# APPLICATION OF INTEGRATED FUZZY-AHP FOR DESIGN EVALUATION IN PRODUCT DEVELOPMENT

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APPLICATION OF INTEGRATED FUZZY-ANALYTICAL HIERARCHY PROCESS FOR DESIGN EVALUATION IN PRODUCT DEVELOPMENT

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This thesis is submitted as partial fulfilment of the requirements for the award of the Bachelor of Manufacturing Engineering (Hons.)

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MAY 2015

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***Specially dedicated to my beloved parents,***

***family, lecturers and all my friends***

# ACKNOWLEDGEMENT

In the name of Allah S.W.T, the Most Beneficent and the Most Merciful. It is deepest sense appreciation of the Almighty that give me strength and ability to complete this thesis. May selawat and salam granted to our beloved Prophet Muhammad S.A.W, to his family and to all his nonle companions.

First and foremost, I express my deepest gratitude to my supervisor, Dr. Faiz Bin Mohd Turan, who has given me insights into the problems encountered during the construction of this project. I really appreciate his guidance from the initial to the final level that enabled me to develop an understanding of this research thoroughly. I also sincerely thanks for the spend time proofreading and correcting my mistaken. I could not have achieved the level of success without his expertise.

I would like to give my deepest appreciation to Mdm. Nur Najmiyah Binti Jaafar for her continuous guiding and advised throughout this project. Not to forget, I would like to express my appreciation to my beloved family, who always support me and be at my side in needs.

Finally, I would like to say thank you to all my friends that give me support and ideas. Thank you for helping me in my way to finish this project and thesis. It is a great opportunity of changing ideas and opinions with them which solved my problems. So, I would like to say thanks again to all my friends.

Thanks You.

# ABSTRACT

The evaluation process of conceptual design alternatives in a new product development environment is a critical point for companies who operate in fast-growing markets. Various methods exist that are able to successfully carry out this difficult and time-consuming process. One of these methods, the Analytical Hierarchy Process (AHP) that been widely used to solve multiple-criteria decision making problems in both academic research and in industrial practice. However, due to vagueness and uncertainty in the decision-maker's judgment, pair-wise comparison with Integrated Fuzzy-AHP may be able to accurately capture the decision-maker's judgment. Therefore, fuzzy is introduced into the pair-wise comparison in the AHP to compensate for this deficiency in the integrated Fuzzy-AHP. This is referred to as integrated fuzzy-AHP. In this paper, a fuzzy-AHP method is used to reduce a set of conceptual design alternatives by eliminating those whose scores are smaller than a predetermined constant value obtained under certain circumstances. Then, simulation analysis is integrated with the fuzzy-AHP method. Finally, the results of integrated fuzzy-AHP are used for Preference Ratio analysis to reach to the final alternative.

# ABSTRAK

Proses penilaian alternatif untuk reka bentuk konsep dalam dunia pembangunan produk baru adalah satu titik penting bagi syarikat-syarikat yang beroperasi dalam pasaran yang berkembang pesat. Terdapat pelbagai kaedah yang berkesan untuk mejalankan operasi yang sukar dan memakan masa. Salah satu kaedahnya, "*Analytic Hierarchy Process"* (*AHP*) telah digunakan secara meluas untuk menyelesaikan pelbagai kriteria untuk membuat keputusan yang bermasalah di kedua penyelidikan akademik dan dalam syarikat industri. Walau bagaimanapun, disebabkan kesamaran dan ketidakpastian dalam penghakiman untuk pembuat keputusan, perbandingan pasangan-bijak dengan "*Fuzzy-AHP"* mungkin dapat buat keputusan dengan tepat membuat penghakiman pembuat keputusan itu. Oleh itu, Fuzzy diperkenalkan ke dalam perbandingan pasangan-bijak dalam AHP untuk mengimbangi kekurangan ini dengan "*Integration of Fuzzy-AHP"*. Ini dinamakan sebagai "*Fuzzy-AHP"*. Dalam kertas kerja ini, satu kaedah "*Fuzzy-AHP"* digunakan untuk mengurangkan satu set alternatif reka bentuk konsep dengan menghapuskan mereka yang skor lebih kecil daripada nilai yang tetap yang telah ditentukan dan diperoleh di bawah keadaan tertentu. Kemudian, analisis simulasi integrasi dengan kaedah "*Fuzzy-AHP"*. Akhir sekali, keputusan "*Integration Fuzzy-AH"P* digunakan untuk menganalisis Nisbah Keutamaan untuk sampai ke alternatif akhir.

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# LIST OF SYMBOLS

| | |
|---|---|
| $Wi$ | Relative Importance |
| $i$ | Criterion |
| $Wij$ | Secondary relative importance |
| $wv$ | Construction of matrix |
| $A$ | Fuzzy judgement matrix |
| $I$ | Index number |
| $\lambda$ | Eigenvalue |
| $\lambda max$ | Maximum eigenvalue |
| $X$ | Non-zero n x l fuzzy vector |
| $J$ | Index number of the columns in the pairwise matrix |
| $I$ | Index number of row in matrix of pairwise |
| $CI$ | Consistency index |
| $CR$ | Consistency ratio |
| $RI$ | Random consistency index |
| $n$ | Number of matrix |
| $TW_{Ak}$ | Total alternatives weight |
| $W_{Ak}$ | Alternative relative important |
| $Ui$ | Criteria |
| $Ai$ | Alternative |
| $Wui$ | Criterion relative important |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| CPM | Comparison Pairwise Matrices |
| NPD | New Product Development |
| QFD | Quality Function Deployment |
| TOPSIS | Technique for Order Preference by Similarity to Ideal Solution |
| HOQ | High of Quality |
| ANP | Analytical Network Process |
| R&D | Research and Development |

# CHAPTER 1

# INTRODUCTION

## 1.0 RESEARCH BACKGROUND

Product development is process of designing, creating and marketing new product to benefit customers. The early step on new product development taken much time for any industry company to create new product. They need to give more attention on this stage. The process need to consider customers demand because from customers demand there has specification on new product. During to develop new product it has to going through step by step. Early process in product development is where teams of product development must identifies the customer needed or demand. By customer's requirement the details of product specification was developed.

The design of product should be evaluate by responder to avoid the late correction. The late correction effect the cost and consume of time for iteration of design. The design evaluation in product development made designer to select the best design on decision making process before they do the final decision. The tools that use to evaluate the best design is integrated Fuzzy-AHP where decision making on multiple criteria. All design will be evaluate with same criterion that been set to find the best design.

The affection on doing design evaluation in product development where if the decision maker failed to select the best design it will effect on time during making decision and of course it will increasing the cost while waiting the product to be produce. Therefore, this is the priority of new product development to conduct evaluation process in correct way to make sure the process of decision making has shorter time and the product can be market early to give benefit for user.

## 1.1 PROBLEM STATEMENT

Ideal condition in developing new products are the involvement of shorter time production and faster delivery process. This condition being dreamed by all business or industry companies in the whole world because they want to gain the profit as earlier they can.

However, due to vagueness and uncertainty in the decision-maker’s judgment, pair-wise comparison with Integrated Fuzzy-AHP may be able to accurately capture the decision-maker’s judgment. Therefore, fuzzy is introduced into the pair-wise comparison in the AHP to compensate for this deficiency in the integrated Fuzzy-AHP. This is referred to as integrated fuzzy-AHP.

The Fuzzy-AHP will help the vagueness of responder to make evaluation on design of new product. With weighting scale the perspective from responder can be verify the condition of design against criteria stated whether it is good or very good or not good. The evaluation method will obtain the ranking with their relevant weight for each responder viewpoint. To achieve ideal condition designer can use integrated Fuzzy-AHP to improve the design evaluation in product development.

## 1.2 OBJECTIVE

i. To develop decision making method for design evaluation using integrated Fuzzy-Analytical Hierarchy Process.

ii. To help design engineers to finalise their choice by selecting the best design concept of case study.

