

THE APPLICATION OF QUALITY FUNCTION DEPLOYMENT (QFD) AND RAPID PROTOTYPING (RP) TECHNOLOGY IN IMPROVING THE DESIGN OF ANTI SLEEP DRIVING ALARM

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ABSTRACT

The purpose of this research is to apply Rapid Prototyping (RP) technique using Fused Deposition Modelling (FDM) in improving the design of anti sleep driving alarm. Quality Function Deployment (QFD) is introduced as a quality tool to analyze and evaluate the criteria and characteristics of the part to be improved. The analysis from QFD and House of Quality is translated into several possible concept designs by utilizing computer aided drafting. The prototypes of the concept designs fabricated using FDM machine are evaluated using concept scoring to determine the most promising concept designs. This research is limited to part build by fused deposition modelling RP process and also to the availability of material, however, the concepts experimented may be applied for other RP processes.

Keywords: Rapid Prototyping, Fused Deposition Modelling, Anti Sleep Driving Alarm, Quality Function Deployment

1.0 INTRODUCTION

Most of accidents occur due to driver error and driver drowsiness is the major one of human error. A great saving in human life and financial loss could be realized by a device that effectively helps to avoid accident due to driver drowsiness. The device which is worn behind the right ear works to response to driver's drowsiness and provides a warning with sound to alert the driver and eliminate the possibility of driving while drowsy.

However, the existing design of this device, known as anti-sleep driving alarm could be redesigned for improvement to increase the usage of this product among drivers. In order to improve the current design, Quality Function Deployment (QFD) was used to determine customer needs. QFD is a structured method for defining customer requirements and the requirements are then translated into specific plans to produce concepts design to meet those needs.

This research will focus on RP technique of Fused Deposition Modelling (FDM) which is the type of rapid prototyping commonly used within engineering design. In this research, FDM technique is preferable since it is a relatively simple process technology which involves no laser, no loss of material as well as no specific requirements to the environment of the machine.

Nomenclatures	
RP	Rapid Prototyping
FDM	Fused Deposition Modelling
QFD	Quality Function Deployment

1.1 Statement of the problem

More than a thousand people in Malaysia die in accidents each year and an equal number are critically injured as a result of fatigued drivers dozing off at the wheel. [Polis Diraja Malaysia : Ops Sikap XVII, 2009]. Referring to figure 1.3, numbers of accident occurred were increasing year by year. As year 2003, the number of accident occurred on the roads 27911 and by October 2008 the number of accident has been increased by 363319. On the other hand, in figure 1.4, Polis Diraja Malaysia has analyzed the cause of accident for Ops Sikap XVII, 2009. The main causes of accident were caused by car overtaking and followed by fatigue, drowsy and sleepiness while driving.

Therefore, there is a large number of competing technologies available in the marketplace to keep drivers stay awake while driving. One of the available technologies

is Anti Sleep Driving Alarm that is a good solution to keep people staying awake through such times. However, the design of existing anti sleep driving alarm in market has great potential to be improved to increase its usage among drivers. Therefore, by using Quality Function Deployment (QFD) quality tool and Fused Deposition Modelling, the design can be successfully analyzed and improved.

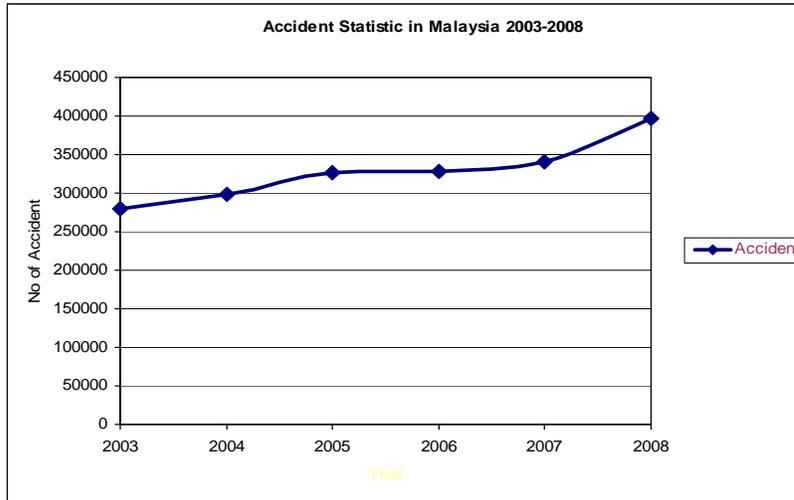


Fig 1.3 : Accident Statistic in Malaysia 2003-2008 [Polis Diraja Malaysia, 2009]

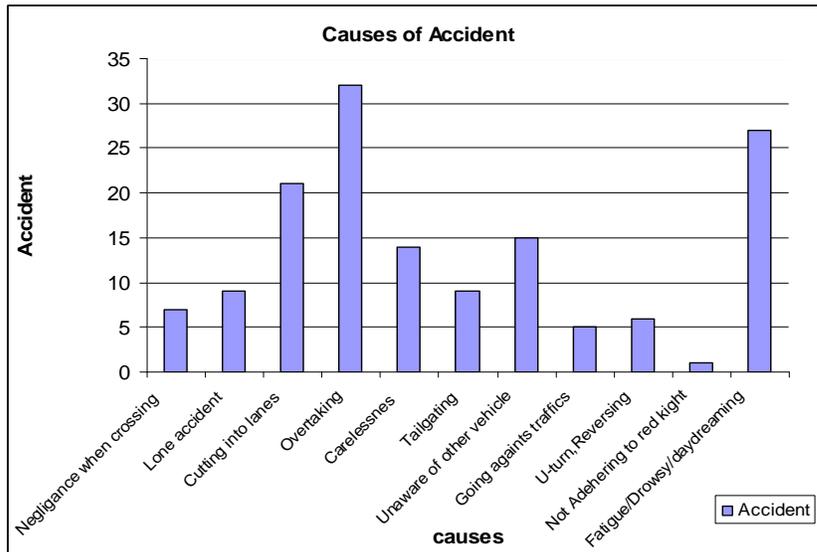


Fig 1.4 : Causes Of Accident [Polis Diraja Malaysia :Ops Sikap XVII, 2009]

1.2 Purpose of the study

This research utilizes the QFD quality tool and RP technology to upgrade and improve the current design of anti sleep driving alarm. The new concept designs are evaluated using concept scoring to select one or more concepts for further development.

