Design of Smart Medicine Box for Elderly Person Based on Quality Function Deployment (QFD)

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***Abstract*—The elderly who has a particular health problem need to take some medicines regularly in a correct dosage. However, they frequently forget to take the medicines because of their lack of memory. A supporting product is required to help elderly in avoiding this situation. This research therefore aims develop a smart medicine box by applying Quality Function Deployment (QFD) method. The elderly requirements are identifying through an Ethnographic approach which are translated to technical parameters for designing a smart medicine box. An interview method is used which involve thirty two elderly person as respondents. The design is focused on two main requirements which have highest importance rating including reminder for taking medicine and automation. The prototype of the smart medicine is developed and tested by using usability test. From this test, it is found that 90% respondents have positive respond on the feature of smart medicine box in terms of the easines of understanding the reminder for taking medicines in the scheduled time. Additionally, 80% of respondents can understand easily the process steps for using smart medicines box.**

Keywords—elderly; QFD; usability; automatic medicine box; RFID

I. INTRODUCTION

Aging is a natural process which happened to the people when they get into the phase of an old age (elderly) characterized by physical changes and behavior. Elderly people who have declining in their body function often need to take some medicines for maintaining their daily health. Due to degradation on their memory ability, some problems are experienced by elderly in maintaining their daily health which include difficulty in remembering what kind of medicine and in what dosage need to consume, as well as, remembering medications schedule .In this situation, they will need to be assisted by product which can helped them to take medicine appropriately.

Some products have been developed for such purpose, For example, Intelligence Medicine Case (iMec). These products are able to determine the type of medicine in a correct dosage.The medicines are detected by using web camera sensor which is installed in medicine cabinet. The product can detect the differences between medicines in terms of dimension, and colors by using image processing [1]. Another product used alarm system with IoT-Enabled Pill Bottle. This productuse force sensor to measure the change of medicines weight (gram) in bottle for twenty four hours which equipped by alarm indicator [2]. Another example is amedicine box for elderly person which designed in the form of weekly pills dispenser that operate automatically by using motor stepper, This product is equipped with alarm and Short Messaging Service (SMS) [3]. Despite there are some product available in the market but these products still not fullfil particular customer need such as features available are too complex so it is not user friendly for the elderly and the cost more expensive.

This paper aims to design a smart medicine box for elderly person. The previous products of medicine box such as iMec, IoT-Enabled Pill Bottle, and weekly pills dispenser are not built by customer needs so that the design dissatisfactory and less incompatible for elderly person. The products design of iMec and IoT-Enabled Pill bottle are expensive because of using sensor web camera meanwhile IoT-Enabled Pill bottle equipped by digital camera. Furthermore, weekly pills dispenser is not concern with usability aspects and the product feature is difficult when elderly used it. In this research, for designing a smart medicine box for Quality Function Deployment method will be applied. QFD is applied for identifying the elderly requirements and then translated to technical responses. Furthermore, the first version of prototype will be made and tested to the elderly by using usability method. By implementing usability method, overall performance of the product while used by responden including learning ability, efficiency, memorability, errors, and satisfaction can be understood.

A. Quality Function Deployment

Quality Function Deployment (QFD) is a structured method to design and develop products based on the specifications required by the customer. This method enable systematic evaluation of the capability of a product or service to meet consumer desires [4]. There are three common methods are often used to collect voice of the customer such as interview by distributing questionnaires, focus group discussion (FGD), and observation of the product during use (Ethnography). The voice of consumers then are translated to a group of technical requirements. A house of quality can be created to map information required to develop a design

including product attributes, product evaluation, objective product, engineering characteristics, matrix interactions, interactions between parameters, analytic techniques, the target value, and feasibility.

B. Usability

Usability is the level of easeness in learning and using a product so that the consumer or user will not find trouble when using the product. Usability aspects consist of learningability, effectiveness, efficiency, flexibility, attitude, satisfaction, and memorability [5].