## 1.3 SCOPES OF PROJECT

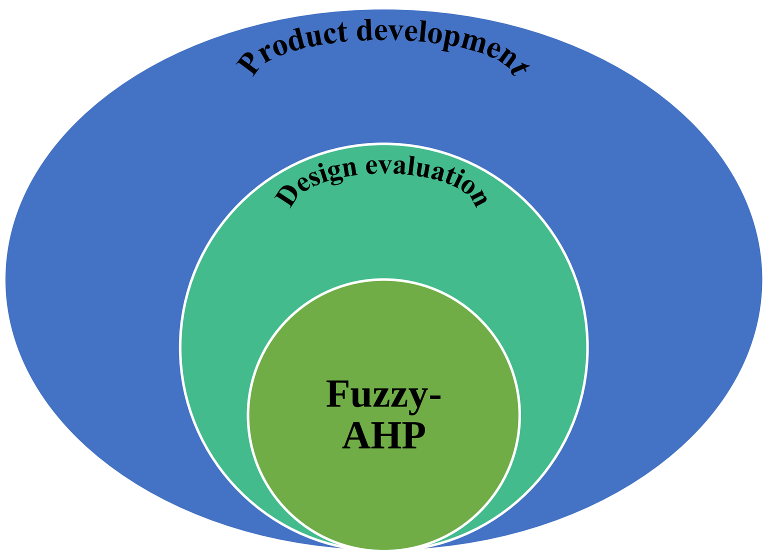



Figure 1.1: Venn diagram for scope of project.

The Venn diagram above shows the product development process, then going to design evaluation process using integrated Fuzzy-Analytical Hierarchy Process (AHP) tool. The integrated Fuzzy-AHP is use to reduce the duration of time on decision making process. The fuzzy method is a process in make selection on design by doing evaluation in terms of criteria on alternative. In fuzzy-AHP represent comparison of pair-wise matrices (CPM) in concept of hierarchy make the selection that should be the first priority as customer demand. This situation involved on research and development department in multinational company.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 INTRODUCTION

Nowadays in the world, there are so many products have been developed according to rapid development of economy. In markets today and from over last ten years there are variety of product has been created compare to ten years before it because the product has their own limited life span, the companies do the heavy investment in new product development to make sure that their product keep growing up. The design engineer should think how to sales their product according to past development in the market. To develop new product it is important to know about product life cycle and the criteria that should take serious which are low cost, high quality of product and shorty time to marketing the product. The product life cycle is divided to five steps which are development of product, introduction of product, growing of product, the maturity of product and last is decline of product. This final year project focused on how to develop the product in excellent way which is low cost, high quality and faster delivery the product. In this chapter explain about review on product development scope.

## 2.1 PRODUCT LIFE CYCLE

"The product life cycle is the concept the product must go through which are market introduction, market growth, market maturity and reduction of sales. Every stages the market product will be change as will its revenue and profit profile" [Perrault-McCarthy, 1997]. In starting a new product must be go through several step that told by Perrault-Mc Carty above to generating new idea, concept specification, analysis of business and design of product, to ensure that the product be successful to entrance the market. Manage the product life cycle is a strategy of company to approach the effectively management on their product.

The exist phases are applicable to all new product growth and it also can be split up to smaller by depends on the product where it must be considered that product is new into market since they direct the performance of product.

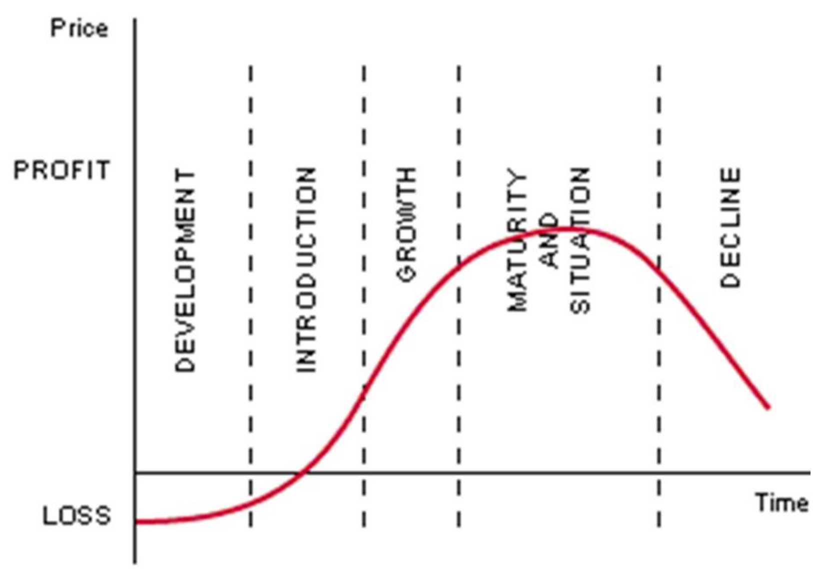



Figure 2.1: Product life cycle

Figure 1 shown the stage or steps the new product must be follow from first stage they must go to product development where the company find the idea to produce a new product by do get some information from customer and find the customer needed. Second stages is how company introduce their product to customer, where do the launching the product. The third stage is about growth the product with offer the satisfaction by seeing the product launch in the market place. Forth phases where the maturity of product in the market being priceless with the variations of product from competitors, so the maturity phase is arrives. Lastly is decline phase withdrawing the product is a complex task and the product must to move out the product from market. As we can see at figure 1 shown the red line which is line where the money condition up or down passing the all phases. Focused on development phase, there are got loss on profit because at that phases has to do investment to develop new product. In this case, just want to give a small contribution to decrease time on development phases.

## 2.2 PRODUCT DEVELOPMENT

"New product development (NPD) is widely recognized as a key to corporate prosperity" [Lam et al., 2007]. "The different process needed to produce different product where there needs new idea to be concerned, developed, selected, tested and launched to the market" [Martinez-Sanchez et al., 2006]. In develop a new product the designer must do the important thing which is generate the ideas that need for completely the new products. Why identify the ideas is important because the companies must avoid the risk that can involve in business as early as possible because the time is about money and the specification, price and schedule of the product must be setting to state as the target in develop a new product. "The development process we must identify the customers need. With using a variety of methods such as Quality Function Deployment (QFD), the teams generates alternative solution concept in response to these needs [Ulrich and Eppinger. 2000].

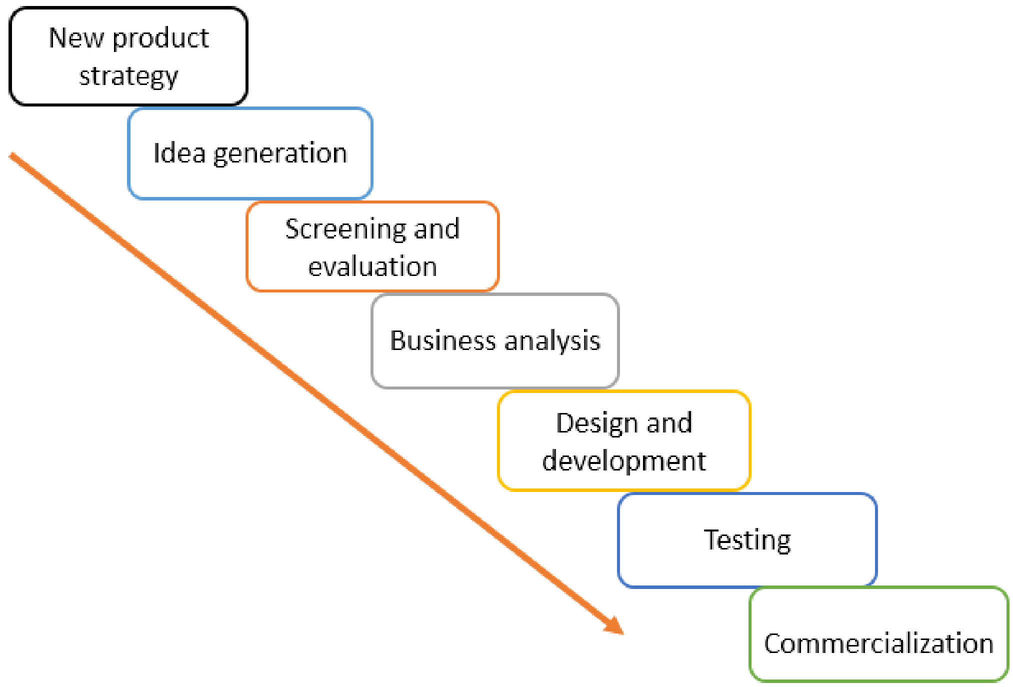



Figure 2.2: Step in new product development (NPD) (Booz, Allen & Hamilton, 1982)

In product lifecycle phases that focused is on phases one which is the product development phase. In product development it has several step as shown in figure 2 need to considered:

i. Strategy to make new product where do screening criteria to establish customers satisfaction and set the objectives.
ii. Generate the idea from customer criteria to achieve the objectives.
iii. Screening is consist of do the early analysis to get more idea generation and detailed in the product development.
iv. Analyze the current business economy from the idea do advance evaluation on the basic quantitative factor such as profits in business and volume of sales.
v. Develop the idea into a paper to demonstrate and able the product.
vi. Next step is testing the product by do the commercialize experiment to verify the judgment of business.

vii. Lastly the product launching by do the real commercialize real product.

