DESIGN FOR ASSEMBLY AND APPLICATION USING HITACHI ASSEMBLABILITY EVALUATION METHOD

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I acknowledge without endless love and relentless support from my family, I would not have been here. My father, mother, sisters and brother that always support and encourage me to success.

ABSTRACT

This project is described about application of Hitachi Assemblability Method (AEM) in Design for Assembly. Using this method, in the early design stage, product design quality is analyzed quantitatively and weakness in the design's assembly producibility are highlighted. The AEM is belongs to class of "point of" methods. The "perfect" part or assembly operation gets the maximum score, usually one hundred, and each element or difficulty is assigned a penalty. The main objective of this project are to determine and calculate the score of AEM for part (E_i) and the product AEM (E) score and also to redesign the current design using application of Hitachi Assemblability Evaluation Method(AEM). Mini radio was chosen as a product in order to accomplish the objective of Design for Assembly using application of Hitachi Assemblability Evaluation Method. The product was chosen because it has a high demand in the market. The mini radio need to disassemble to identified total number of part that contains to produce a whole mini radio. The disassemble part then, need to modeling in 3D using solidworks to show the explode view of the product. Improvement of product (redesign) also need to modeling in 3D using solidworks. Calculate of the score for reducing part and also the whole product by adding up the penalty for each process. The score need to do judgment either it obey the desirable value (above 80) or not. The score of AEM for part and product need to tabulate to give a clear view in order to achieve the main objective of this project to come out with the score. From this project, the component of mini radio have been reduce from 21 part to 16 part by combining some component that made from same material and not necessary component become one part. The assembly efficiency also has increase after modification. The significance of this project is, AEM score part and product can be determined and some of unknown penalty can be determine by reverse calculation. Enable to reduce part attaches in assembly process using application of Hitachi Assemblability Evaluation Method.

ABSTRAK

Projek ini menerangkan mengenai pengunaan *Hitachi Assembly Evaluation Method* dalam *Design for Assembly.* Mengunakan cara ini pada peringkat permulaam lakaran, kualiti lakaran produk dan yang berkenaan boleh dianalisis dan kelemahan lakaran produk boleh dikenalpasti. Cara ini tergolong dalam cara "*Point* of". Kebiasaannya, permasagan yang sempurna akan diberi markah sebanyak seratus peratus dan setiap kesulitan dalam proses pemasagan akan dikenakan denda. Tujuan utama projek ini adalah untuk menentukan skor AEM untuk bahagian atau kompenan dan skor AEM untuk produk serta mengubahsuai reka bentuk sedia ada dengan mengunakan konsep *Hitachi Assembleability Evaluation Method (AEM)*. Produk yang dipilih untuk mencapai matlamat projek ini ialah radio mini. Produk ini dipilih kerana permintaan yang tinggi dalam pasaran. Radio mini perlu dihuraikan untuk mengetahui jumlah komponen yang terlibat dalam penghasilan radio mini. Produk yang telah dihuraikan perlu diunjurkan lukisan 3D mengunakan perisian solidworks untuk menunjukkan pecahan kompenan dalam produk mini radio. Unjuran lukisan 3D juga perlu untuk produk yang telah diubahsuai dan dibangunkan mengunakan perisian solidworks. Pengiraan skor untuk pengurangan komponen dan produk keseluruhannya dengan menambah penalti bagi setiap proses yang dilakukan. Skor yang diperolehi dinilai samada memenuhi nilai yang ditetapkan iaitu melebihi 80 atau tidak. Skor yang diperolehi dijadualkan untuk memberikan tafsiran yang jelas tentang objektif yang ditetapkan. Daripada projek ini jumlah kompenan dalam radio mini dapat dikurangkan daripada 21 kompenan kepada 16 kompenan dengan menyatukan kompenan yang terdiri dari bahan yang sama dan tidak mempunyai kepentingan. Sementara itu peratus keberkesanan produk juga telah meningkat selepas pengubahsuaian. Signifikasi daripada projek ini, skor AEM untuk komponen dan produk dapat ditentukan dan beberapa penalti yang tidak diketahui dapat juga ditentukan. Jumlah komponen dalam penghasilan radio mini dapat dikurangkan dengan mengunakan kaedah *Hitachi Assembleability Evaluation Method.*

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DFA	Design For Assembly
AEM	Assemblability Evaluation Method
UMP	Universiti Malaysia Pahang
Assy	Assembly
Effy	Efficiency

CHAPTER 1

INTRODUCTION

1.1 Introduction

Home appliance is one of the products that highly demand in the market nowadays. The change of the technology also changes the features of the home appliance product. In modern era nowadays, we can see how technology has change a lot of home appliance design and features in a market. The home appliance product in the market nowadays is more compact, light and user friendly and also in the same time offers the best price that affordable to buy. It's become a challenge to industry especially manufacturing industry that assembled home appliance product.

Industry that involves in production and assembly the home appliance product should be more competitive and creative in producing home appliance product in the same time can reduce the cost of assemble and also can reduce time of assembly. Therefore, design for assembly becomes a core for industry to improve the product and maintain the quality.