1.3 Objectives of the study

- To apply QFD as a quality tool to investigate, analyse and improve the existing design of anti sleep driving alarm.
- To apply RP technology using the FDM machine to produce prototypes of the proposed design of anti sleep device.
- To improve anti sleep driving alarm in research and development using RP

1.5 Significant of the study

This research will help to improve the existing design of anti sleep device in term of its ergonomic by applying quality function deployment and rapid prototyping technology.

1.6 Scope of study

This research only focuses on an anti sleep driving alarm design and constructing the model of the improved design. Selection of material for fabrication using Fused Deposition Modelling machine is limited to the machine and material availability in the university.

2.0 LITERATURE REVIEW

2.1 Definition of Anti Sleep Driving Alarm

Anti Sleep Driving Alarm is a device that will keep driver awake while driving. This device is actually intended for drivers who run the risk of falling asleep behind the wheel. This device is used behind ear and will sound anytime the wearer's head move forward more than 30 degrees. It will wake drivers up anytime they are asleep while driving. It is a device that will be useful for drivers to ensure their driving safety. What all the users have to do is switch the device on and place it behind their ears. Whenever their heads lean forward at a steeper angle than the "safe" setting (generally 30 degrees or lower), the wake-up angle will start alarming strong enough for the wearer to immediately wake up. There is no vibration and alarm generated when the driver keeps normal driving status with eyes looking forward. In short, anti sleep driving alarm was designed to raise drivers' awareness of momentary lapses caused by sleepiness and tiredness.

2.2 Quality Function Deployment

Yoji Akao developed QFD during the late 1960s in Japan. It was first applied at Mitsubishi Kobe Shipyards in 1972 to assure customer satisfaction. Masao Kogure and Yoji Akao introduced QFD to the USA in the article "Quality function deployment and CWQC in Japan" which appeared in Quality Progress in October issue of 1983. QFD is a structured approach to seek out customers and understand their needs. It begins by matching customer requirement, which on turn match with necessary corresponding production requirement, and so on, to ensure that the needs of the customer met. If done right QFD is likely to be one contributing factor to product or service success [4]. The key benefit of implementing QFD is that engineering knowledge is retained in systematic manner so that it can be easily applied to future similar designs. The whole QFD procedure uses a series of matrices called house to express the linkage between inputs and outputs of different phases of development. [2]