In these step this project only focus on stage from three and above where at there the decision making process is happen.

## 2.3 DECISION MAKING

The general decision making is defined by Drummond (1994) and Niromi Seram (2012) the find out a specific choice option of actions. Product development process, firstly the customer satisfaction must be achieved in order to sales the product. From customer needed we can get the information how the condition of product should be. In the way to get the best specification by customer, it may have so many criteria whether from engineer, human resources department and also from user. There are so many criteria has been list then we need to optimize the as minimized possible. From other research there are many method have been done such as Fuzzy-Analytical Hierarchy Process method, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, High of Quality (HOQ) method in quality function development and more method but not mention here. In this research focused on fuzzy-AHP method.

There are several step that involve in decision making process:

i. Identify the problem
ii. Identifying decision criteria
iii. Allocating weight to criteria
iv. Developing alternatives
v. Analyzing alternatives
vi. Choosing the best alternative
vii. Evaluate decision effectiveness

The step above is to make the choosing on the best alternatives by identify the criteria. The criteria is weighing to evaluate which one is the best alternative that should be choose. Where the best alternative it has the highest weight compared with another alternatives. Besides that, in this research the similarity of criteria is be doing to make sure that all the alternative has the same criteria to make it fair selection.

## 2.4 REVIEW OF OTHER RESEARCHERS' WORK

There are related literature about design evaluation method in decision making process have been introduced to make decision making process fast. The idea in screening criteria for new product development with group of decision makers having imprecise, inconsistent and uncertain preference and this idea from Chin Chun Lo, Ping Wang and Kuang Shing Chao (2006) where them used idea-screening method integrated with vague set to treating the negative evidence. Cengkiz Kahraman, Gulcin Buyu kozhan and Nufer Yasin Ates (2006) they give idea to identify the nondominated of new product candidates and the selection of the best new product idea which to compose integrated approach on a fuzzy heuristic multi-attribute utility method and hierarchical fuzzy TOPSIS method. Improvement of effectiveness and objectivity of the design concept evaluation process by used integrated rough grey analysis. Zeki Ayag (2004) used fuzzy-AHP method to reduce a set of conceptual design alternatives by eliminating those whose scores are smaller than a predetermined constant value obtained under certain circumstance and also used hybrid method to evaluate the remaining alternatives from the fuzzy-AHP method. In this year (2014) Zeki Ayag again do the integrated approach to concept evaluation in a new product development in presence of many alternatives and selection criteria, the selection problem becomes a multiple-criteria decision making concept selection problem, he used the modified technique for order preference by similarity to ideal solution (TOPSIS) and the analytical network process (ANP).

In literature have been reviewed, there found that less researchers do design evaluation using integrated Fuzzy-AHP method with other method in developing product.

Most of them used sole method for doing decision making process in product development. The method have been decided doing this paper is using integrated Fuzzy-AHP.

## 2.4 INTEGRATED FUZZY-ANALITICAL HIERARCHY PROCESS

The new product development need the user opinion to give their specification about that product and this process named evaluation process. In this case it cannot be evaluate by only one person because different people has their own perspective. For this case study the responder that be evaluator are original equipment manufacturer, distributor, sales department, top management and manufacturer department. The form evaluation is taken about fifteen person for each department and the data that got will be average. The responders evaluate the designs by criterion that have been decide at early process.

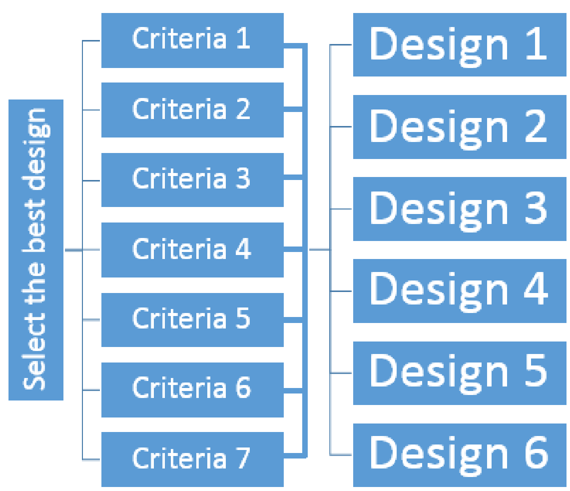



Figure 2.3: Analytical Hierarchical Process.

The Analytical Hierarchical process consider a set of evaluation of criteria and a set of alternative option among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that be the best option is the one which optimize each single criterion, rather the one which achieves the most suitable trade-off among the different criteria.

The concept of pair-wise comparison the hierarchy is represented in fuzzy. The decision making designer must to compare the element that has been give level on pair wise based on estimating the important relative on relation of the element to immediately proceed level. The fuzzy-AHP method is conduct the designer to reduce the alternative numbers. This method process use scale in weight is assuming to determine the value of low or high criteria. The step to make the scale as:

i. If the alternative number in between two and six, the value of constant is no need to use and to reduce the alternatives number.
ii. When the number alternatives is in between seven until twelve we must to discard any alternative that scores on less than 0.08.
iii. Lastly when the number in between thirteen until twenty-four we must discard the score with 0.05.

## 2.6 SUMMARY

The product development process is very difficult to obtain the lower cost and minimum in time marketing. According to lower cost and short time delivery the product objective we must do some collection of information from customer or user to make sure the customer satisfaction is accomplish. The fuzzy-AHP is help the designer to minimize the criteria that have been collected. However, the fuzzy-AHP only the method that used in limited range of application because the parameter already programmed in SIMAN application. By using the integrated fuzzy-AHP the decision making process can be improve.

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

This chapter explain the methodology involved to develop new product using design evaluation in making decision. Method is important on doing some work and by set correct method it will help the project success. The method use to achieve the objectives been set for this project. The main objective is to develop design evaluation for decision making using integrated Fuzzy-AHP. This method will help the decision makers to solve the problem during select the best design of product. Each designs are noted as alternatives where will be evaluate to select the best design.

## 3.2 FRAMEWORK

The proposed solution is to help decision makers to improve their decision making process of new product development on design evaluation where the evaluation process is effect the cost and time of the company. The flow chart in Figure 3.1 shown the process that will be follow to conduct the research. The general framework is picture in the flow chart, where the process is before to develop new product. These work has been doing on R & D department in multinational company in Ampang, Kuala Lumpur. By following the flow chart it allow the decision makers to focus on their own description hierarchy with differently criteria.

The data are collected by design engineer and they do the evaluation on designs and do choosing the criteria must be follow and the put in hierarchy. The data collected refer to appendix A. The design method of integration can be made using Fuzzy-AHP where will be discussed in section 3.1 show the step of Fuzzy-AHP.

