, and delivery of the product [8][10]. Successful economic of manufacturing designer depends on the ability to identify customer needs and then create the product based customer needs accurately with the low cost. The main goals of product design methodologies includes (a) help new products meet the specification related to customer needs, quality, price, manufacturing, recycling, etc; (b) reduce development costs and time necessary for commercialization; (c) co-ordinate and schedule the activities involved in the design and development of products; (d) integrate the above objective into a development strategy in line with the company's capacities [3]. According to References [8][10][16], there are 6 step of product design product planning, concept development, system level design, detail design, testing and improvement, initial production. In concept development phase, customer need identified. To be successful, an organization should focus its efforts primarily to the collection, knowledge, understanding and meeting requirements, needs and expectations of all its internal, external, current and potential customers [2][9].

B. Quality Function Deployment (QFD)

This research will use QFD method to design the drinking bottle that meets customer needs. QFD is a highly reliable and tested tool method for improving quality in the process of planning, developing or improving the quality of a product or service. With the creation of communication between the user (voice of costumer) and the maker (voice of engineer), a product will avoid the possibility of market misses when marketed. According to references [4][5][6][10][8][9][12][13][15][16], QFD (Quality Function Deployment) is a structured method used in the planning and product development process to define the specifications of customer needs and desires and systematically evaluate, the capability of a product or service in meeting the needs and wants of customers.

There are 5 steps in QFD [6][10][11][16]:

1. Determining the voice of customer
   Voice of customer is the attributes that needed by the customers. This attributes obtained by using questionnaire or interview with the customers.
2. Develop a planning matrix
   This matrix describes customer perceptions based on market surveys, including the relative importance and customer needs or company performance in fulfilling those desires.
3. Determining technical responses (voice of company) Cohen (1995) [10] uses an impact symbol to determine the relationship. The symbols are:

TABLE I - IMPACT SYMBOL

Symbol	Meaning	Value
●	Very strong relationship	9
○	Strong relationship	3
△	Weak relationship	1
(empty)	No relationship	0

4. Determine the correlation between product features
After product features are linked to requirements, the next step is to connect between the product features itself with the following symbols:

TABLE II - DEGREES OF TECHNICAL IMPACT

Symbol	Description
√√	Strong positive relationship
√	Moderate Positive relationship
(empty)	No relationship
X	Moderate negative relationship

5. Determining absolute importance and relative importance
To get the absolute importance of each technical response using the equation:

$$Absolute\ importace = \sum relationship\ strenght\ x\ importance\ rating \quad \text{(eq. 1)}$$

Meanwhile, to get relative importance by calculating the percentage of each absolute importance value to obtain the order of technical requirements.

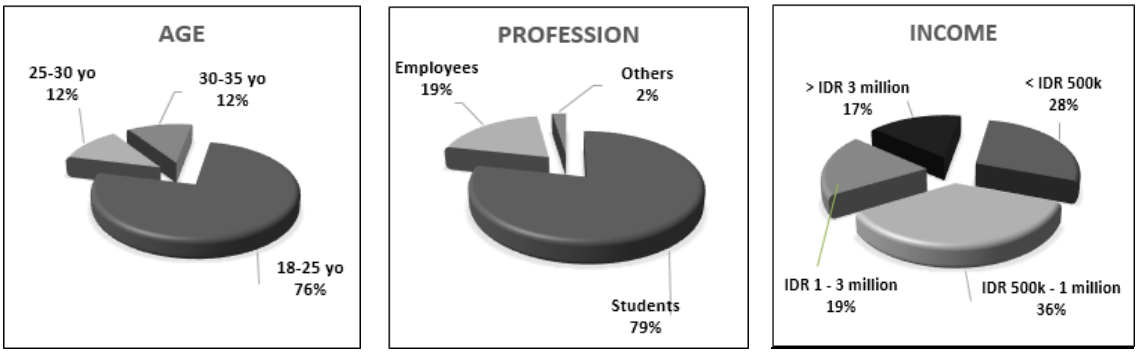
III. RESEARCH METHOD

This research is and advanced research of Solihin et.al. [9], where the data from Kano models are attributed to customer needs for this research, while this research aims to design the product that meets the customer needs using QFD method. The unit of analysis in this study was 42 adults as a sample of the study. The first step is to obtain the customer's performance and importance level using questionnaire. After the data obtained, it will be tested with validity and reliability test to make sure that the data can be used for this research. After the test, the data is used to develop a planning matrix and determining the technical response. After that we can determine the correlation between product features, absolute importance and relative importance. The results are technical response with highest priority that will be used to gain the solution. After we generate the solution, we make the alternatives for the product combination. The product combination then selected and we start to design the product.