1.2 Project Background

The purposes of Design for Assembly (DFA) are to make the process of fabrication and assembly easier, reduce of cost, and simplify the product and also to make the product more reliable. If engineers can carry out their design in order to achieve Design for Assembly (DFA) analysis, they can protect product function and will learn that there is little chance that function will be seriously impaired.

There are several methods that widely use in industry to achieve Design for Assembly (DFA). The most widely use in industry nowadays is Boothroyd Dewhurst method, Hitachi Assembly Evaluation Method and Lucas Hull method. However, in this project is only focus on Design for Assembly using Hitachi Assembleability Evaluation Method (AEM).

The case study of this project is more on analysis a mini radio and improving the design. The target of this analysis is to evaluate score of AEM for each part and score of AEM for the product. The product was chosen because mini radio is home appliance that people always use in their daily life and still have a chance for design improvement.

1.3 Problem Statement

Design for Assembly is a tool for industry to reduce time and cost of assembly product in the same time can improve the quality of the product. Design for Assembly as the basic concurrent engineering studies to provide guidance to the design team in simplifying the product structure, to reduce manufacturing and assembly cost, and to quantify the improvement because before this most of them using an over the wall approach. Design for assembly also as a benchmarking tool to study competitor's products and quantify manufacturing and assembly difficulties. Therefore, this project focus on redesign current mini radio and reducing the part attaches except the electronic component.

1.4 Project Objective

The aims of this project are to:

1. Determine and calculate the part AEM scores (E_i) and the product AEM (E) score.
2. Redesign the current product by using application of Hitachi Assemblability Method.

1.5 Scope of study

The scopes of study are proposed in order to achieve the objective of this project:

1. Literature recitation on Design for Assembly (DFA) and various method of DFA like Boothroyd Dewhurst, Hitachi Assemblability Evaluation Method and Lucas Hull Method.
2. Gather the information about mini radio:
   i) Determine the each component function and total of the component to make finish product.
   ii) Determine the dimension of the current design and all the part.
   iii) 3D modeling using solidworks software for current design and improve design.
3. Evaluate the AEM score for the part and product based on Hitachi Assembleability Method.
4. Tabulate the finding for part and product AEM score to give a clear view about the improvement design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide information and review about the Design for Assembly (DFA) and the past research about Design for Assembly using various methods such as Boothroyd Dewhurst DFA, Hitachi Assembleabilty Evaluation Method (AEM) and Lucas Hull DFA.

2.2 Design for Assembly (DFA)

Design is a complex iterative creative process that begin with the recognition of a need desire and terminates with a product or process that uses available resources, energy and technology to fulfill the original need within some set of defined constraint. Assembly is a process of joining components into complex product.

Design For Assembly (DFA) is an approach to reduce the cost and time of assembly by simplifying the product and process through such means as reducing the number of parts, combining two part into one part, reducing or eliminating adjustments, simplifying assembly operations, designing for part handling, selecting fasteners for ease of assembly and minimizing parts tangling.

The purposes of DFA are to design a product for easy and economical production and also incorporate product design early in the design phase. Beside that, by using Design for Assembly we can improve quality, reduces cost and shortens time to design and manufacture.

2.3 Basic Approaches for implementing Design for Assembly

There are four basic approaches for implementing Design for Assembly (DFA) that have been identified which is design principles and rules, Quantitative evaluation procedures, Expert/ knowledge-based approach, Computer-Aided DFA methods

I. Design principles and rules

Design principles and rules are more based on human oriented knowledge. It also involve Collectively design data and convert assembly knowledge to design principles, rules and guidelines.

II. Quantitative evaluation procedures

It is based on evaluation procedure and also need to determine the assembly process operation by operation. Then, all the quantitative measured is calculated.

III. Expert/ knowledge-based approach

Expert or knowledge-based approach is based on knowledge and technology. It is a knowledge base, inference, communication and knowledge acquisition.

IV. Computer- Aided DFA methods

Design for Assembly (DFA) systems are integrated with CAD software. The purpose is the representation of technical objects and procedures for extraction and processing of assemblability attributes from 3D CAD models.

2.4 Design For Assembly (DFA) Guidelines

I. **Aim for simplicity**

The aim for simplicity is more focuses on minimize part numbers, part variety, assembly surface; simplify assembly sequences, component handling and insertion.

This is to make all the process in assembly faster and more reliable.

II. **Standardizes**

The purpose of this guidelines is to standardizes on material usage, components and aim as much off-the-shelf component as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes.

III. **Rationalizes product design**

Rationalizes product design is to standardize on materials, components and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. It also employs modularity to allow variety to be introduced late in the assembly sequence and simplify JIT production.

IV. **Use the widest possible tolerance**

By using the widest possible tolerance we can reduce the tolerance on non-critical components and thus reduce operations, and process times.

V. **Choose materials to suit function and production process**

Avoid choosing materials purely for functional characteristics and material choice must also favour the production process to ensure product reliability.

VI. Minimize non-value adding operations

The minimization of handling, excessive finishing and inspection will reduce costs and lead time.

VII. Design for process

Take advantage of process capability to reduce unnecessary components or additional processing such as the porous of nature of sintered component for lubricant retention. Besides that we need to design in features and functions to overcome process limitation, such as features to aid mechanical feeding. Design for process also needed to avoid unnecessary restriction of process to allow manufacturing flexibility process planning.