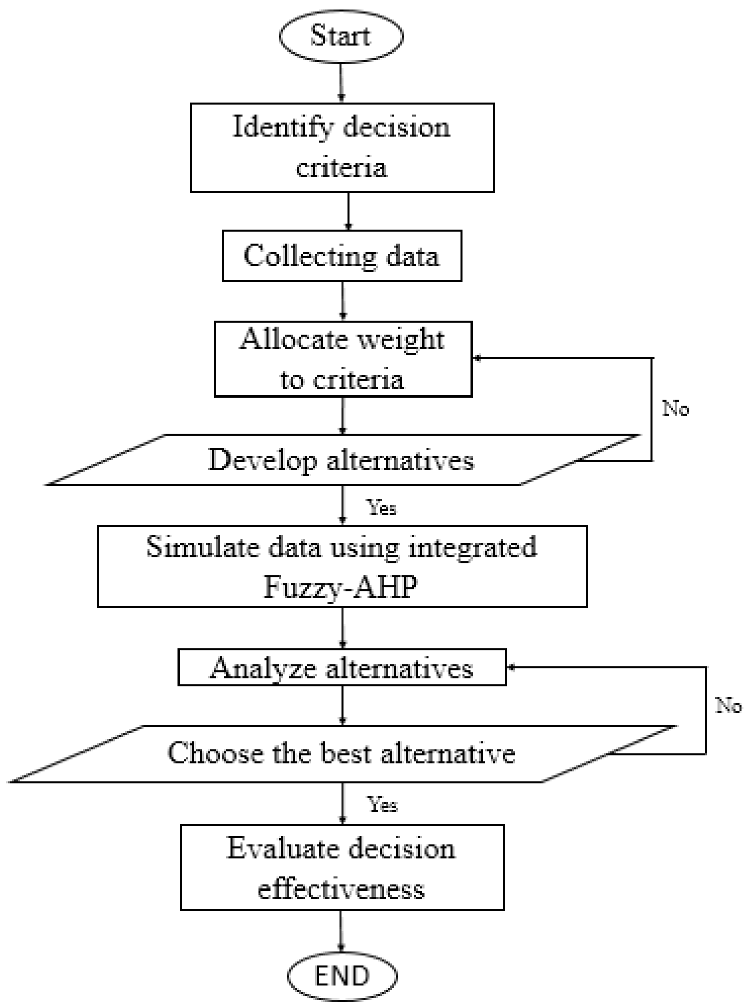



Figure 3.1: General propose framework approach.

### 3.2.1 Identify Decision Criteria

The criteria for evaluate each design must be set and the criteria must against to all designs. The set of criteria is shown on Table 3.1 and the responder will weighting the design based on criterion set.

Table 3.1: The criteria.

| Criteria | Description |
|---|---|
| $\hat{w}_1$ | Attractive design |
| $\hat{w}_2$ | Fulfill market standard |
| $\hat{w}_3$ | Price |
| $\hat{W}_4$ | Safety standard |
| $\hat{w}_5$ | Patent |
| $\hat{w}_6$ | Good performance |
| $\hat{w}_7$ | Fulfill environmental standard |

The $\hat{w}_1$ is note for criteria attractive design of the each design. The responder will look over to the knob whether it is good design or not. The fulfill market standard was noted as $\hat{w}_2$ and it meet market standard or not. Next for price there's noted as ŵ3, the price in this case study is not mentioned about the price because of company policy that should be followed. Then $\hat{w}_4$ noted for safety standard, $\hat{w}_5$ noted as patent, $\hat{w}_6$ noted as good performance and lastly is $\hat{w}_7$ noted as fulfill environmental standard. All the designs shown in Figure 3.2 will be evaluate based on stated criteria on Table 3.1.


Figure 3.2: Type of knob design as new product development.

### 3.2.2 Collecting Data

The data will collect by design engineer and the responder that will be evaluate the all design are OEM, distributor, sales, TOP management and manufacturing department. The responder will be evaluate on company industry and not involves outsider because this is company policy that should be followed. The evaluation form can refer to appendix A and there has six form to be evaluate because of design that have are six.

### 3.2.3 Allocate Weight to Criteria

The weighting scale used for give the value for responder to make evaluation. This is the easy way to numbering the perception of people thinking. The evaluator evaluate by 0 until 10 to show what they think about the design.

Table 3.2: Weighting criteria scale.

| Numerical rating | Description |
|---|---|
| 0 | Absolutely useless |
| 1 | Very inadequate |
| 2 | Weak |
| 3 | Tolerable |
| 4 | Adequate |
| 5 | Satisfactory |
| 6 | Good with few drawbacks |
| 7 | Good |
| 8 | Very good |
| 9 | Exceeding the requirement |
| 10 | Ideal |

### 3.2.4 Develop Alternatives

From figure 3.2 there's can see the alternative that developed to be evaluate. Each design represent as alternatives for this analysis process. For example design 1 represent the alternative 1 and same for all design.

### 3.2.5 Simulate Data Using Integrated Fuzzy-AHP

The fuzzy-AHP present the hierarchy pairwise comparison of selected concept must be done as first priority. When the hierarchy is constructed, the decision makers must to compare the element based on given pair-wise to estimate their relative importance in relative element at immediately level. In this case the design of product is be named as alternatives that want to evaluate then each alternative must be listed the characteristic to be evaluate. The eigenvector method corresponding to the pair-wise largest eigenvalue at matrix provides the priority factors and preference of preserves ordinal among the alternatives. That's mean if one alternative is preferred to another possibility, then the component of eigenvector is larger than other possibility. The weight vector is obtained from comparison matrix pair-wise that reflect to the various factor relative performance.

There are four step to evaluate using fuzzy-AHP.

Step 1: Build up and benchmarking the hierarchy structure model. The proposed of Fuzzy-AHP to provides a framework as first priority.

Step 2: Constructing the pair-wise comparison matrices (PCM) which is fuzzy comparison matrix. The pairwise comparison matrices need input from various layer of decision makers. Compared the relative importance of *Wi* (*i=1,2,3,4,5,6,7*) as general criteria because that's importance for the final decision making. Next level is comparison *Wij(∀i,j)* with respect to *Wi,* the element must be compare for each level according to their area as per preference given in table 3.1.

$$A = \begin{bmatrix} 1 & \frac{wv_1}{wv_2} & \frac{wv_1}{wv_3} & \frac{wv_1}{wv_4} \\ \frac{wv_2}{wv_1} & 1 & \frac{wv_2}{wv_3} & \frac{wv_2}{wv_4} \\ \frac{wv_3}{wv_1} & \frac{wv_3}{wv_2} & 1 & \frac{wv_3}{wv_4} \\ \frac{wv_4}{wv_1} & \frac{wv_4}{wv_2} & \frac{wv_4}{wv_3} & 1 \end{bmatrix} \tag{3.1}$$

Table 3.3: Scale of AHP pairwise comparison.

| Numerical rating | Evaluation scale | Description |
|---|---|---|
| 1 | Equal importance of both elements | Two elements contribute equally |
| 3 | Moderate importance of one element over another | Experience and judgment favor one over another |
| 5 | Strong importance of one element over another | An element strongly favored |
| 7 | Very strong importance of one element to another | An element is very strongly dominant |
| 2,4,6 | Intermediate value | Used to compromised between two judgment |

Step 3: Calculate the eigenvectors of elements using fuzzy-PCM. The eigenvector also known as element relative importance can calculated in various ways. After solve the characteristic matrix of equation of $\boldsymbol{A}$ ($\boldsymbol{A}$-$\boldsymbol{\lambda I}$) = 0 and then the bigger eigenvalue substitute into equation, $\boldsymbol{AX}=\boldsymbol{\lambda}_{\boldsymbol{max}}\boldsymbol{X}$. The relative is to determine the priority weight using following formula:

$$w_i = \frac{\sum_{i=1}^{I}\left(\frac{aij}{\sum_{j=1}^{J} aij}\right)}{J} \tag{3.2}$$

The relative importance for criteria $i$ is known as $w_i$. $J$ known as index number of the columns in the pairwise matrix, $I$ known as the index number of row in matrix of pairwise.

Check the consistency in judgment of decision makers by calculate $\boldsymbol{\lambda_{max}}$ and $\boldsymbol{CI}$ for all the pairwise comparison matrix shown as following where to find $\boldsymbol{\lambda_{max}}$:

$$\mathbf{Aw} = \boldsymbol{\lambda}_{\mathbf{max}}\mathbf{w} \tag{3.3}$$

where $\boldsymbol{A}$ is the pairwise matrix and $\boldsymbol{w}$ is the column of matrix.

Table 3.4: Average consistencies indexes of random matrices.

| Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.00 | 0.52 | 0.89 | 1.17 | 1.25 | 1.35 | 1.40 | 1.45 | 1.49 |

Table 3.2 shown the random index of each size of matrix that used in analyze data. In this case study there used six times six of matrix and the index of random number that use is 1.25. This random index used to check the consistency ratio of the criteria.