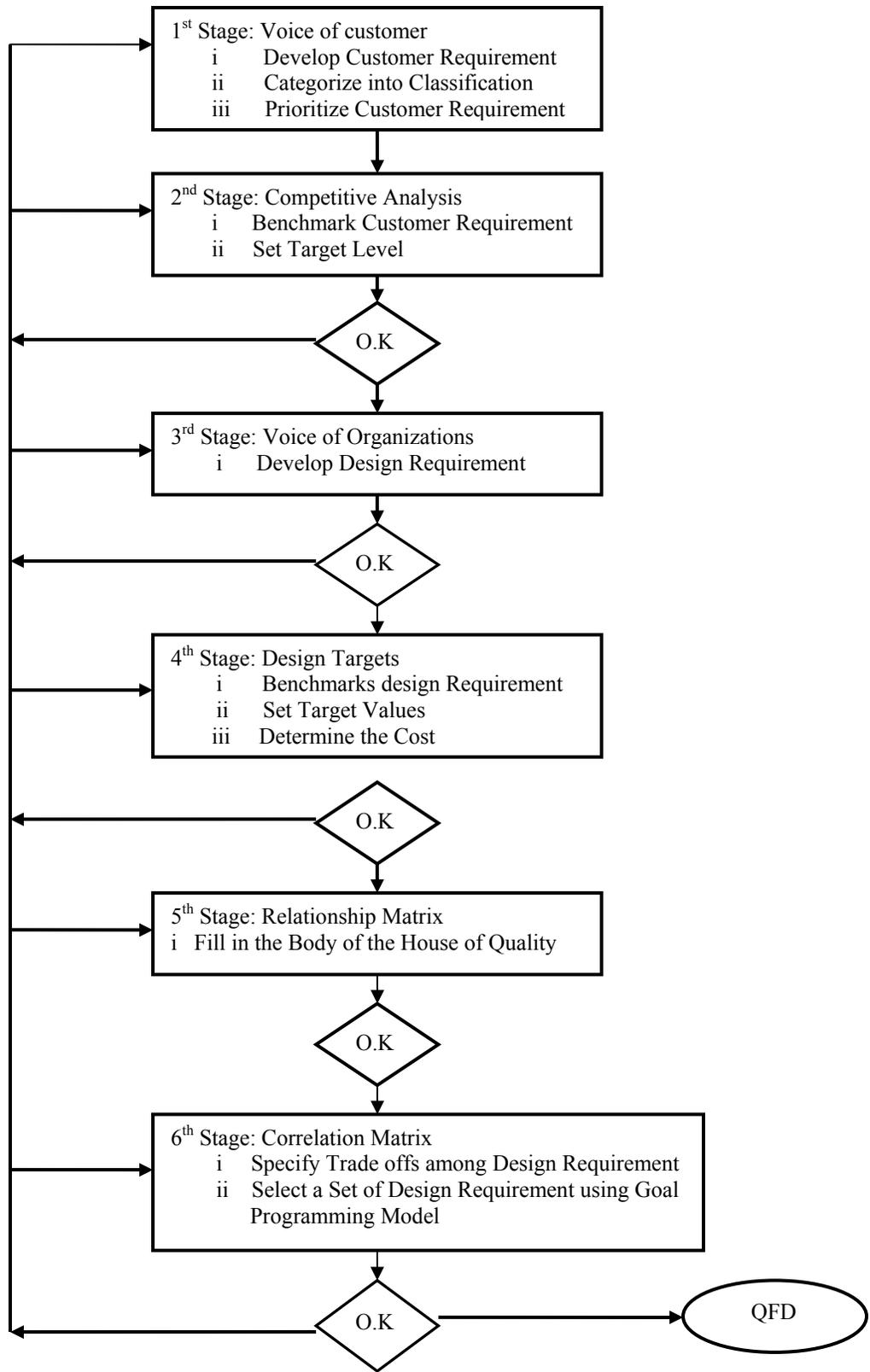


Fig. 2.1 : Hierarchical Frame [Shaw & Ebrahimpour,2000]

2.3 Rapid Prototyping

Generally, Rapid Prototyping (RP) refers to the layer-by-layer fabrication of 3-D physical models directly from a computer-aided design (CAD). It has also been referred to as solid free-form manufacturing; computer automated manufacturing, and layered manufacturing. It has obvious use as a vehicle for visualization. It can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. [1]

In addition, RP techniques have been developed from experimental techniques into invaluable development tools for engineers. Many companies are now using the capabilities of rapid prototyping to speed up the development and time to market of their products. Rapid prototyping utilizes an ever increasing range of materials, from epoxy resins to ceramics and metals.

Due to the intense competition in software, products that are successful in the market place are functional, reasonably priced, as well as easy to learn and use. Pricing aside, it is difficult and time-consuming to develop products with these characteristics. However, one way to minimize effort and time spent is to use the rapid prototyping process of product development since by implementing RP, development time can be optimized by allowing corrections to a product to be made early in the process. [9]

2.4 Fused Deposition Modeling

FDM system is one of the most popular RP techniques. By referring to Serope Kalpakjian & Schmid, S., 2006, the process of FDM is clean, simple, easy to operate and produces no waste due to it is all computer controlled. It is able to produce part at speed within minutes to a few hours. Since FDM uses high strength ABS plastic, it is the favoured technology for prototyping plastic parts requiring strength. The technology utilizes true desktop manufacturing system that can be run in office environment and there is no worry of exposure to toxic fume and chemicals.

It is a relatively simple process technology which involves no laser, no loss of material as well as no specific requirements to the environment of the machine. All parts that can be designed on a CAD application can be produced accurately (accurate to within 0.005 in) at scales part to fit inside machine production space which proves that it has limited design restrictions. The materials used are also less expensive and very cost effective since the material is supplied in spool form which is easy to handle and can be changed in minutes.

The material is fed into a heated extruding head, melting it to a temperature just above its solidification state prior to deposition. Within a heated build chamber, the machine head fills in the 2-dimensional profile of each slice in the X and Y directions on a movable build platform to form each layer. The material solidifies as it is placed, creating a laminate of each slice, but is kept at an optimal temperature within the build chamber to allow for fusing with the next layer.

A second material, which forms the support structure for overhanging features, is also traced onto the same layer if needed. The part is then lowered by the platform to allow for the next layer to be added; repeating the process for each slice until the 3-dimensional object is completely built. Once the part has finished its successive layers and the build is complete, the part is removed from the FDM. The supports of the part should break away easily from the completed model. After the supports have been removed successfully, the completed model is sanded to enhance surface finish. [15]

3.0 METHODOLOGY

Figure 3.1 showed sequence of completing this research.