2.5 Various Method of Design for Assembly

There are various methods that have been using in Design for Assembly in industry nowadays such as:

- The DFA method exploited by Boothroyd Dewhurst Inc, USA
- The Hitachi Assemblability Evaluation Method (AEM) by Hitachi Ltd, Japan
- The Lucas Design for Assembly Methodology by Lucas-Hull, UK.

2.5.1 Boothroyd Dewhurst Method

Boothroyd and his colleagues, Swift and Redford was the first who analyzed automatics parts feeder such as vibratory bowls. Design of these items is more an art than a science, and boothroyd realized that some part are harder to feed automatically than others for reasons that could be avoided if part designers had more information. He then turned to manual assembly and identified two main phases of single assembly, namely handling (which includes grasping and orienting) and insertion. Each of these is also affected by part design.

Assembly Efficiency for Manual Assembly:

$$= \frac{3}{}$$

Where:

NM= theoretical minimum number of part

TM= total manual assembly time

2.5.2 Hitachi Assemblability Evaluation Method

The Assemblability Evaluation Method (AEM) is an effective tool developed by Hitachi Ltd. to improved design quality for better assembly producibility. The AEM has been widely used by the Hitachi Group as well as by more than 20 other well known companies around the world. Using this method, in the early design stage, product design quality is analyzed quantitatively and weakness in the design's assembly producibility are highlighted. In addition, the effects of design improvement are confirmed with respect to assembly cost.

Miyakawa, Iwata and Ohashi who have done research on the Hitachi Assemblability Evaluation Method said that the AEM is belongs to class of "point of" methods. Miyakawa and his colleague also said that in this method, the "perfect" part or assembly operation gets the maximum score, usually one hundred, and each element or difficulty is assigned a penalty. There are twenty different operational circumstances, each with its own penalty. Each circumstance is accompanied by simple icon for identification, permitting the method to be applied easily with little training.

Based on Miyakawa and his colleagues, he said that the method is applied manually or with the aid of commercially available software. When a part or operation is fully evaluated, all the penalties are added up and subtracted from one hundred. If the score is less than some cut off value, say eighty, the operation or part is to be subjected to analysis to improves its score. The penalties and time estimates have been refined based on the experience of the entire Hitachi Corporation, which makes a wide range of consumer and industrial goods such as camcorders, television sets, microwave ovens, automobile components, and nuclear power stations.

The evaluation takes place in two stages. First, each operation is evaluated, yielding an evaluation score E_i for operation. If several operations are required on one part, an average score E is calculated. The score for the entire product is either the sum of all the individual part scores or the average of the part scores. In either case, it is possible that an assembly with fewer parts will have a higher score simply because fewer penalties are available to reduce it. In this case, the method clearly states, "reduction in part count is preferable to better score." However, the method does not include a systematic way of identifying which part might be eliminated.