II. RESEARCH METHODOLOGY

The process to designthe proposed smart medicine box by using QFD composed by four main phases. The first phase is identifying of the needs and limitations of the elderly. This phase is conducted by applying Ethography approach that involving interview stages. The interview is done by using two types questionnaires including introduction questionnaire and customer need questionnaire. Thesecond phase is designing product based on customer needs by using Quality Function Deployment (QFD) method. The third phase is calculating project objectives to get the weight of each attributes values. The purpose of this phase is to prioritize the product atributes and designing process. The fourth phase is building the technical matrix that describes the overall correlation of attributes of the product and technical response, incorporating the results of the quantitative calculation of the correlation that has been established previously. The result of these four phases is the smart medicine box concepts. This concepts will be use to create the prototype.

A. Collecting and Processing Data

To design a smart medicine box, customer needs are identified. As mentioned previously, customer needs were collected through ethnographic approach. The one of etnographic approach that used to design smart medicine box is direct interviewing. Researchers held direct observation to the thirty two of elderly persons who have stayed in Werdha Hargodedali Surabaya nursing home. Interview is conducted which involve thirty two respondents between 60-95 years old. They have asked to fill questionnaires for obtaining information about the respondent characteristics data, cognitive and sensory abilities, the ability to interact with technology, medical histories and medication. Figure 1 present the elderly charactheristic data.

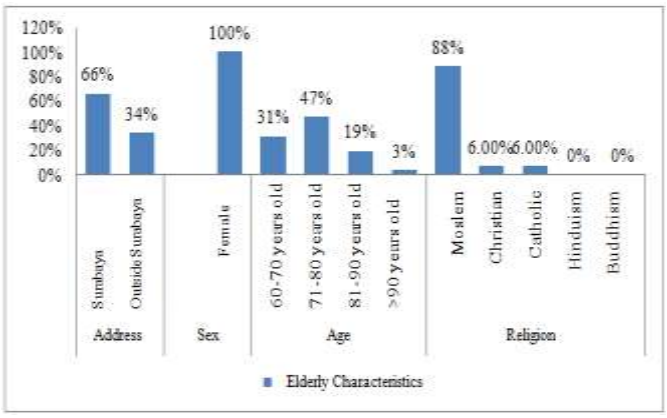


Figure 1. Elderly Characteristics Data (Part I)

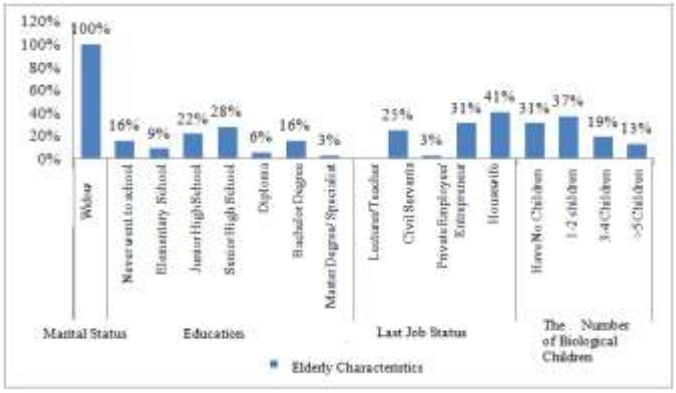


Figure 2. Elderly Characteristics Data (Part II)

The results from the preliminary questionnaire reveal the elderly health complaintswhich is presented in pie charts as is shown in Figure 3 dan Figure 4. Figure 3 show the information about the physical condition of the elderly and product requirement that can help to take medication daily., While Figure 4 presents the percentage of health complaints experienced by the elderly, problems that occur in the elderly while taking the medicine.