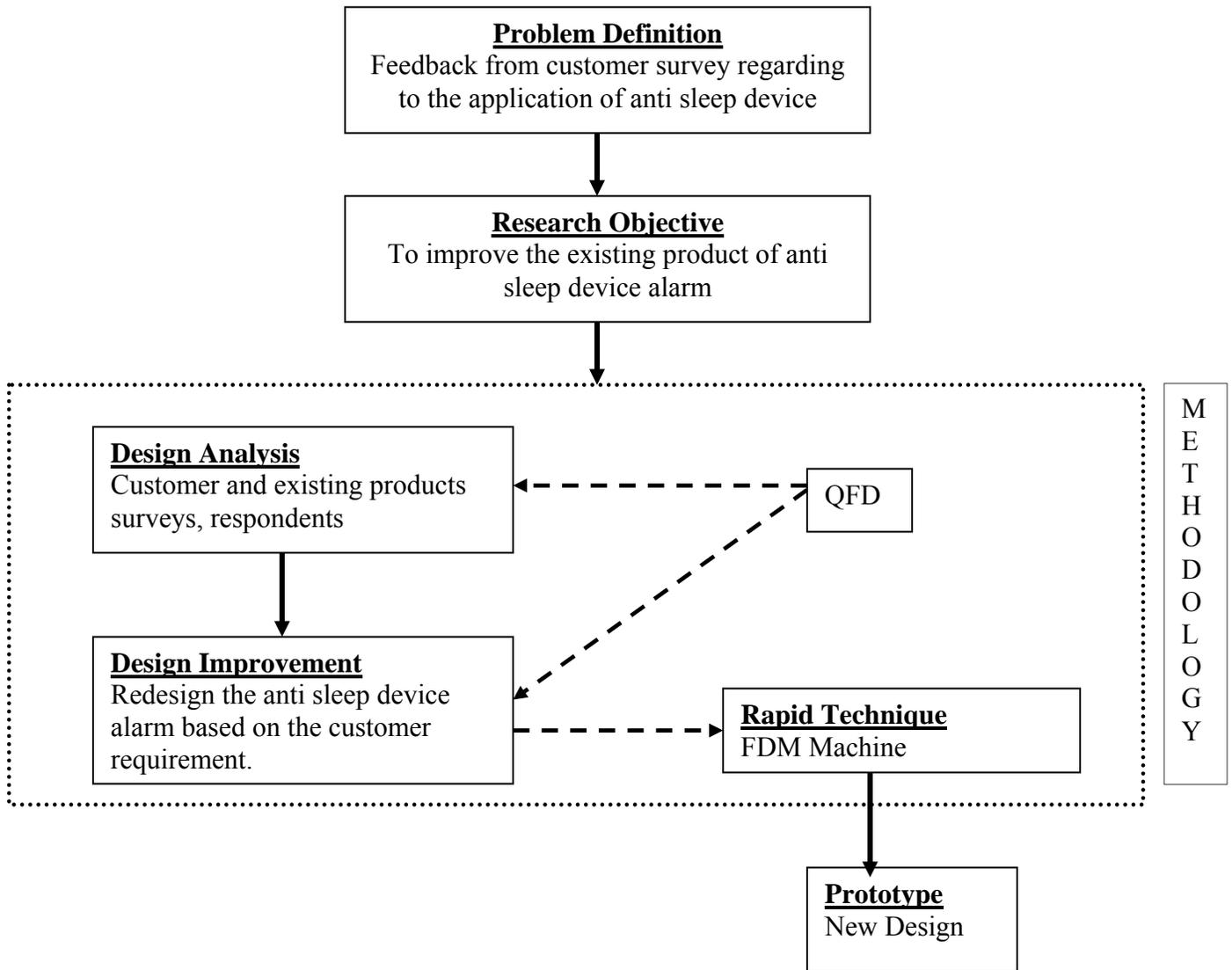


Fig 3.1 : Research Methodology

3.2 Respondents of the research

The respondents of the study were drivers' age range from 20 to 50 years old from Malaysia. In September 2009 a total of 250 questionnaires were distributed to drivers at different states in the country. A total of 232 drivers returned the questionnaires. Of these numbers, 140 were male drivers while the rest (92) were female drivers. Ten drivers were selected to provide in-depths information about the topics through interview sessions. All respondents held a full, current driving license and had driven a car on at least two occasions in the last three months.

3.3 Research instrument used

This research utilized both the quantitative and qualitative research methodology. So the instrument used to collect the data was questionnaire, interview and observation. A set of questionnaire containing 35 questions divided into 4 sections was developed. Different question types such as ranking, category, open-ended and scales were used in the questionnaire. The different sections of the questionnaire were i) demographic information ii) source of financial aid iii) reason for using anti sleep driving alarm iv) price of current anti sleep driving alarm and v) comments. The questionnaire was piloted to a group of 20 drivers to assess its validity before it was distributed. In this study observations is used for the purpose of obtaining need to redesign and improving the anti sleep driving alarm among selected respondents.

3.4 Research Procedure

Firstly, the problems on the existing anti sleep devices that available in market are determined. A few model and design of anti sleep device are analyzed and the advantages and disadvantages for each model are identified. In order to optimize access to the increasing amount of information, a classic solution has been data representation. QFD (quality function deployment) is used as a planning tool which is based on user needs and

expectations allowing the planning and design of RP. Survey done to a group of drivers is then interpreted into a house of quality.

A series of linked deployments provides the implied factors and requirements, relating, filtering and seeking relevant information through customers and potential customer surveys. By means of these deployments, the analysis of the customer needs and product quality and their corresponding relationships provides an excellent picture for the quality planning and design of the improved product using RP. This is the application from which the technology derives its name. From QFD, in the development cycle, once a design has been conceptualized, analyzed, and synthesized, it is then subjected to many proofing tests. The prototype or model is built out using FDM technique then tested for performance and functions. [2]

3.5 Fabrication and Design Process

There are several steps involved to fabricate the prototypes into physical forms. The fabrication methodology is shown in Fig. 3.2. As its name implied, it is simply the way or method that covers all aspects for fabrication from the starting stage to the final stage to translate the design concepts into physical models. After all product requirements are analyzed and characterized using QFD, the prototype is fabricated using RP technique which is Fused Deposition Modelling. For this research, the tasks to produce the prototype were divided into certain steps. These steps or methodology are believed to be this research guidance in conducting the design process of the final products.