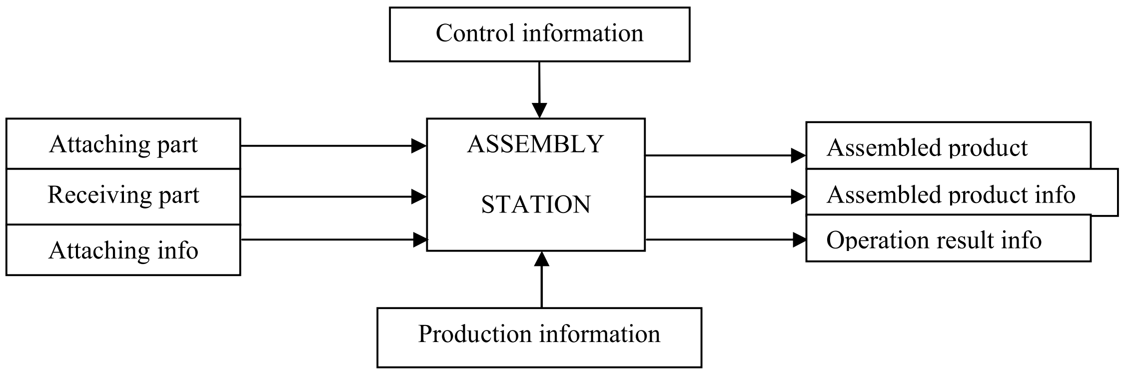


Figure 2.1: Assembly process

2.5.2.1 Basic process of evaluation index calculation

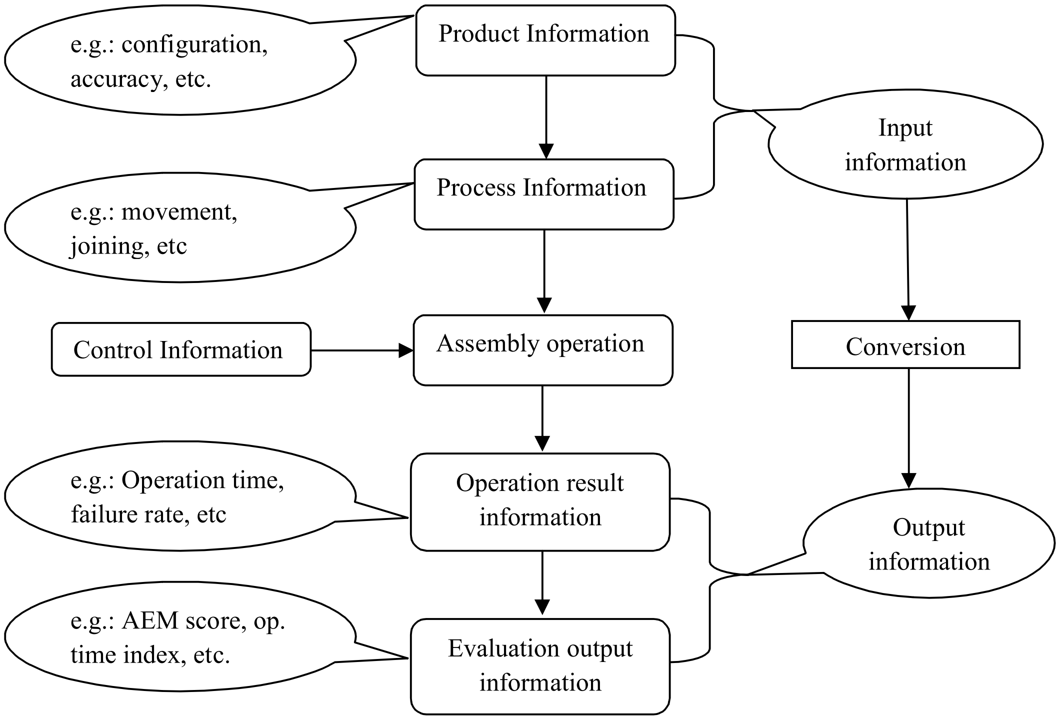


Figure 2.2: Process of evaluation

The basic information processing scheme of the evaluation system shown in Fig. 2 means the follows:

(a) Attaching operation time for a part is expressed as a function of basic and supplementary element coefficients.

(b) Using the estimated part attachment time value, the part AEM score is calculated. The product AEM score is calculated as the average value of the part AEM scores.

2.5.2.2 Calculation formulas for the evaluation

i. Calculation of part attachment cost and time

For a part "*i*", the attachment time ${}_aT_i$ and attachment cost ${}_aC_i$ are expressed by the following equation.

$${}_aT_i = \sum {}_aT_{ij}$$

$${}_aC_i = {}_aA \cdot {}_aT_i$$

Where:

${}_aA$: shop rate of the assembly shop where part "*i*" is attached

${}_aT_{ij}$: attaching time of part "*i*". (A part is attached by multiple operations sometimes such as "movement and joining". Subscripted prefix "$_a$" denotes "assembly".

The attachment time for the *j*th operation of part "*i*" can also be expressed as follows:

$${}_aT_{ij} = f_1 \text{ (design factor, production environment factor)}$$

Where:

"Design factor" is a factor that influences attaching operation time.

${}_aT_{ij} = f_2$ (basic coefficient, supplementary coefficient, production environment factor)

$= f_3$ (structure coefficient)$\cdot {}_aT_{oi} = {}_aD_{ij} \cdot {}_aT_{oi}$

Where:

${}_aT_{oi}$: shop basic assembly time, a constant that reflect the average operation speed of the shop.

${}_aD_{ij}$: structural coefficient that indicates the assembly operation complexity.

ii. Determination of design factors and basic elements

The estimated attachment time ${}_aT_{ij}$ for the *j*th operation of part "*i*" and ${}_aT_i$ for part "*i*" are defined as follows:

$${}_aT_{ij} = {}_aT_{oi} \cdot f_3({}_a\beta_{ii}, {}_a\lambda_{ij}, {}_a\mu_{ij}, {}_a\theta_{ij}, {}_a\gamma_{ij})$$

$${}_aT_i = {}_aT_{oi} \cdot \sum f_3({}_a\beta_{ii}, {}_a\lambda_{ij}, {}_a\mu_{ij}, {}_a\theta_{ij}, {}_a\gamma_{ij})$$

Where:

${}_a\beta_i$: Basic coefficient for the *j*th operation of the part "*i*". For (↓), 1 is given.

${}_a\lambda_{ij}$: size coefficient for the *j*th operation of the part "*i*". For the standard size, 1 is given.

${}_a\mu_{ij}$: dimensional accuracy coefficient for the *j*th operation of part "*i*".

${}_a\theta_{ij}$: configurational and orientational accuracy coefficient for the *j*th operation of part "*i*"

iii. Calculation of AEM score

The part AEM Score ${}_aE_i$ is defined so that it decrease when the attaching difficulty of a part, i.e., assembly operation cost ${}_aC_i$, or operation time ${}_aT_i$ increase. More concretely, "part AEM Score ${}_aE_i$" for the part "*i*" is defined by the following formula:

$${}_aE_i = f_4\text{(estimated assembly operation cost)}$$
$$= f_5\text{ (design factor)}$$
$$= f_6\text{(element coefficient, supplementary coefficient)}$$
$$= 100 - \text{(part elimination score)}$$
$$= 100 - {}_a\tau[({}_aT_i \,/\, {}_aT_{bi}) - 1]$$

Where:

${}_a\tau$: constant value that determines the sensitivity of the AEM score to the attaching time increment

${}_aT_{bi}$: the part attachment operation time of a part the size of which is equivalent to that of part "*i*". all the other factors are the same as for standard conditions.