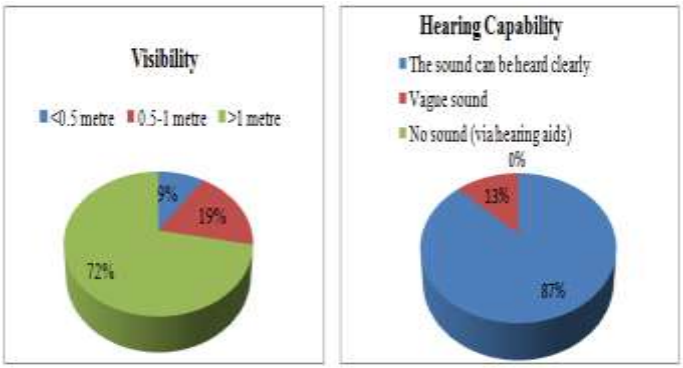


Figure 3. Elderly Physical Condition

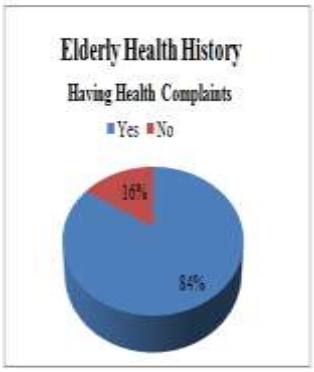


Figure 4. Elderly Health Complaints

Most of respondents have health problems so that they must take some medicine in everyday life. The average number of medicine consumed per person for each day are three pills and the total number of medicines types consumed by thirty two respondents are ten types of medicines includeamlodipine, neurodex, glimepirid, glibenclamide,

nifedipine, allopurinol, glucopax, antasida doen, simvastatin, and asam mefenamat. Figure 5 depict about how the elderly remembering the types of medication and the methods that can help them taking their daily medication.

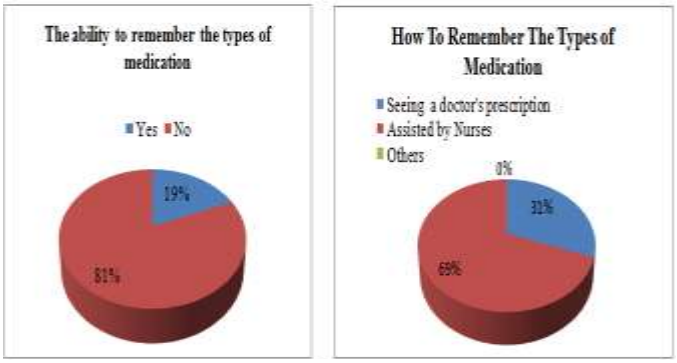


Figure 5. How Elderly Remembering The Types of Medication

B. *Product Concept Development*

After collecting the voice of customer data, the next step is to identify proposed product concept based on customer needs by using Quality Function Deployment (QFD) method. The steps in QFD will be explained as follow:.

- Determining product attributes based on voice of customer which taken from the result of questionnaires.
- Outlining each attribute into a number of technical response such as the factors affecting performance of attributes to meet the target value that has been specified in the design of products that will be developed.
- Making matrix interaction or composing HOQ (House Of Quality). This matrix serves to measure the relationship (relationship) between product attributes, technical parameters, and other parameters.
- Determining targets and priority improvements on the new medicine box by considering the level of importance (priority) of the technical parameters and degree of satisfaction with existing medicine box.
- Selecting products concept involving electronics experts and nurses who set the schedule medication for the elderly. Then, doing concept of screening and scoring so we would have only one selection product concept that will be used in making a new smart medicine box.
- Determining of the level of product approach is create a physical prototype based on elderly needs.

Questionnaire criteria for consumers desires consists of two parts,a questionnaire based on the level of importance and satisfaction level. In the questionnaire of the importance level shows the priority of product attributes for designing smart medicine box. Furthermore, a questionnaire based on satisfaction level is used to evaluate weekly pills dispenser which is already be made.

C. *Project Objectives*

The next step is calculating project objectives. Calculations used to get the weight of project objectives for each attribute value. The weight of attributes value is obtained by multiplying the value of the degree of improvement (improvement rate) with the level of importance (important rating). The value of improvement is calculating by dividing the target value to be achieved by the evaluation score. Score evaluation value is obtained from the level of customer satisfaction with the product box and the value of the existing drug targets derived from the target value improvement (level of importance) of the new medicine box. Table 1 present the result of calculation of project objectives.