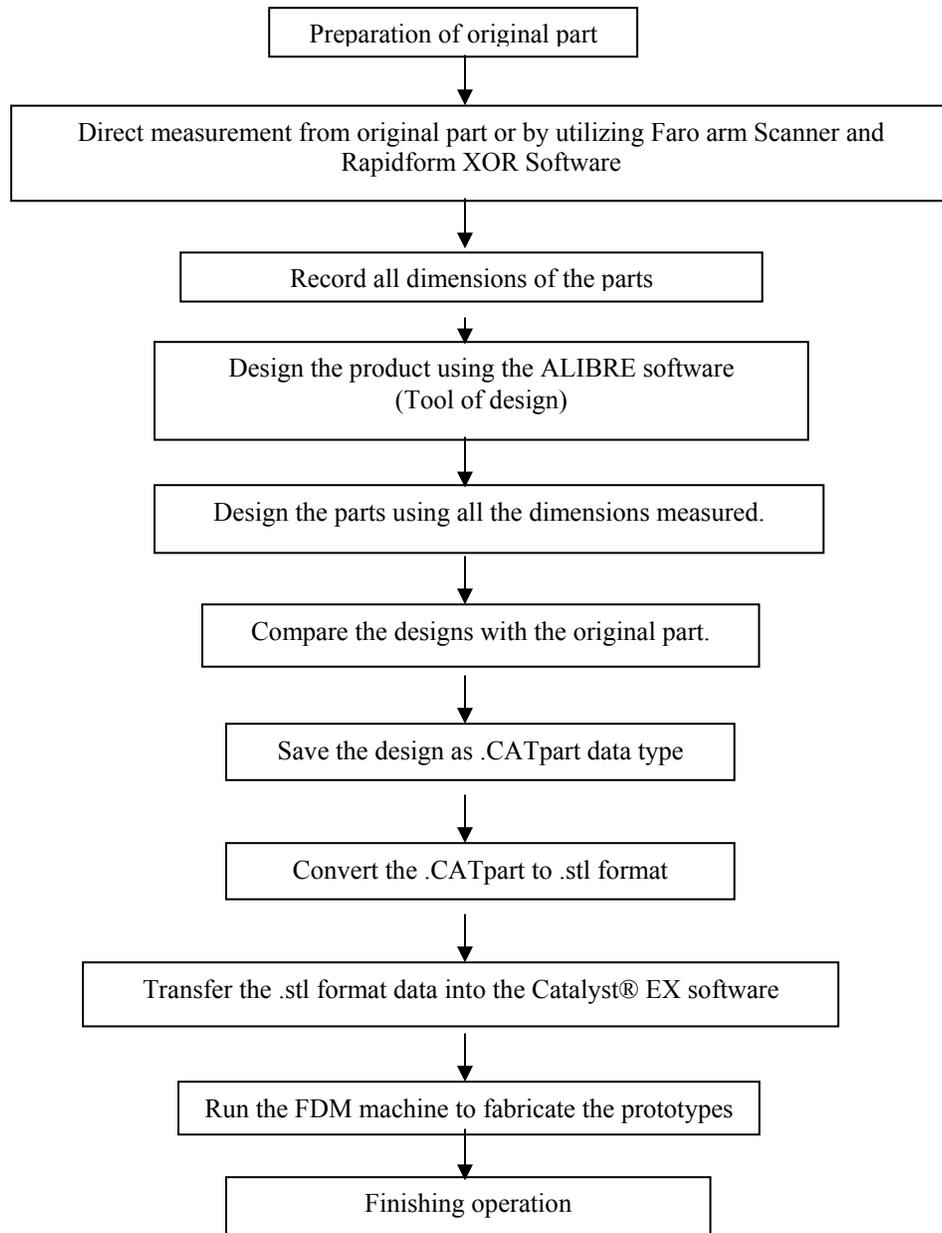


Fig. 3.2 : Methodology of design process

Faro machine and Rapidform XOR were the tools used to get direct measurement from original part. Faro machine is an arm robot with the probe and laser at the end of the arm. The laser and probe is used to scan the target object and the result of the scanned is illustrated in the Rapidform XOR software. This reading reflected from the scanned

object is converted in term of surface of product by the thousands of dot. Rapidform Firstly, the part to be scanned by Faro machine is prepared and setup. Faro arm robot can be moved in 360° degree and with 12 degree of freedom. The good scan can be obtained through training and distance from the object. In addition, the scan is limited by the work space of the arm robot.



Fig. 3.3 : Application of Faro arm scanner

Fused Deposition Modelling machine (FDM) was used to transform the concept design into physical form which is the prototypes. The specific model of this machine is the Dimension SST 768 machine. Fig. 3.4 shows the FDM machine for producing the prototypes:



Fig. 3.4 : Dimension SST 768 machine and its build material and support material

Dimension machines used Catalyst® EX software. This software automatically imports STL files, orients the part, slices the file, generates support structures (if necessary), and creates a precise deposition path to build the model. Multiple models can

be packed within the bounding box to maximize efficiency. Catalyst® EX are also provides file management capabilities, build time, material status and system status information. For developing support structure, Catalyst® EX software automatically creates any needed support structures to complete the part.

The basic methodology for rapid prototyping techniques can be summarized as follows:

- i. A CAD model is constructed, and then converted to STL format. The resolution can be set to minimize stair stepping.
- ii. The RP machine processes the .STL file by creating sliced layers of the model.
- iii. The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model.
- iv. The model and any supports are removed. The surface of the model is then finished and cleaned.

3.6 Concept Selection Method

Concept selection is the process of evaluating concepts with respect to customer requirements and other criteria, comparing the relative strengths and weaknesses of the concepts and selecting one or more concepts for further investigation or development. In this research, concept scoring method was used. By referring to Ulrich, K.T and Epinge, S.D., the steps for developing concept scoring can be summarized as :

Table 2 : Relative performance and score ranking for concepts

Relative performance	Rating
The most preferred	4
Fair	3
Poor	2
The least preferred	1

Step 1 : Preparing the selection matrix

Specifications	Model 1	Model 2	Model 3	Model 4
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As in the screening stage, the matrix was prepared and the concepts that have been selected for analysis were entered on the top of matrix. The concepts have typically been refined to some extent since concept screening. After the criteria were entered, importance weights were added to the matrix. In order to weigh the criteria, 100 percentage points was allocated among them.

Step 2 : Rating the design concepts

As in the screening stage, the concepts were rated and compared through surveys to 260 respondents, consists of existing and potential customer of the anti sleep driving alarm. Due to the need for additional resolution to distinguish among competing concepts, a finer scale was used as in Table 2 :

Step 3 : Ranking the design concepts

Once the ratings were entered for each concept, weighted scores were calculated by multiplying the raw scores by the criteria weights. The total score for each concept is the sum of the weighted scores :

$$S_j = \sum r_{ij} w_i \dots\dots\dots\text{equation (1)}$$

Where r_{ij} = rating of the concept j for the ith criterion

w_i = weighting for the ith criterion

n = number of criteria

S_j = total score for concept j

				
Dimension (mm)	67 x 23 x 18	60 x 70 x 15	70 x 40 x 20	65 x 70 x 18
Weight	23 gm	15 gm	50 gm	90 gm
Ergonomic design	Fits around back of ear (applicable to both right and left ear)	Fits around back of right ear only	Fits around back of right ear only	Fits around back of ear (applicable to both right and left ear)
Function : Degree of nod (to produce alarm)	More than 45 °	15 ° - 20 °	More than 40 °	More than 30 °
Type of Alarm	High pitched alarm (sound)	Vibration, sound	'Bip' sound	Vibration
Colour	Black and Grey	Black, Yellow	Black	Black and Pink
Material (Body)	ABS grade plastic	ABS grade plastic + rubber	ABS Plastic	ABS Plastic

Table 3 :Existing Product Specifications

Finally, each concept was given a rank corresponding to its total score and the most preferred concept by customers was selected.