IV. ANALYSIS

A. Analysis of Respondent Characteristic

Characteristics of respondents used to determine the diversity of respondents based on several attributes. It is expected to provide explicit description of the respondent condition and its relation to the problem and purpose of the research. The characteristics respondents divided by gender, age, profession, and monthly income. Based on the questionnaires, the results obtained that the percentage of male respondents were 64.29% while female respondents were 35.71%. Most of the respondents are male, it is because men's physical activity higher than women, so drinking water needs for men is higher to replace the lost body fluids. Besides the gender, Fig. 1 shows the graph of respondents characteristics based on age, profession, and monthly income. The diversity of respondents by age in Fig 1a shows that respondents from highest are aged between 18-25 years (76%), the aged between 25-30 years and 30-35 years has the same percentage value of 12%. Most of the respondents aged between 18-25 years because the area to spread the questionnaire relatively young people who have high activities. Based on profession characteristics in Fig 1b above shows that respondents as students of 79%, employees of 19%, and others profession (including civil servants, entrepreneurs, and other) only 2%. Most respondents are students, where learners have many activities both mentally (lecturing) and physically which result in discharge of body fluids. In addition, students who study in air conditioned rooms are encouraged to drink more to adapt their body to cold air, and prevent from dehydration and dryness skin. Water intake also affects a student's learning ability. Fig 1c presents the respondents characteristics with monthly income < IDR 500.000 of 28%, between IDR 500.000 – 1.000.000 of 36%, between IDR 1.000.000 of 19%, and > IDR 3.000.000 of 17%. Most respondents have monthly income between IDR 500.000 – 1.000.000 because most of them are students who have low buying power. Therefore, the low income will be consideration in product design and development of water bottled.



(a) (b) (c)

Fig. 1. Respondent Characteristics by (a) an age; (b) profession; (c) monthly income

B. Analysis of Validity and Reliability Test

The validity and reliability test is used to determine the items in the questionnaire are valid and reliable to use. If there is an invalid attribute, then the attribute will be eliminated. The results of validity test can be seen in table III while the results of reliability tests in table IV.

TABLE IIII - RESULT OF VALIDITY TEST

	Satisfaction Level		Importance Level	
Attribute	R	Status	R	Status
X1	0.530462	Valid	0.515078	Valid
X2	0.558240	Valid	0.616722	Valid
X3	0.627937	Valid	0.599057	Valid
X4	0.396981	Valid	0.560163	Valid
X5	0.443452	Valid	0.599472	Valid
X6	0.660316	Valid	0.740348	Valid
X7	0.613592	Valid	0.598073	Valid
X8	0.725064	Valid	0.657070	Valid
X9	0.533944	Valid	0.735355	Valid
X10	0.651242	Valid	0.559071	Valid

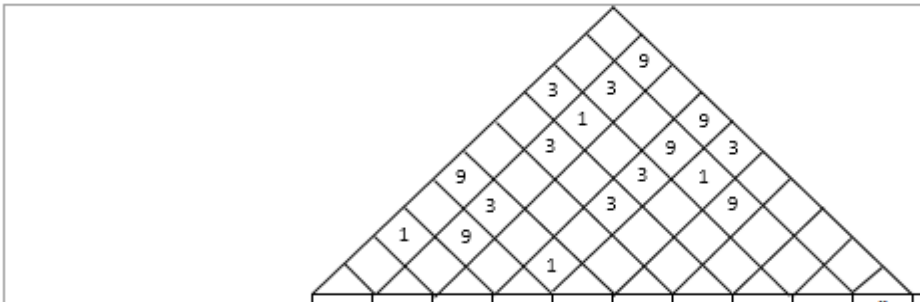
TABLE IV - RESULT OF RELIABILITY TEST

	Cronbach's Alpha	N of Items
Satisfaction level	0.772934	10
Importance level	0.817073	10

Based on Tables III and IV, it can be seen that all attributes are valid and good reliability (more than 0.7). This means that all attributes in the questionnaire can be used in the next step.