2.5.2.3 Symbol in Hitachi Assemblability Method

- Direction of motion of a part

Symbol	Penalty Point	Description of Operation
↓	0	Straight Downward
↑	30	Straight Upward
← →	20	Move Horizontally
↗ ↙	30	Move diagonally up/down
∩ C	30	Turn like a screw
R	40	Turn or lift the whole assembly to insert a part

- Fixture and forming requirement

Symbol	Penalty Point	Description of Operation
f	20	Hold a part for next one operation
F	40	Hold a part for more than next one operation
G	40	Deform a soft/flexible part (O-ring/gasket)
P	20	Bend or cut (wire,..)

- Joining and processing requirements

Symbol	Penalty Point	Description of Operation
B	20	Bond with adhesive or heat or lubricate a part
W	20	Weld

S	30	solder
M	60	Machine a part to join

- Other symbol without penalty point

Symbol	Penalty Point	Description of Operation
—	0	Base part for assembly
|	0	Pipe to keep track of assembly

- Additional 15% penalty point per each operation for a second operation and beyond:
  - Strong incentive for simpler assembly operation
  - More critical for automatic assembly

2.5.3 Lucas Hull DFA method

Although the Boothroyd Dewhurst method is widely used, it is based on timing each of the handling and insertion method. Although tables of data are available, the most accurate numbers are compiled through times studies in particular factories.

Lucas Corporation in the United Kingdom was developed the Lucas DFA method early year of 1980's. The Lucas Method is differing from Boothroyd method, where the Lucas Hull method is based on "point scale" which gives a relative measure of assembly difficulty. The method is based on three separate and sequential analyses. These are best described as part of the assembly sequence flowchart (ASF):

1. Specification
2. Design
3. Functional analysis (this is the first Lucas analysis)
   Possibly loop back to step 2 if the analysis yields problems
4. Feeding analysis (this is the second Lucas analysis)

5. Fitting analysis (this is the third Lucas analysis)
6. Assessment
7. Possibly return to step 2 if the analyses identify problems

In this analysis, the components of the product are reviewed only for their function. The components are divided into two groups. Parts that belong to Group A are those that are deemed to be essential to the product's function; Group B parts are those that are not essential to the product's function. Group B functions include fastening, locating and etc.

The functional efficiency of the design can be calculated as:

$$E_d = A/(A+B) \times 100\%$$

Where:

A: the number of essential components

B : the number of non-essential components.

Note that the design efficiency is used to pre-screen a design alternative before more time is spent on it. This is different than the Boothroyd-Dewhurst method (which assumes a design is already available). This analysis is intended to reduce the part count in the product. Typically, a design efficiency of 60% is targeted for initial designs.

Similar to the Boothroyd – Dewhurst analysis, both the part handling and insertion times are examined here. In the feeding analysis, the problems associated with the handling of the part are score using an appropriate table. For each part, the individual feeding index is scored. Generally, the target index for a part is 1.5. If the index is greater than 1.5, the part should be considered for redesign. An ideal feeding ratio is generally taken to be 2.5. Overall, all of the product's components should meet a "feeding ratio" defined as:

$$\text{Feeding Ratio} = (\text{Total Feeding Index}) / (\text{number of essential components})$$

Where:

Total feeding index: sum of all the indices of all the parts

Number of essential: the value A from the functional analysis

The fitting Analysis is calculated similarly to the feeding analysis. A fitting index of 1.5 is a goal value for each assembly. However, it should be noted that there is usually greater variance in the fitting indices than in the feeding indices. In fitting, an overall fitting ratio also 2.5.

2.6 Conclusion

This chapter is about the summary of journals or reference or finding those others people have done that related to this project. This chapter covers up about design for Assembly with various methods such as Boothroyd Dewhurst method, Hitachi Assemblablility Evaluation Method and Lucas Hull Method.