Table 1. Project Objectives

Product Attributes	**Improvement Rate**	***RII***	***Weight***	***% Weight***
Schedule reminder to take medication by using alarm	1.67	4.88	8.13	5.1
Easy to learn	1.67	4.88	8.13	5.1
Easy to learn	1.67	4.81	8.02	5
Access to opening medicine containers via RFID Card Tag	2.50	4.78	11.95	7.5
Pillbox made automatically	2.50	4.75	11.88	7.4
Safety system for human error	2.50	4.75	11.88	7.4
Electricity Safety	1.67	4.72	7.87	4.9
Menu display is easy to read	1.67	4.69	7.82	4.9
The placement of the system components for system activation are easy to reach	1.0	4.66	4.66	2.9
Usage of gallon water by 6 litre volume	2.50	4.63	11.58	7.2
Hot water usage	2.50	4.63	11.58	7.2
Easy to move	2.50	4.59	11.48	7.2
Easy to place gallon water	2.50	4.53	11.33	7.1
Body cover model looks eye-catching	1	3.84	3.84	2.4
Body cover model looks minimalist	1	3.78	3.78	2.4
Production costs	1	3.78	3.78	2.4
Easily rectified if there are some damages	1.33	3.69	4.92	3.1
Durable materials	1	3.63	3.63	2.3
Lightweight material and robust material	1	3.56	3.56	2.2
Durable electronic components	1	3.50	3.50	2.2
Maintenance costs	1	3.50	3.50	2.2
Ease of maintenance of electronic components used	1	3.47	3.47	2.2
Total			160.29	100

From the calculation of project objectives the weight values for each attributes needed to the design of smart medicine box are determined. The result of project objective calcualtion show that the most important atribute for the smart medicine box is the need for automatic smart medicine. The value on product attribute for automatic medicine is 11.95 percentage. One solution for this isto use RFID card tag for opening medicine cabinet..

D. House of Quality

House of Quality is technical matrix that describes the overall correlation of attributes of the product and technical response, incorporating the results of the quantitative calculation of the correlation that has been established previously. The calculation determine the relative importance index, project objectives, and the relationship matrix. Then, determine the ranking from the calculation of the correlation between product attributes with technical response so that can be a priority in product development and product quality improvement for planning of the new medicine box based on the target value so that the ultimate goal can be realized through of the physical prototypes. The result shows that the components used has the largest percentage with value of 16.03%. This mean component used is the most priority for technical respond.Table 2 show correlation between technical responses and product attributes

	Relative mportance Index	Components use	The use of procedures	Primary material supporting materials	Simple Features on product
	4.88	●	●		●
		45.90	**45.90**		**45.90**
	4.88	□	●		●
		15.30	**45.90**		**45.90**
	4.81	□	●		●
		15.00	**45.00**		**45.00**
	4.78	●	●		●
		67.50	**67.50**		**67.50**
	4.75	●		●	
		66.60		**66.60**	
	4.75	●	●		●
		66.60	**66.60**		**66.60**
	4.69	●	●		
		44.10	**44.10**		
	4.66	●			
		26.10			
	4.63	●	●	□	
		64.80	**64.80**	**21.60**	
Score		**492.90**	**443.70**	**292.80**	**270.90**
Priority		**16.03**	**14.43**	**9.52**	**8.81**
Rangking		**1**	**2**	**3**	**4**

Furthermore, the concept selection process is done to select tone best concept which will be developed in the form of physical prototype. The process selection of product concepts involveed designers, electronics experts, and caregiver who is provide medicine and arrange medication schedules for elderly. The product concepts that use to design smart medicine box consists of three alternatives concept which have different electronic components types, selection of material for body mechanics, make some variation designs of smart medicine box, determine size of body mechanics, specify of procedure for using product, determine the total number of saved medicines into the medicine box, specify of water gallon size, installation security system for reducing human error and make some variation models design of water dispenser for each alternatives concepts.