4.0 RESULT ANALYSIS AND DISCUSSION

4.1 Design analysis and improvement

Design and technical specifications were determined from customer and QFD quality tool in Appendix B. Customer surveys are analyzed and evaluated as in Appendix A. Table 3 illustrates the product specifications of the existing products in the market in terms of dimension or size, weight, ergonomic design, functionality, type of alarm as well as material used. Hence, the technical specifications for the proposed design were based on ergonomics, weight, appearance, size, function and performance.

Based on QFD and HOQ shown in Appendix B, by relating customer requirements to technical specification of the product, functional requirement of compact design has the greatest importance to customers, followed by small size, light weight, ergonomic design and easily portable. Ergonomic design means the device can be fixed properly behind ears and at the same time it functions properly as its intended service.

With the product chosen, the improvement of the product was conducted through several steps. The first step was to compare the four models of existing anti sleep driving alarm in term of their design and specifications based on 250 customers' survey. Figure in Table 3 shows four models of anti sleep driving models that have been used as references in this research.

A competitive benchmarking chart was constructed with rows corresponding to the customers' needs and columns corresponding to the existing competitive products as shown in Table 4. This chart is used to compare customers' perceptions of the relative degree to which the product satisfy needs. Hence, constructing this chart requires collecting customers' perception data through surveys. As shown in the Table 4, four "dots" (●●●●) represents the highest satisfaction while one "dots" (●) represents the lowest satisfaction perceived by customers. The imp (importance rating is assigned to each criteria as to weigh the criteria relative to its importance.

From these four samples, each product was examined, analyzed and compared in terms of its pros and cons in the design engineering using Quality Function Deployment (QFD) tool. Thus, from here, the possible upgrade of the current design for the anti sleep driving alarm was developed.

Table 4 : Competitive benchmarking chart based on perceived satisfaction of needs

	Model 1	Model 2	Model 3	Model 4
Small Size	••••	•••	•	••
Light Weight	•••	••••	••	•
User Friendly	••	•••	•	••••
Fix properly behind ears	•••	••••	•	••
Durable (does not break)	••	••	••	••
Function Very Well to Alert Sleepy Driver	•	•••	••••	••
Easily Portable	••	••	••	••
Attractive	•••	•••	•	••••
Easy Maintenance	•••	•••	•••	•••
Ergonomics	••	•••	•	••
Good Vibration/ Sound Quality	•••	••	••••	••
Soft Features	•	•••	•	••
Flexibility (Can be used to both ears)	••	•	•	•••
Convenient to Use	•••	•••	•••	•••

The four concept designs were drawn using ALIBRE software based on the customers and technical requirements gained.

4.2 Fabrication and Design Process.

The four designs created using ALIBRE software were made so that the product will be more ergonomics, which means that it should fix properly and comfortably behind ears, having smaller size than the existing product, more attractive and at the same time can be used to optimum performance. After the CAD was designed using ALIBRE software, the prototypes were fabricated using FDM Machine. For the build material, acrylonitrile butadiene styrene (ABS) plastic in standard white was used; the standard code is 340-20000-White ABS Filament Cartridge. The support material used here is 340-30200- Soluble Support Cartridge.

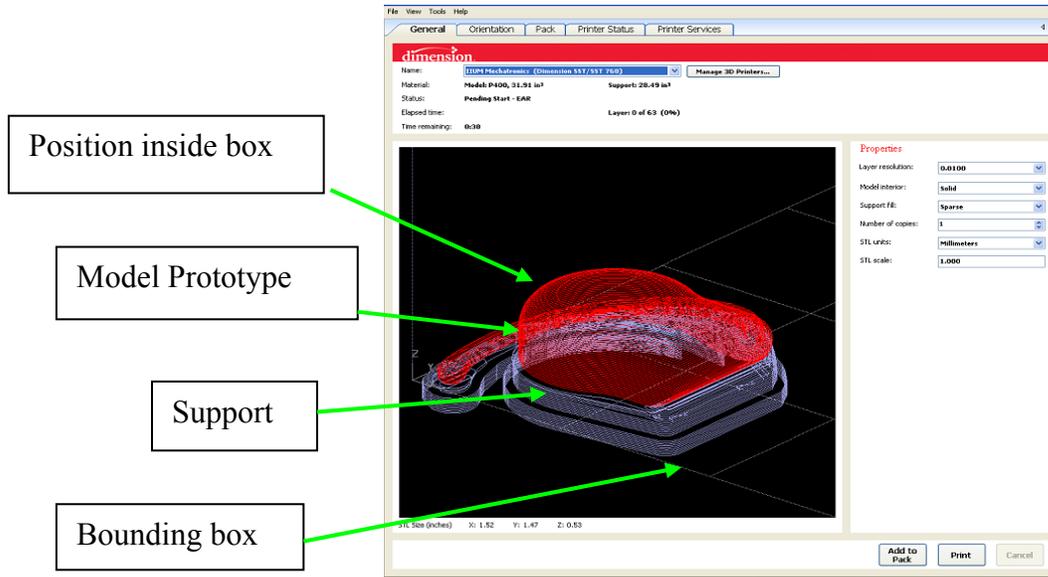
The fabrication processes were as followed:

4.2.1 Computer Aided Design File Preparation

Before fabricating a part using RP machine (FDM), the CAD file has to be converted into .STL file and utilized in Catalyst® EX software. Catalyst® EX gives some option for fabrication method used such as the layer resolution, model interior, support fill, number of copies, STL units, and STL scale. For higher definition models, thinner slices may be used but this will increase the time required to complete a part build. As for less accuracy parts can be built much faster using thicker slice value.