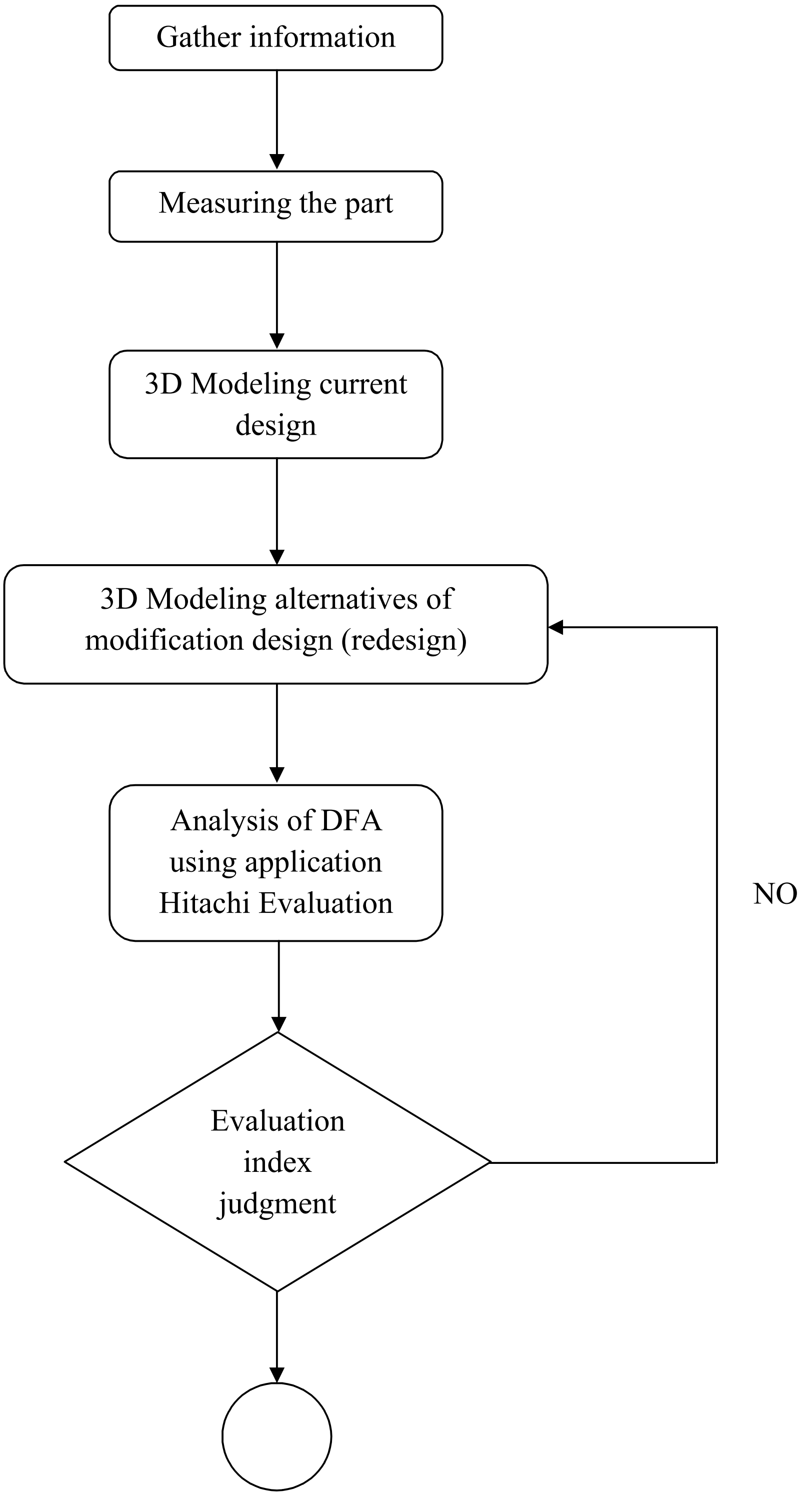
CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes overall framework of methodology of the Design for Assembly and application using Hitachi Assembleability Evalution Method (AEM). The proposed framework for redesigning and reduce the part of the product is illustrated in figure 3.1. The framework of methodology consists of the following steps:

i. Identified number of part and function of each part.
ii. Dimensioning all the part
iii. 3D modeling current design using solidworks.
iv. 3D modeling alternatives of modification design (redesign)
v. Analysis of DFA using application Hitachi Assembleability Method (AEM)
vi. Tabulate all the AEM score for each part


Gather information
Measuring the part
3D Modeling current design
3D Modeling alternatives of modification design (redesign)
Analysis of DFA using application Hitachi Evaluation
Evaluation index judgment
NO

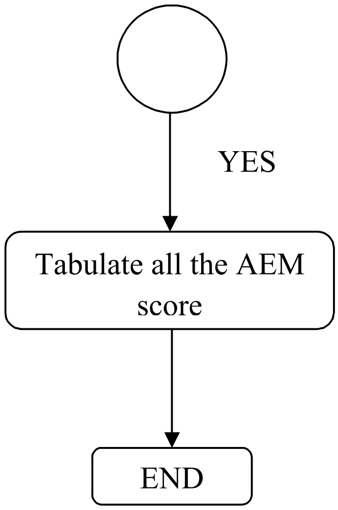


Figure 3.1: The Framework of methodology

3.2 Gather Information

The mechanism of redesign the product is beginning with finding the information about the current product. The product that has been chosen for this project is Mini radio. The mini radio must be totally disassemble to get know the number of part or component to make the complete product.

3.3 Measuring the part

The part or component that has been disassembled must be measured to know the exact dimension. The measuring of the part is consists of measure the diameter, length, thickness and also the width. The data of all dimensioning part are needed to draw the current design in solidwork.

3.4 3D modeling current design

The current design need do 3D modeling using the Solidwork software. The 3D modeling of part or component must base on exact dimension. The design need to show in explode three dimensional drawing because it will explain virtually how the each part is assemble and also shows the total part of the mini radio in the current design.

3.5 3D modeling alternatives of modification design (redesign)

Modify the current design (redesign) by reduce the part or component that need to assembly to make a complete product. This modification or redesign must be in 3D modeling using solidworks also. So those, it easy to determine or to compare between current designs with alternatives design.