Screening concept is used to determine a feasible alternative to continue. Total score for concepts I and II is calculated in order to select the best concept. Table 5 show that weight value (%) obtained from the calculation of the concept of project objectives earlier. The highest score will be implemented to the product design of smart medicine box.

Table 3. Scoring Concepts

Kriteria	***Weight* (%)**	**I**		**II**	
		Rating	***Score***	***Rating***	***Score***
Schedule reminders to take medication by using alarm	5.1	5	0.255	5	0.255
Easy to learn	5.1	4	0.204	4	0.204
Easy to use	5	4	0.200	4	0.200
Access to opening medicine containers via RFID Card Tag	7.5	5	0.375	3	0.225
Pillbox made automatically	7.4	5	0.370	4	0.296
Safety system for human error	7.4	5	0.370	3	0.222
Electricity Safety	4.9	3	0.147	3	0.147
Menu display is easy to read	4.9	3	0.147	5	0.245
The placement of the system components for system activation are easy to reach	2.9	5	0.145	5	0.145
Usage of gallon water by 6 litre volume	7.2	4	0.288	3	0.216
Hot water usage	7.2	3	0.216	3	0.216
Easy to move	7.2	4	0.288	4	0.288
Easy to place gallon water	7.1	4	0.284	4	0.284
Body cover model looks eye-catching	2.4	4	0.096	4	0.096
Body cover model looks minimalist	2.4	4	0.096	4	0.096
Production costs	2.4	3	0.072	3	0.072
Easily rectified if there are some troubles	3.1	3	0.093	3	0.093
Durable materials	2.3	4	0.092	3	0.069
Lightweight material and robust material	2.2	4	0.088	3	0.066
Durable electronic components	2.2	3	0.066	2	0.044
Maintenance costs	2.2	3	0.066	2	0.044
Ease of maintenance of electronic components used	2.2	3	0.066	2	0.044
Total Score			**4.024**		**3.567**
Ranking			**1**		**2**
Continue?			**Yes**		**No**

Scoring concept of the calculation results explain that the concept I is the greatest total score = 4,024 so it is considered better and deserves to be continued into physical prototypes than the concept II only has a total score of 3,567. Before starting the design phase, the goals and limitations need to be determined so that the result of physical prototype is not excessive that can be impact on high selling price to the customers. The main purposes of smart medicine box are able to help elderly within remembering the medication time through reminder alarm that the time has been set correctly by

caregiver. The elderly takes medicines in the cabinet by using RFID card after they hearing pill reminder alarm. The product design of smart medicine box can only use for one user equipped with water dispenser and has a storage medicine capacity with maximum five types per cabinets. The caregiver can refill medicines for user in every two days. The smart medicine box consist of six cabinets which each box filled by morning time, afternoon time, and evening time. From Figure 7 below shown 3D design of smart medicine box by using AutoCAD 2012 which formed by Voice of Customer (VoC).

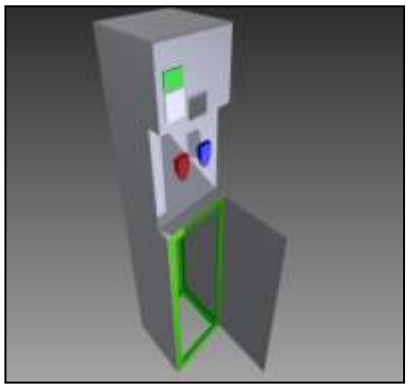


Figure 7. Smart medicine box

Pillbox has a size of 23 cm x 4 cm x 6 cm equipped with mini servo as many as 1 piece mounted on the right and left side so that the medicine cabinet can be opened and closed automatically when refilling medicines and 6 pieces of mini servo which is installed at the bottom of a box of medicine that has a function to pull out medicine automatically. Figure 8 and Figure 9 below show a part of bill box which is use for saving some medicines.