Determine the ***CI*** and ***CR*** with the formula below:

$$\boldsymbol{CI} = \frac{\boldsymbol{\lambda_{max} - n}}{\boldsymbol{n - 1}} \tag{3.4}$$

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \tag{3.5}$$

Depends on sizes of matrix ***n*** is random consistency index (***RI***) in appropriate value that choose to calculate ***CR***. If the ***CR*** and ***CI*** is less than 0.10, then the comparisons are acceptable, otherwise they are not acceptable.

Step 4: Calculate the overall priority for each alternatives. By considered the individual weight from secondary criteria calculate the total prioritization weight (***TW***) as represent below:

$$\boldsymbol{TW_{Ak}} = \sum_{\boldsymbol{k}} \boldsymbol{W_{Ui}} \times \boldsymbol{U_{Uij} W_{Ak}} \forall \boldsymbol{k} \tag{3.6}$$

Where, $\boldsymbol{W_{Ui}}$ is the general criterion important relative $\boldsymbol{Ui}$ that relevant to the secondary criteria $\boldsymbol{Uij}$.

### 3.2.6 Analyze alternative and choose the best alternative

After done analysis using Fuzzy-AHP, ranking for all design will be develop and there's can see the highest one. The highest one is the best design that get from data given or collected.

## 3.3 SUMMARY

After implement the methodology that have been set there can obtain result to analysis the data. The data was collected will use stated methodology to help design engineer.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.0 INTRODUCTION

The conducted methodology will generate results and from that results, the discussion will be define. The data was got from multinational company at Ampang, Kuala Lumpur. The data are shown in table where the data was get from evaluation by responder from department of OEM, department of distributor, department of sales, TOP management and manufacturing department. The evaluation are created to select the best design to be develop but the data need to go through analysis process first.

## 4.1 EVALUATION DATA

This project need collaboration from user to get the right design to be develop. They need to do the evaluation that based on criteria given as shown at table 4.1, 4.2, 4.3, 4.4, 4.5, 4.5, 4.6 and 4.7 and from evaluation there can get see the highest and lowest one.

Table 4.1: Evaluation results by OEM.

| Chosen criteria | OEM | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 2. Safety standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3. Patent | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 4. Fulfill environmental standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5. Attractive design | 6 | 6 | 6 | 4 | 6 | 6 | 6 |
| 6. Fulfill market standard | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 7. Universal | 7 | 5 | 5 | 3 | 5 | 7 | 7 |

Table 4.2: Evaluation results by distributor.

| Chosen criteria | Distributor | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 2. Safety standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3. Patent | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 4. Fulfill environmental standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5. Attractive design | 7 | 7 | 7 | 4 | 7 | 7 | 7 |
| 6. Fulfill market standard | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 7. Universal | 7 | 5 | 5 | 3 | 5 | 7 | 7 |

Table 4.3: Evaluation results by sales department.

| Chosen criteria | Sales | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 2. Safety standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3. Patent | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 4. Fulfill environmental standard | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 5. Attractive design | 6 | 6 | 6 | 4 | 6 | 6 | 6 |
| 6. Fulfill market standard | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 7. Universal | 7 | 5 | 5 | 3 | 5 | 7 | 7 |

Table 4.4: Evaluation results by top management.

| Chosen criteria | Top management | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 2. Safety standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3. Patent | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 4. Fulfill environmental standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5. Attractive design | 7 | 7 | 7 | 4 | 7 | 7 | 7 |
| 6. Fulfill market standard | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 7. Universal | 7 | 5 | 5 | 3 | 5 | 7 | 7 |

Table 4.5: Evaluation results by manufacturing department.

| Chosen criteria | Manufacturing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 2. Safety standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 3. Patent | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 4. Fulfill environmental standard | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5. Attractive design | 7 | 7 | 7 | 4 | 7 | 7 | 7 |
| 6. Fulfill market standard | 7 | 5 | 5 | 4 | 5 | 7 | 7 |
| 7. Universal | 7 | 5 | 5 | 3 | 5 | 7 | 7 |

## 4.2 AVERAGE OF EVALUATION

The evaluation data given must to calculate the average for each evaluator and also by each design. Table 4.6 shown the summarization of the data to make easier to make analysis process.

Table 4.6: Average for each design.

| Criteria | Total | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Design 6 | Design 7 |
| 1. Mass and size | 7.0 | 5.0 | 5.0 | 4.0 | 5.0 | 7.0 | 7.0 |
| 2. Safety standard | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 3. Patent | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 |
| 4. Fulfill environmental standard | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 |
| 5. Attractive design | 6.6 | 6.6 | 6.6 | 4.0 | 6.6 | 6.6 | 6.6 |
| 6. Fulfill market standard | 7.0 | 5.0 | 5.0 | 4.0 | 5.0 | 7.0 | 7.0 |
| 7. Universal | 7.0 | 5.0 | 5.0 | 3.0 | 5.0 | 7.0 | 7.0 |

## 4.3 MATRICES OF EACH CRITERIA

From total data can build the matrix for each criteria. The matrix is used to doing the analysis data process because that one of method in doing this project.

Criteria 1: Mass and size

$$A_1 = \begin{bmatrix} 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 0.571 & 0.800 & 0.800 & 1.000 & 0.800 & 0.571 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \end{bmatrix}$$

Criteria 2: Safety standard

$$A_2 = \begin{bmatrix} 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \end{bmatrix}$$

Criteria 3: Patent

$$A_3 = \begin{bmatrix} 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \end{bmatrix}$$

Criteria 4: Fulfill environmental standard.

$$A_4 = \begin{bmatrix} 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \end{bmatrix}$$

Criteria 5: Attractive design

$$A_5 = \begin{bmatrix} 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 0.714 & 1.000 & 1.000 & 5.000 & 1.000 & 0.714 \\ 0.571 & 4.000 & 0.800 & 1.000 & 0.8 & 0.571 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \end{bmatrix}$$

Criteria 6: Fulfill market standard

$$A_6 = \begin{bmatrix} 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 0.714 & 1.000 & 1.000 & 5.000 & 1.000 & 0.714 \\ 0.571 & 4.000 & 0.800 & 1.000 & 0.800 & 0.571 \\ 0.714 & 1.000 & 1.000 & 1.250 & 1.000 & 0.714 \\ 1.000 & 1.400 & 1.400 & 1.750 & 1.400 & 1.000 \end{bmatrix}$$

Criteria 7: Universal

$$A_7 = \begin{bmatrix} 1.000 & 1.400 & 1.400 & 2.333 & 1.400 & 1.000 \\ 0.714 & 1.000 & 1.000 & 1.667 & 1.000 & 0.714 \\ 0.714 & 1.000 & 1.000 & 1.700 & 1.000 & 0.714 \\ 0.428 & 0.600 & 0.600 & 1.000 & 0.600 & 0.429 \\ 0.714 & 1.000 & 1.000 & 1.667 & 1.000 & 0.715 \\ 1.000 & 1.400 & 1.400 & 2.333 & 1.400 & 1.000 \end{bmatrix}$$

The matrices was develop to find the eigenvalue or eigenvector, consistency index and consistency ratio. From matrices also there can find the ranking of alternatives.

## 4.4 RESULTS

From the matrices for each criteria there can get the eigenvalue, consistency index and consistency ratio. Refer appendix C. There are the result below that computed:

Table 4.7: Prioritisation weight of alternatives summary for case study.

| Criteria | λmax | C.I. | C.R |
|---|---|---|---|
| 1. Attractive design | 6.001 | 0.0003 | 0.0002 |
| 2. Fulfill market standard | 6.003 | 0.0006 | 0.0005 |
| 3. Price | 6.013 | 0.0027 | 0.0022 |
| 4. Safety standard | 5.988 | -0.0024 | -0.0019 |
| 5. Patent | 5.988 | -0.0024 | -0.0019 |
| 6. Good performance | 5.998 | -0.0003 | -0.0002 |
| 7. Fulfill environmental standard | 5.988 | -0.0024 | -0.0019 |

From pair-wise matrix analysis, the Table 4.7 was obtained and the result for each criteria was gain. All criteria in acceptable because the consistency ratio and consistency index of the criteria lower than 0.1.