C. Analysis of Customer Needs using QFD

QFD method aims to determine the attributes that have an influence on the customer satisfaction level as well as determining the product characteristics techniques that need to be developed, so as to realize customer needs. From the Fig.2 and Fig.3 can be seen the 10 attributes and the order of customer's importance level. The highest importance level is 3.76 that are safety (not easy to spill) and portable attributes. From the Fig.2 and Fig.3 also can be seen the highest current satisfaction performance is 3.405 that is safety (not easy to spill) attribute. The value of the goal is a set value by giving the target to be achieved by researchers to meet customer needs. In the above table the value of the goal is expressed in the form of a numerical scale. Determination of the value of this goal is done by considering the value of importance and level of customer satisfaction. Improvement ratio is a value that aims to measure the degree of customer satisfaction on each user attribute for each listed quality. Overall the interest rate of the customers is the affordable price (11%), portable (10.9%), lightweight (10.8%), easy to use (10.8%), safety (10.7%), thermostat (9.98%), large capacity (9.93%), simple design (9.11%), elegant appearance (9.02%), glass storage (7.69%). The comparison of this percent importance can be seen in Fig.4. The Next step is to make a technical response based on the customer needs.



		Material	Dimension	Color	Shape	total mass (weight)	cover mechanism	handle	thermostat	cover shape	additional store space	*Importance to customer*	*Current satisfaction performance*	*Goal*	*Improvement ratio*	*Adjusted importance*	*Percent importance*
1	Ease of use						9	3	9	3		3.55	3.19	4	1.25	4.45	**10.8**
2	Glass storage		9		3	3	1			3	9	2.64	2.5	3	1.2	3.17	**7.69**
3	Thermostat	3			3	1		3	9			3.02	2.57	3.5	1.36	4.12	**9.98**
4	Elegant Appearance	3	3	9	9			3		9	3	3.21	3.02	3.5	1.16	3.72	**9.02**
5	Simple Design	3	3	9	9	3	3	3		9	3	3.48	3.24	3.5	1.08	3.76	**9.11**
6	Light	9	9		3	9					1	3.55	3.19	4	1.25	4.45	**10.8**
7	Large capacity		9		9	9				3	3	3.29	2.81	3.5	1.25	4.09	**9.93**
8	Affordable price	9	9	3	3	3	1		9			3.6	3.17	4	1.26	4.54	**11**
9	Safety / not easy to spill	9			3		9	9		9		3.76	3.4	4	1.17	4.42	**10.7**
10	Portable	3	9		3	3		9				3.76	3.33	4	1.2	4.51	**10.9**
	Total	**410**	**508**	**196**	**436**	**313**	**240**	**312**	**286**	**345**	**164**					41.2	**100**
	Technical Importance	**410**	**508**	**196**	**436**	**313**	**240**	**312**	**286**	**345**	**164**						
	Priority (%)	**12.8**	**15.8**	**6.12**	**13.6**	**9.74**	**7.47**	**9.71**	**8.91**	**10.7**	**5.12**						

Fig. 2. Customer Needs Identification using Quality Function Deployment (QFD) Technique

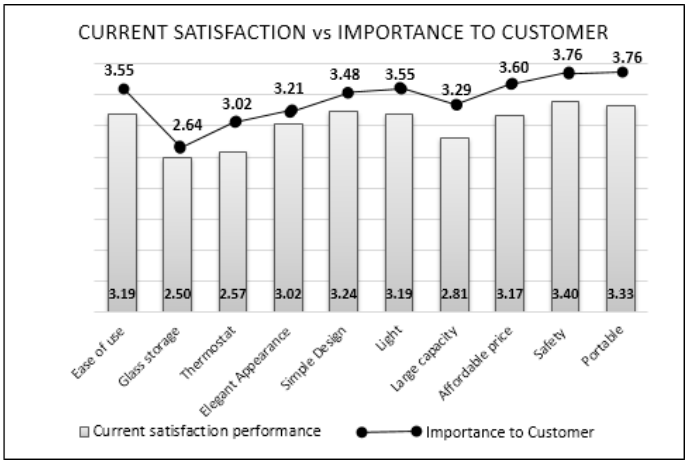


Fig. 3. The comparison between Customer Current Satisfaction and Importance to Customer

In this technical response, customer needs will be translated in the form of technical terms. List of technical characteristics of bottle is material, bottle dimension, bottle colour, bottle shape, total bottle mass (weight), bottle cap (cover) mechanism system, bottle handle, temperature control system, bottle cap (cover) shape, additional storage space. Based on the results of the correlation between the customer needs with the technical characteristics, as well as relationships between technical characteristics can be seen in the picture above. Based on the calculation as a whole, we obtained the order of priority of technical responses. The following are the specification targets in the design and development of adult bottles from the highest technical response value are: Bottle dimension (15.8%), bottle shape (13.6%), bottle material (12.8%), bottle cap (10.7%), total mass of bottle (9.74%), bottle handle (9.71%), temperature control system (8.91%), bottle open system (7.47%), bottle colour (6.12%), and additional storage space (5.12%).