3.6 Analysis of DFA using application Hitachi Assemblabilty Evaluation Method

Analysis Design for Assembly 3D modeling alternatives of modification design using application Hitachi Assemblabilty Evaluation Method (AEM). The entire penalty for each process must be considered and calculate the AEM score for each part of modification.

3.7 Evaluation index judgment

All the penalties and AEM score then evaluate either it can be acceptable or not. If the score of AEM for each part over 80 points are desirable so that the design is acceptable and if the score of AEM is below than 80 so that the design is need to redesign and do some modification.

3.8 Tabulate all the AEM score

Then, all the data of AEM score need to tabulate to ensure that the data for redesign the product well organize.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter brief in detail on the result of the project. The design for Assembly result for the selected product was analyzed by using method of Hitachi Assemblability Evaluation Method (AEM).

4.2 Specification of mini radio

The current selected mini radio consists of 21 components to produce a complete product. The details of product are shown in table 4.1.

Table 4.1: Specification of product

Product Specification	
Manufacturer	Manbo Electronic, China
Product Name	Auto Scan FM radio receiver
Model	5003
Weight	300 g
Features	Small, lightweight and easy to bring anywhere
Application	Receive frequency from radio station and convert it to an audio
No of Part	21

4.3 Part critique

The table 4.2 below shows the critique point of each part for the mini radio and also the material of the part made of.

Table 4.2: Part critique and material

No	Part Name	Critique	Material
1	Speaker Cover	Cover a speaker and allow sound to come out from the speaker to environment clearly.	Plastic
2	Speaker ring	Attach with cover to ensure the speaker cover and cover are attach tightly and.	Plastic
3	Cover	Hold the speaker cover, speaker ring and also act as cover to hiding the entire component inside the mini radio.	Plastic
4	Speaker screw	Attaching speaker cover with cover in order to ensure the speaker and cover are attaching securely and tightly.	Steel
5	Speaker	Convert the received frequency into an audio.	Steel
6	Button cover	As place to hold the button securely.	Plastic
7	Button	Use to select the desire frequency and also to switch on the torch light	Plastic
8	Torch frame	Hold securely the LED at the cover	Plastic
9	Electronic circuit	Allow current to flow and transmitted the frequency	Ceramics

10	Inner spring negative terminal	Allow current flow from battery to supply the power to mini radio	Steel
11	Adapter pin	Allow customer to use electricity as power supply beside battery.	Plastic and steel
12	Handle	Easy to handle and give comfortable to customer to carry the mini radio.	Plastic
13	Main body	Keep and hide all the part in one main body and also attach with the cover	Plastic
14	Right spring	Allow current flow from battery to supply the power to mini radio	Steel
15	Outer positive terminal	Allow current flow from battery to supply the power to mini radio	Steel
16	Positive and negative terminal	Allow current flow from battery to supply the power to mini radio	Steel
17	Battery cover	Cover the battery and avoid from direct touch in the same to avoid battery lost from it position.	Plastic
18	Outer screw	Attach the main body and cover securely and tightly	Steel
19	Aerial ring	Displacer between aerial screw and aerial.	Steel
20	Aerial	Receive the frequency from customer desire radio	Steel
21	Aerial screw	Attach aerial with circuit receiver together with aerial ring	Steel

4.4 Figures and dimension of the part

Below are figure and dimension of the original part of the mini radio and also quantity of the part.

Figure 4.1: Speaker cover

Part Name	Speaker Cover
Dimension	Ø36mm x 8mm
Quantity	2
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.2: Speaker ring

Part Name	Speaker Ring
Dimension	Ø39mm x 4mm
Quantity	2
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.3: Cover

Part Name	Cover
Dimension	109mm x 26mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.4: Speaker screw

Part Name	Speaker screw
Dimension	Ø 3mm x 6mm
Quantity	2
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.5: Speaker

Part Name	Speaker
Dimension	Ø 40mm x 5mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.6: Button cover

Part Name	Button cover
Dimension	76mm x 9mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.7: Button

Part Name	Button
Dimension	49mm x 14mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.8: Torch Frame

Part Name	Torch Frame
Dimension	17mm x 3mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.9: Electronic Circuit

Part Name	Electronic Circuit
Dimension	110mm x 12mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.10: Inner spring negative terminal

Part Name	Inner spring negative terminal
Dimension	Ø 9mm x 10mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

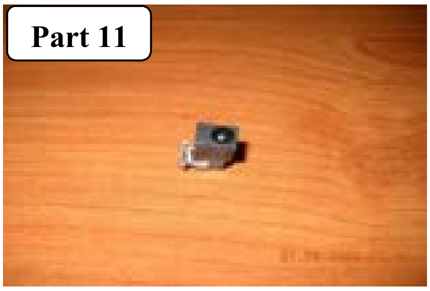


Figure 4.11: Adapter Pin

Part Name	Adapter Pin
Dimension	5mm x 115mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.12: Handle

Part Name	Handle
Dimension	74mm x 9mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.13: Main Body

Part Name	Main Body
Dimension	110mm x 40mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.14: Right Spring

Part Name	Right Spring
Dimension	235mm x 9mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.15: Outer positive terminal

Part Name	Outer positive terminal
Dimension	13mm x 1mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.16: Left spring