Table 4.8: The alternatives ranking.

| Alternative relative important, TWak | Total Relative Important | Ranking |
|---|---|---|
| A1 | 0.12782 | 1 |
| A2 | 0.11290 | 4 |
| A3 | 0.10174 | 5 |
| A4 | 0.08042 | 6 |
| A5 | 0.11814 | 3 |
| A6 | 0.12775 | 2 |

The alternative ranking shown on Table 4.8. The ranking result was gained from appendix C and also get from matrix was build.

## 4.5 DISCUSSIONS

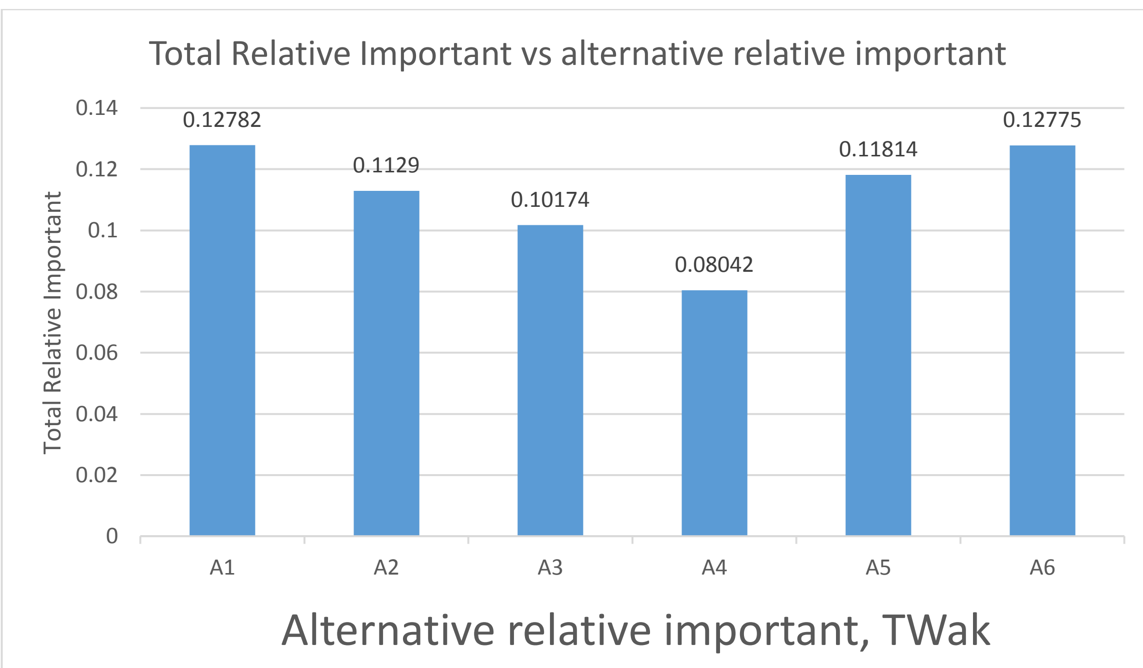



Figure 4.1: Graph for ranking of alternatives.

The suggested design evaluation using integrated fuzzy-AHP present the result of prioritization weight calculations for the alternatives with respect to the criteria. In this case study, the consistency index value for all the pairwise comparison matrices have been found to be less than 0.1 which means the all the criteria are consistent and acceptable for all alternatives.

The result shown at Table 4.8 suggested that alternative 1 which is design number 1 is the highest one, where the total relative important is 0.12782 compared with six others. The proposed method give the result from analysis process provide the value of the real problem in industry. The weight from evaluation for each criteria to each alternatives affect the ranking of the design from formulating the data given.

As we can see at Figure 5.1, there's show the different between alternative 1 and alternative 6 and the value is 0.12782 and 0.12775. The value is quite similar because the significant is have bit difference. Because of bit difference made designer hard to make the selection.

From analysis result there's shows the ranking which one the best design compared to six others. According to objectives for this project the decision making method was develop for design evaluation using integrated Fuzzy-Analytical Hierarchy Process. By method of design evaluation it can help design engineers to pick their best design by do select the best design concept. Thus this integrated Fuzzy-AHP will help the designer pick the best design and this project objective was achieved to help designer.

# CHAPTER 5

# CONCLUSION

The aim of this research is to develop decision making method for design evaluation using integrated Fuzzy-Analytical Hierarchy Process and also to help design engineers to finalise their choice by selecting the best design concept. Both are achieved where there has another option to designer can use to make decision making process. All criteria get their own consistency index, consistency ratio and eigenvalue, from the result the all criteria is accepted and consistent.

This project use integrated fuzzy-analytical hierarchy process as tool to generate best design. During conduct this project its focus only on first stage on product development which is idea screening and evaluation by doing decision making process. This stage given big impact to company because if the process evaluation can be conduct in short time so the product also can be production early and can be sale to market to gain profit.

During new product development process the data got from responder. The data is not have big different value compared each other because all the responder quite has same view on that criteria of product. So the data that have been analysis is supposed to variant and from that there can get different value of eigenvalue, consistency index and consistency ratio to be analysis. The results develop from data it just because the responder doesn't has a variation thought about the product that want to be produce. The quite similar data causes the result not has big different value between each design.

Based on the analyze result, it can be concluded that this method will help designer make the decision making process using integrated Fuzzy-Analytical Hierarchy Process. The design engineer also can finalise the choice by made selecting the best design concept of this case study. The objective this project was achieved.

A decision maker can use this integrated Fuzzy-AHP to analyze the data collected for each design and be evaluate by stated criterion. This method helped the designer to achieve the desired design to be develop. For this case study the designer get the desired one after produce the ranking of the alternatives or design. From the ranking the design that fit customers satisfaction. In future research, the design engineer need to collect the data from many group of responder to get the variant data. In this case study the responder could not be evaluate by user from outside company because the undeveloped product should not be show to user and it is because company policy.

## REFEERENCES

Zeki Ayag. (2014). An integrated approach to concept evaluation in a new product development.

Zeki Ayag. (2004). A fuzzy AHP-based simulation approach to concept evaluation in NPD environment.

Niromi Seram. (2012). Decision making in product development- A review of the literature,. International Journal of Engineering and Applied Sciences.

Yejun Xu, Kevin W.Li, Huimin Wang. (2013). Distance-based consensus model and multiplicative preference relations,. Science Direct.

Susan Finger and John R. Dixon. (1989). A Review of Research in Mechanical Engineering Design. Part II; Representations, Analysis and Design for the Life Cycle.

Wade D. Cook, Moshe Kress, Lawrence M.Seiford. (1995). Theory and Methodology of A General framework for distance-based consensus in ordinal ranking models.

Yu-Cheng Tang and Malcolm J. Beynon. (2005). Application and Development of a Fuzzy Analytic Hierarchy Process within a Capital Investment Study. Journal of Economics and Management.

Oliver Meixner(2011). Fuzzy ahp group decision analysis and its application for the evaluation of energy sources.

Xiaojun Wang, Hing Kai Chan, Dong Li (2014). A case study of an integrated fuzzy methodology for green product Development. European Journal of Operational Research.

Mohd Azroy Mohd Razikin, Hambali Arep @ Ariff, Ab Rahman Mahmood, Isa Halim (2013). The use of analytical hierarchy process (ahp) in product Development process. Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.

# APPENDIX A

## DESIGN EVALUATION FORM

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 1 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.

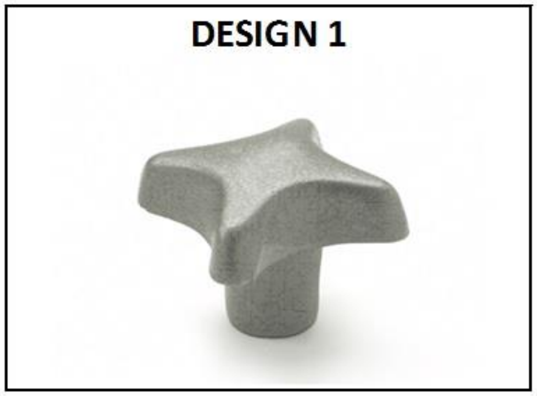



**Figure 1**: Knob for design 1

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

**DESIGN EVALUATION FORM**

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 2 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.