Figure 8. Pillbox for saving medicines

Figure 9. Pillbox for refilling medicines

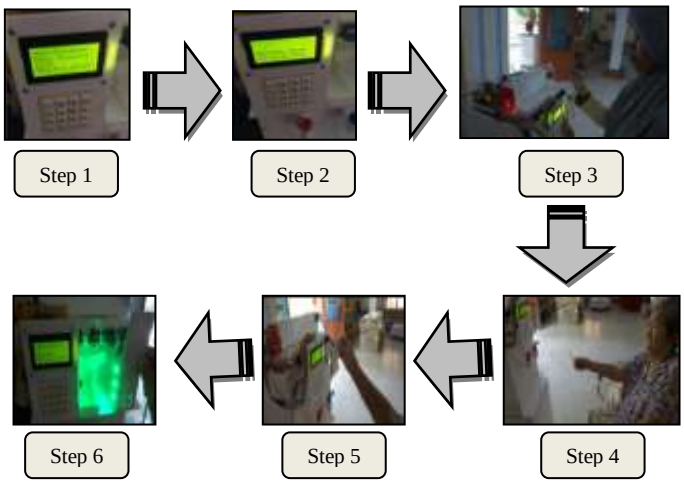
Smart medicine box is also equipped with a water dispenser volume of six liters of gallon, so that the elderly will have not complication while they take water drinking to drink medicine. Smart medicine box has a size of 35 cm x 35 cm x 130 cm with design position gallons is placed at the bottom and fitted with a door in the front so that the replacement of gallons of water that runs out can be done easily by the elderly. Then, water dispenser also equipped with hot water in accordance with the needs of the elderly when fill in customer need questionnaires. Figure 10 below show overall of smart medicine box equipped with water dispenser.

Figure 10. Smart medicine case equipped with water dispenser

III. RESULT

A. *Usability Testing*

The first step of usability testing is to select ten respondents from the age group 68-85 years for using the designed product, after giving elderly training on how to operate smart medicine box. Then, the elderly are given several tasks related to the steps of smart medicine box. Figure 11 explain about tests of elderly while using a smart medicine box and result will be assessed by usability questionnaire.



B. Usability Assessment

Usability methods that used in this research is taken from Rubin (1994) concepts such as learnability, efficiency, memorability, errors, and satisfaction. Usability determines the ease level of elderly people when they using smart medicine box. Usability assessments on using product are subjective and the final results collected through questionnaire answers. After completed the tests, ten elderly fill out questionnaire questions which contains some usability aspects such as learn ability, efficiency, memorability, errors, and satisfaction. The result value of learn ability aspects are 90% of elderly agree that technology RFID Card Tag can ease to open the medicine cabinet automatically and easy to hear voice information about the time schedule of medication through reminder alarm. Then, the result of efficiency aspect is 80% of elderly agree that can operate smart medicine box easily. The result of memorability aspect is 80% of elderly agree that can understand about the procedure steps of product. The result of errors aspect is 80% of elderly agree that the product has minimum error function. Furthermore, the result of satisfaction aspects are 60 % of elderly disagree because contrast lighting on Lcd display does not comply with visual condition of the elderly.

C. Conclusion

The result of this research is first version prototype of smart medicine box. The important result of the smart medicine box development are concluded as follow:

1) Voice of Customer (VoC) show that 81 percent of elderly could not recall the types of medicines and 69 percent of elderly is assisted by caregiver in terms of setting the schedule for taking the medication daily.
2) The design of smart medicine box twenty two of attributes product which collected from customer needs.
3) The technical matrix result in the House of Quality known that the technical responses which have the highest percentage are the used components that is equal to 16.03 percentage. The value 16.03 percentage obtained by correlation product attributes and technical responses.
4) Product testing shows that 90 percentage of respondents agree that product fulfill in learn ability aspects within usability methods such as easy to hear voice information about the time schedule of medication through reminder alarm and technology RFID Card Tag can ease to open the medicine cabinet automatically.

Acknowledgment

We thank all of the participants who took the time to fill in questionnaires and surveys. We are deeply indebted to Werdha Hargodedali Surabaya nursing home.

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