4.2.2 Part Size

Before fabricating the product, design's part size must be set. The part must be confirmed to fit exactly in the bounding box; otherwise, scaling has to be applied. The part must also be rearranged correctly since the fabricating process of the multiple designs in a one single run so that the parts produced are not overlapping. Fig. 4.9 shows the Catalyst Software used for RP operation.



4.2.3 Orientation / positioning

In this research, the parts were positioned as lying by the most surface at the bottom side, to reduce the usage of support material. With this, the time for fabrication and the materials used for making prototypes can be optimized.

4.2.4 Slicing

The next step was the slicing. It is a software operation that creates thin, horizontal cross sections of the STL file that gives the instruction to the machine to do the fabrication operations. When finish with the slicing, PRINT option was clicked to start the fabrication process.

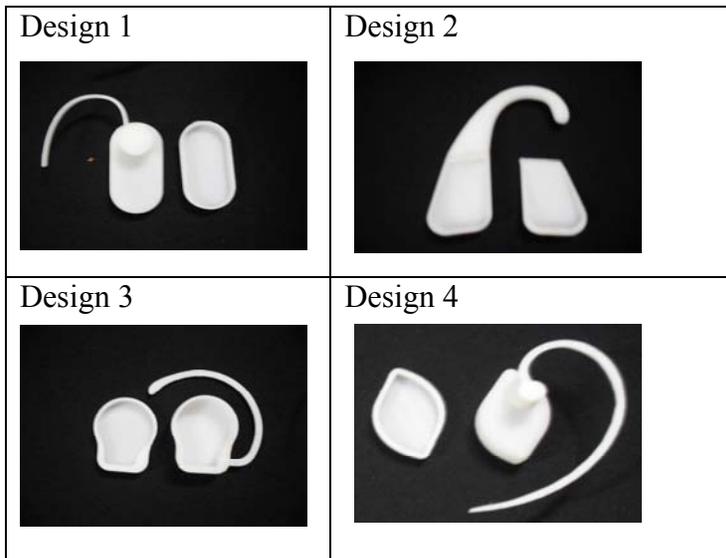
4.2.5 Building Prototype

The software setup requires most of the time for preparation, and once the machine begins to operate for fabrication; the prototypes were created in a single run.

4.2.6 Finishing the Completed Prototypes

Finishing operation is only required for certain parts at which the support material is difficult to be removed from parts. The support material can be removed easily only by peeling it by hand or knife. The soluble liquid concentration was used with certain temperature and the part was down into it to remove any unnecessary materials attach to the prototypes.

Figures below illustrate the finished prototypes fabricated through Fused Deposition Modelling machine.



4.3 Concept Evaluation and Selection

In order to evaluate the competing design concepts, concept scoring is used due to increased resolution able to better differentiate among competing concepts. The criteria of the design to be compared are in terms of ease of use, portability, ergonomics (fix behind ear), comfortability, weight, design (aesthetic / appearance), functionality and ease of handling. The electronic components are inserted into each prototype to be tested by users and potential users of the product. The device function is based on electronic balance. As the drivers fall asleep and nod their head below presetting angle (generally

30 °), the device produces a loud alarm enough to wake up and alerting the drivers. The four prototypes were tested on 260 drivers and their satisfaction on the device characteristics were ranked and utilized in concept scoring. Fig. 4.15 illustrates the prototype being used by driver by attaching it at the driver's ear.

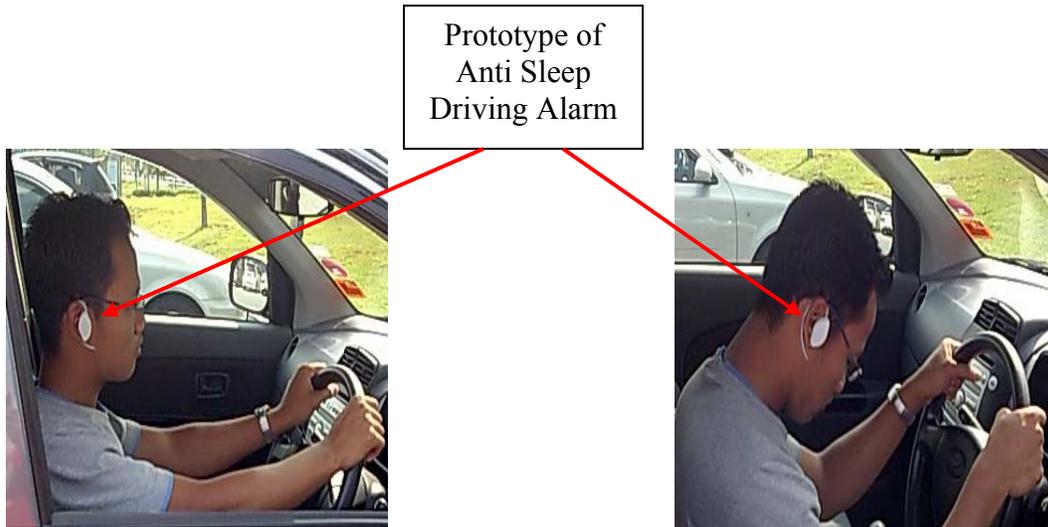


Fig. 4.15 (a) : Prototype being tested by driver

Fig. 4.15 (b) : Prototype being tested by driver

In this evaluation stage of concept scoring, the relative importance of the selection criteria were weighted and refined comparison with respect to each criterion was used. The concept scores were determined by the weighted sum of ratings. In describing the concept scoring process, focus was given on the differences relative to concept screening. Table 5 illustrates the scoring matrix used in this stage.