D. Analysis of Refilled Bottled Water Product Design

Once the technical priority is known, the next step is to determine the solution and find the most suitable combination to be the final product specifications with concept generation

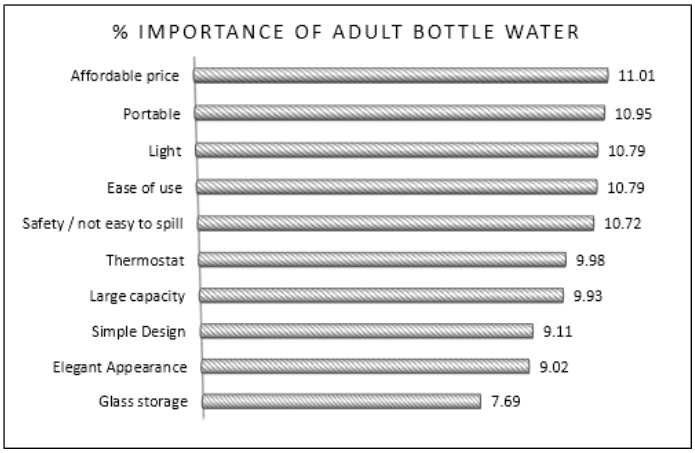


Fig. 4. Importance Percentage of Adult Bottled Water

The highest priority of technical response is Bottle dimension (15.8%), bottle shape (13.6%), and material (12.8%). The dimension and the shape of the product have very strong relationship. The technical response solution can be seen on Table V.

TABLE V - SOLUTION OF TECHNICAL RESPONSE

No	Technical response	Solution
1	Bottle dimension	• Fit in the hand and Ergonomic dimension
2	Bottle shape	• Square • Cylindrical
3	Bottle material	• Plastic • Aluminum

TABLE VI - PRODUCT COMBINATION SELECTION

Combination	1 (Square-Plastic)	2 (Square-Aluminium)	3 (Cylindrical-Plastic)	4 (Cylindrical-Aluminum)
Ease of manufacturing	-	-	+	+
Production cost	+	-	+	-
Ease of use	0	0	+	+
Effectiveness of use	0	+	0	+
Total (+)	1	1	3	3
Total (0)	2	1	1	0
Total (-)	1	2	0	1
Final score	0	-1	3	2
Ranking	3	4	1	2
Conclusion	stop	stop	continue	stop

Fig 5. Product Design of Refilled Bottled Water without curve (left-alternatives 1) and with curve (right-alternatives 2)

The bottle dimension has one solution, that is has to fit in the hand and has the ergonomic dimension. The dimension for this bottle is 8 cm for the diameter.

While the solution for the bottle shape are square and cylindrical. These two shapes are the most favourite for the customers and the solution for the material are plastic and aluminium. The plastic that we used is PP (Polypropylene). Once the various solutions are obtained, the next step is to create a combination of existing solutions and select them into final product specifications with concept selection. The number of combinations that are formed will be 1x2x2 = 4 combinations. Criteria assessments are required to select the combination. These criteria are manufacturing ease, production cost, ease of use and effectiveness of use. Assessment of the combination of these products can be seen in Table VI. From the Table VI, we conclude that the 3rd combination will be continued to the next step. The next step is making the design using the selected combination. The design can be seen in the Fig. 5. The design has two alternatives that are cylindrical with curve and without curve. Based on the first technical response, we have to make the design that has ergonomic function, so we decided that the cylindrical with curve is better.

V. CONCLUSIONS

From this research, we have found that most respondent characteristics in this research are male respondent (64.29%), aged between 18-25 years (76%), student profession (79%), and monthly income between IDR 500.000 – 1.000.000 (36%). Students have many activities both mentally (lecturing) and physically which result in discharge of body fluids. In addition, students who study in air conditioned rooms are encouraged to drink more to adapt cold air, and prevent from dehydration and dryness skin. Water intake also affects a student's learning ability. But, students have low buying power, which will be product design consideration.Bottle dimension, shape and material are technical response that has highest priority for the technical response and the design that will be continue has the ergonomic dimension that fit in the hand (8 cm for the diameter), cylindrical shape and made from PP (Polypropylene) materials.

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