**Figure 2**: Knob for design 2

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

**DESIGN EVALUATION FORM**

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 3 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.


**Figure 3**: Knob for design 3

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

**DESIGN EVALUATION FORM**

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 4 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.


**Figure 4**: Knob for design 4

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

**DESIGN EVALUATION FORM**

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 5 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.

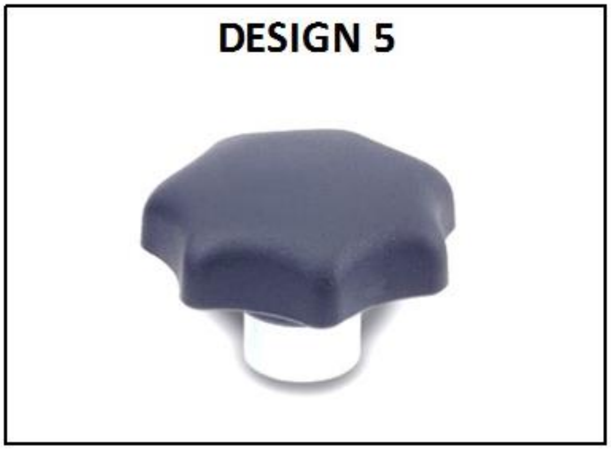



**Figure 5**: Knob for design 5

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

**DESIGN EVALUATION FORM**

The following is criteria to evaluate the design on figure 1 below. Based on figure of design 6 what do you think the given criterion is good or not good? The no of 0 until 10 is scale that to be use to your evaluation and the description is shown on below.


**Figure 6**: Knob for design 6

The scale description for evaluation:

0: Absolutely useless
1: Very inadequate
2: Weak
3: Tolerable
4: Adequate
5: Satisfactory
6: Good with few drawbacks
7: Good
8: Very good
9: Exceeding the requirement
10: Ideal

| Criterion | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Attractive design | | | | | | | | | | | |
| 2. Fulfil market standard | | | | | | | | | | | |
| 3. Price | | | | | | | | | | | |
| 4. Safety standard | | | | | | | | | | | |
| 5. Patent | | | | | | | | | | | |
| 6. Good performance | | | | | | | | | | | |
| 7. Fulfil environmental standard | | | | | | | | | | | |

# APPENDIX B

## RAW DATA

Table B1: Average data from OEM department.

| Criteria | OEM | | | | | |
|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 | #6 |
| Attractive design (ŵ1) | 6 | 6 | 6 | 3 | 6 | 6 |
| Fulfill market standard (ŵ2) | 7 | 5 | 5 | 3 | 5 | 7 |
| Price (ŵ3) | 6 | 5 | 3 | 3 | 5 | 6 |
| Safety standard (ŵ4) | 5 | 5 | 5 | 5 | 5 | 5 |
| Patent (ŵ5) | 5 | 5 | 5 | 5 | 5 | 5 |
| Good performance (ŵ6) | 5 | 5 | 5 | 3 | 6 | 5 |
| Fulfill environmental standard (ŵ7) | 5 | 5 | 5 | 5 | 5 | 5 |

Table B2: Average data from Distributor department.

| Criteria | Distributor | | | | | |
|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 | #6 |
| Attractive design (ŵ1) | 7 | 7 | 7 | 3 | 7 | 7 |
| Fulfill market standard (ŵ2) | 7 | 5 | 5 | 3 | 5 | 7 |
| Price (ŵ3) | 7 | 5 | 3 | 3 | 5 | 7 |
| Safety standard (ŵ4) | 5 | 5 | 5 | 5 | 5 | 5 |
| Patent (ŵ5) | 5 | 5 | 5 | 5 | 5 | 5 |
| Good performance (ŵ6) | 5 | 5 | 5 | 3 | 7 | 5 |
| Fulfill environmental standard (ŵ7) | 5 | 5 | 5 | 5 | 5 | 5 |

Table B3: Average data from Sale department.

| Criteria | Sales | | | | | |
|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 | #6 |
| Attractive design (ŵ1) | 6 | 6 | 6 | 3 | 6 | 6 |
| Fulfill market standard (ŵ2) | 7 | 5 | 5 | 3 | 5 | 7 |
| Price (ŵ3) | 6 | 5 | 3 | 3 | 5 | 6 |
| Safety standard (ŵ4) | 5 | 5 | 5 | 5 | 5 | 5 |
| Patent (ŵ5) | 6 | 6 | 6 | 6 | 6 | 6 |
| Good performance (ŵ6) | 5 | 5 | 5 | 3 | 6 | 5 |
| Fulfill environmental standard (ŵ7) | 4 | 4 | 4 | 4 | 4 | 4 |

Table B4: Average data from TOP management department.

| Criteria | Top management | | | | | |
|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 | #6 |
| Attractive design (ŵ1) | 7 | 7 | 7 | 3 | 7 | 7 |
| Fulfill market standard (ŵ2) | 7 | 5 | 5 | 3 | 5 | 7 |
| Price (ŵ3) | 5 | 4 | 3 | 3 | 4 | 5 |
| Safety standard (ŵ4) | 5 | 5 | 5 | 5 | 5 | 5 |
| Patent (ŵ5) | 5 | 5 | 5 | 5 | 5 | 5 |
| Good performance (ŵ6) | 5 | 5 | 5 | 3 | 7 | 5 |
| Fulfill environmental standard (ŵ7) | 5 | 5 | 5 | 5 | 5 | 5 |

Table B5: Average data from manufacturing department.

| Criteria | Manufacturing | | | | | |
|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | #5 | #6 |
| Attractive design (ŵ1) | 7 | 7 | 7 | 3 | 7 | 7 |
| Fulfill market standard (ŵ2) | 7 | 5 | 5 | 3 | 5 | 7 |
| Price (ŵ3) | 7 | 5 | 3 | 3 | 5 | 7 |
| Safety standard (ŵ4) | 5 | 5 | 5 | 5 | 5 | 5 |
| Patent (ŵ5) | 5 | 5 | 5 | 5 | 5 | 5 |
| Good performance (ŵ6) | 5 | 5 | 5 | 3 | 6 | 5 |
| Fulfill environmental standard (ŵ7) | 5 | 5 | 5 | 5 | 5 | 5 |

## APPENDIX C

## COMPUTED DATA

Table of Dummy attribute ratings charts.

| Matrix | | | | | | | Wak | I | II | λmax | C.I. | C.R. | REQ. WEI | REL. IMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 = | 1.000 | 1.000 | 1.200 | 2.200 | 1.000 | 1.000 | 0.190 | 1.136 | 6.005 | 6.001 | 0.000284 | 0.000227 | 0.232 | 0.069 |
| | 1.000 | 1.000 | 1.200 | 2.200 | 1.000 | 1.000 | 0.189 | 1.136 | 6.005 | | | | | |
| | 0.833 | 0.833 | 1.000 | 1.833 | 0.833 | 0.833 | 0.158 | 0.946 | 5.987 | | | | | |
| | 0.455 | 0.455 | 0.545 | 1.000 | 0.455 | 0.455 | 0.086 | 0.516 | 6.000 | | | | | |
| | 1.000 | 1.000 | 1.200 | 2.200 | 1.000 | 1.000 | 0.189 | 1.136 | 6.005 | | | | | |
| | 1.000 | 1.000 | 1.200 | 2.200 | 1.000 | 1.000 | 0.189 | 1.136 | 6.005 | | | | | |
| W2 = | 1.000 | 1.400 | 1.400 | 2.333 | 1.400 | 1.000 | 0.219 | 1.313 | 5.995 | 6.003 | 0.000623 | 0.000498 | 0.378 | 0.113 |
| | 0.714 | 1.000 | 1.000 | 1.667 | 1.000 | 0.714 | 0.156 | 0.938 | 6.013 | | | | | |
| | 0.714 | 1.000 | 1.000 | 1.667 | 1.000 | 0.714 | 0.156 | 0.938 | 6.013 | | | | | |
| | 0.429 | 0.600 | 0.600 | 1.000 | 0.600 | 0.429 | 0.094 | 0.563 | 5.989 | | | | | |
| | 0.714 | 1.000 | 1.000 | 1.667 | 1.000 | 0.714 | 0.156 | 0.938 | 6.013 | | | | | |
| | 1.000 | 1.400 | 1.400 | 2.333 | 1.400 | 1.000 | 0.219 | 1.313 | 5.995 | | | | | |
| W3 = | 1.000 | 1.292 | 2.067 | 2.067 | 1.292 | 1.000 | 0.221 | 1.329 | 6.014 | 6.013 | 0.002698 | 0.002158 | 0.391 | 0.116 |
| | 0.774 | 1.000 | 1.600 | 1.600 | 1.000 | 0.774 | 0.171 | 1.029 | 6.018 | | | | | |
| | 0.484 | 0.625 | 1.000 | 1.000 | 0.625 | 0.484 | 0.107 | 0.643 | 6.009 | | | | | |
| | 0.484 | 0.625 | 1.000 | 1.000 | 0.625 | 0.484 | 0.107 | 0.643 | 6.009 | | | | | |
| | 0.774 | 1.000 | 1.600 | 1.600 | 1.000 | 0.774 | 0.171 | 1.029 | 6.018 | | | | | |
| | 1.000 | 1.292 | 2.067 | 2.067 | 1.292 | 1.000 | 0.221 | 1.329 | 6.014 | | | | | |