Table 5 illustrates concept scoring which is completed by using equation (1)

Table 5 : Concept Scoring for design evaluation

Selection criteria	Weight (w_i)	Concepts							
		1		2		3		4	
		Rating (r_{ij})	Weighted score						
Ease of use	10 %	20	2	60	6	150	15	30	3
Portability	5 %	50	2.5	95	4.75	73	3.65	42	2.1
Ergonomics (fix behind ear)	20 %	65	13	70	14	89	17.8	36	7.2
Comfortability	10 %	79	7.9	64	6.4	81	8.1	36	3.6
Applicable for women wearing hijab	10 %	20	2	52	5.2	170	17	18	1.8
Weight	20 %	32	6.4	112	22.4	83	16.6	33	6.6
Design (appearance)	15 %	25	3.75	65	9.75	100	15	70	10.5
Ease of handling	10 %	50	5	74	7.4	68	6.8	68	6.8
Total score (S_j)		42.55		75.9		99.95		41.6	
Rank		3		2		1		4	

As a final step, since the design concept 3 has the higher score, thus, design 3 can be considered and selected for further investigations and developments.

In this research, the essential parameters that were used in fabricating the four prototypes using FDM machine are:

Table 6 : Parameters for prototypes fabrication

Model	Build time (minutes)	Volume of model material used (in ³)	Volume of support material used (in ³)
Model 1 	49	0.212	0.308
Model 2 	58	0.324	0.259
Model 3 	54	0.246	0.264
Model 4 	59	0.233	0.254

As shown in the Table 6, Model 4 takes the longest time to be fabricated into prototype which is about 59 minutes, followed by Model 2 (58 minutes), Model 3 (54 minutes) and Model 1 (49 minutes). In terms of volume of material used, Model 4 consumes the fewest material (which is 0.233 in³ for model material and 0.254 in³ for support material), and

Model 2 consumes the highest material (which is 0.324 in³ for model material and 0.259 in³ for support material).

Cost	Formula for Calculation
Material	$\text{Model} = \text{Volume} \times \frac{\text{Price per cartridge}}{\text{Volume per cartridge}}$
	$\text{Support} = \text{Volume} \times \frac{\text{Price per cartridge}}{\text{Volume per cartridge}}$
Labour	$\frac{\text{Basic Salary per month}}{26 \text{ working days}} \times \frac{1 \text{ day}}{8 \text{ hours}} \times \text{Built time}$
Electricity	$\text{Electricity} = \text{Power} \times \text{Built time (hour)} \times \text{rate per hour}$ $\text{Power} = \text{Voltage} \times \text{Current}$
Total Cost	$\text{Model Material Cost} + \text{Support Material Cost} + \text{Labour Cost} + \text{Electricity Cost}$

Table 8 : Estimated Cost Calculation to Build the Prototypes Using FDM

Model	Estimated Cost Calculation to Make Prototype	Total Cost
Model 1 	<u>Material</u> Model = RM 5.63 Support = RM 8.17 Total = RM 5.63 + RM 8.17 = RM 13.80	RM 20.27
	Labour = RM 5.88	
	<u>Electricity</u> Power = 3300 Watts Electricity = RM 0.59	
Model 2 	<u>Material</u> Model = RM 8.60 Support = RM 6.87 Total = RM 8.60 + RM .87 = RM 15.47	RM 23.14
	Labour = RM 6.97	
	<u>Electricity</u> Power = 3300 Watts Electricity = RM 0.70	
Model 3 	<u>Material</u> Model = RM 6.53 Support = RM 7.00 Total = RM 6.53 + RM 7.00 = RM 13.53	RM 20.67
	Labour = RM 6.49	
	<u>Electricity</u> Power = 3300 Watts Electricity = RM 0.65	
Model 4 	<u>Material</u> Model = RM 6.18 Support = RM 6.74 Total = RM 6.18 + RM 6.74 = RM 12.92	RM 20.72
	Labour = RM 7.09	
	<u>Electricity</u> Power = 3300 Watts Electricity = RM 0.71	

5.0 CONCLUSION

Through this research, **The Application of QFD and Rapid Prototyping Technology in Improving the Design of Anti Sleep Driving Alarm** was applied effectively and the objectives of this research were successfully achieved. QFD quality tool has been applied to evaluate customers' requirements and develop characteristics for design improvement to satisfy those needs. Using RP technology which is the additive process in producing prototypes is much convenient compared to traditional method fabrication which is subtractive process since it offers great deals in saving cost, time, and material usage for the tested and producible model before being commercialized.

With the surveys and QFD quality tools, customer requirements were analyzed to improve the existing design and all the deficiencies could be tracked down. With that, QFD provides an analytical and systematic approach, when relating customer needs and product technical specifications. The development of these specifications ensures the product meets the defined requirements. Several technologies can be used to redesign the product. By applying technology such as Faro Arm Robot, the time to measure dimension can be greatly reduced depending on the complexity of the product shape. This technology implies the method of direct measurement from the complex parts.

Designing software such as ALIBRE software is very helpful to visualize the concept design in 2D and 3D dimension by utilizing various design functions in designing phase. Throughout the design stage, several functions in the software has been used to build up or design the part such as part design option, chamfer tool, sketch tool, transform tool and many more.

6.0 RECOMMENDATION

Due to certain limitations in conducting this research, there are some recommendations for developing this research in the future.

1. Cost consideration.

As this research is only for academic purposes, it will be more effective if the cost for producing the prototypes as a functional part to be considered. The machine's application, the materials used, time consumed, and design process flow costs should put into consideration into the research.

2. Different materials used.

Other than ABS type, other type of material should also be used in the research to compare which material is the most suitable material for producing the prototypes.

3. Different type of Rapid Prototyping machines

There are many type of RP, thus, different rapid prototyping machines and techniques such as sterolithography, selective laser sintering, and laminated object manufacturing should also be used in fabricating the prototypes. By applying various RP machines, the prototypes generated using different RP techniques can be compared and analyzed specifically.

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