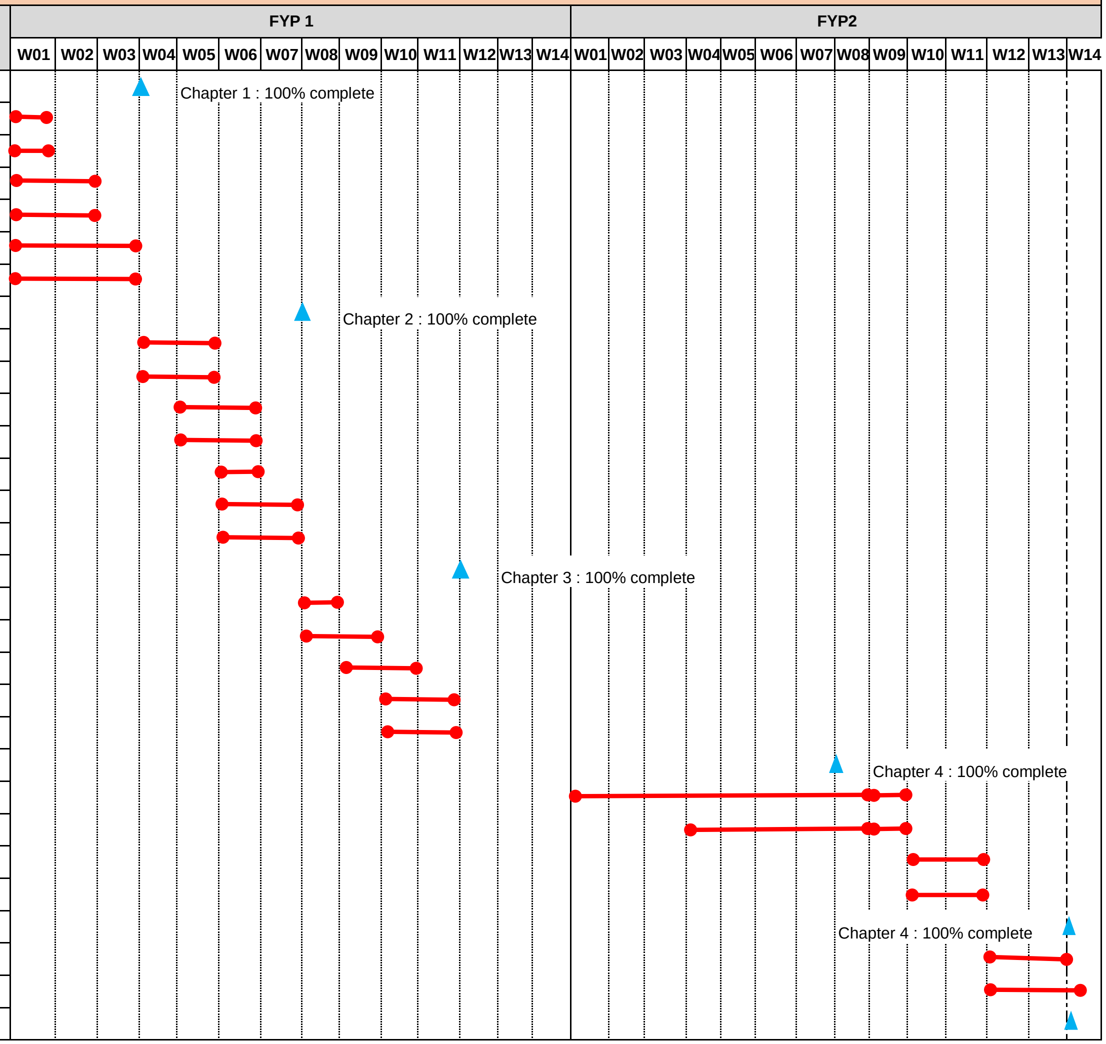
| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W4 = | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | 5.988 | -0.0024 | -0.00192 | 0.376 | 0.112 |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| W5 = | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | 5.988 | -0.0024 | -0.00192 | 0.414 | 0.123 |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| W6 = | 1.000 | 1.000 | 1.000 | 1.667 | 0.781 | 1.000 | 0.170 | 1.020 | 6.000 | 5.998 | -0.00031 | -0.00024 | 0.566 | 0.169 |
| | 1.000 | 1.000 | 1.000 | 1.667 | 0.781 | 1.000 | 0.170 | 1.020 | 6.000 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.667 | 0.781 | 1.000 | 0.170 | 1.020 | 6.000 | | | | | |
| | 0.600 | 0.600 | 0.600 | 1.000 | 0.469 | 0.600 | 0.102 | 0.612 | 6.000 | | | | | |
| | 1.280 | 1.280 | 1.280 | 2.133 | 1.000 | 1.280 | 0.218 | 1.306 | 5.991 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.667 | 0.781 | 1.000 | 0.170 | 1.020 | 6.000 | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 = | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | 5.988 | -0.0024 | -0.00192 | 1.000 | 0.298 |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |
| | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.167 | 1.000 | 5.988 | | | | | |

APPENDIX D

**FINAL YEAR PROJECT (FYP) 2014-2015**

**Tittle:Application of Integrated Fuzzy-AHP for Design Evaluation in Product Development**




| Task No. | Task Description |
|---|---|
| 1 | CHAPTER 1:INTRODUCTION |
| 1.1 | Determine what to do |
| 1.2 | Problem formulation |
| 1.3 | Selecting a problem (establish selecting criteria) |
| 1.4 | Identifying the variables (describe particular characteristic) |
| 1.5 | Evaluating the problem (feasibility check) |
| 1.6 | Hypothesis |
| 2 | CHAPTER 2 : LITERATURE REVIEW |
| 2.1 | Define idea in general terms using general sources |
| 2.2 | Compile a list of key words & term |
| 2.3 | Search through the secondary sources |
| 2.4 | Search through the primary sources |
| 2.5 | Collect materials of previous work |
| 2.6 | Study and understand those revelant materials |
| 2.7 | Organize the notes |
| 3 | CHAPTER 3: RESEARCH METHODOLOGY |
| 3.1 | Identifying the method of research |
| 3.2 | Specify the subject of study |
| 3.3 | Select an adequate representative sample of subjects |
| 3.4 | Construct valid & reliable tool for measuring the variables |
| 3.5 | Select a research design and describe the procedure |
| 4 | CHAPTER 4: RESULT & DISCUSSION |
| 4.1 | Collecting data |
| 4.2 | Analysis & interpreting result |
| 4.3 | Modification (if necessary) |
| 4.4 | Discussion |
| 5 | CHAPTER 5: CONCLUSION & RECOMMENDATION |
| 5.1 | Conclusion |
| 5.2 | Suggestions for futher work |
| 6 | Final Year Project End |