Part Name	Left spring
Dimension	205mm x 9mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.17: Battery cover

Part Name	Battery cover
Dimension	52mm x 5mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 18: Outer Screw

Part Name	Outer Screw
Dimension	7mm x 4mm
Quantity	4
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.19: Aerial Ring

Part Name	Aerial Ring
Dimension	Ø 0.01 x 4mm
Quantity	2
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.20: Aerial

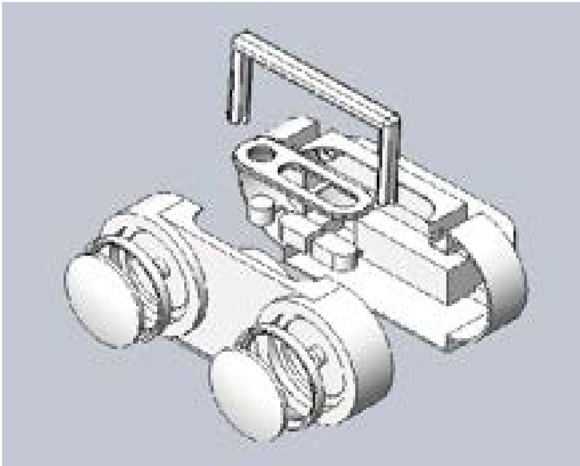
Part Name	Aerial
Dimension	259mm x Ø 5mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

Figure 4.21: Aerial Screw

Part Name	Aerial Screw
Dimension	Ø 3mm x 4mm
Quantity	1
Function	Refer table 4.2
Material	Refer table 4.2

4.5 Product Tree for current design

The mini radio has been divided into five subsystems for an easy analysis as shown in product tree below.

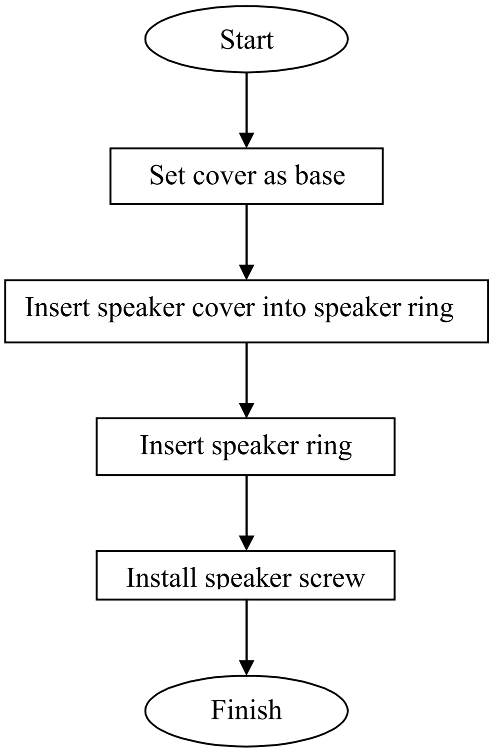


- Mini Radio
  - Sound System
    - Speaker cover (2)
    - Speaker ring (2)
    - Speaker screw (2)
    - Speaker (1)
  - Power system
    - Inner spring negative terminal (1)
    - Outer positive terminal (1)
    - Right spring (1)
    - Left spring (1)
    - Adapter pin (1)
  - Main Assembly
    - Main body [1]
    - Electrical circuit [1]
    - Sound system [1]
    - Scanning system [1]
    - Button cover [1]
    - Torchlight system [1]
    - Cover [1]
    - Outer screw [4]
    - Power system [1]
    - Battery cover
  - Torchlight system
    - Torch frame [1]
  - Tuning System
    - Aerial [1]
    - Aerial ring [2]
    - Aerial screw [1]
    - Button [1]

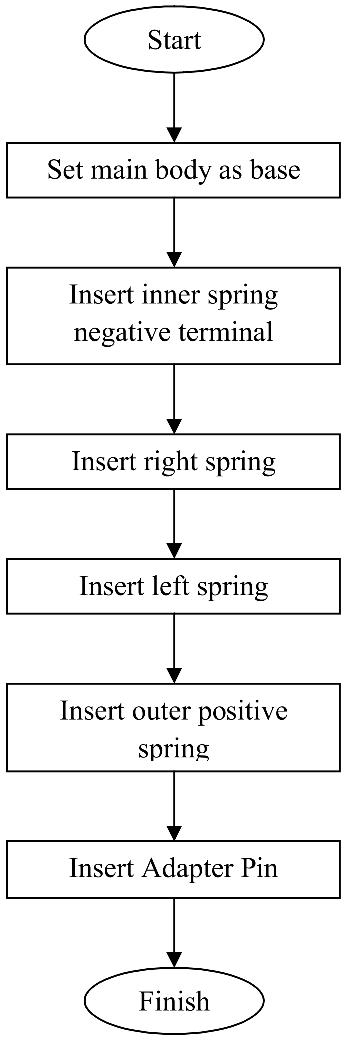
4.6 Product assembly operation sequence for current design

Assembly operation sequence is needed in order to determine the step to produce the complete mini radio. Therefore every subsystem must be analyzing the assembly sequence in order to achieve objective design for assembly by using application Hitachi Assemblability Evaluation Method (AEM).

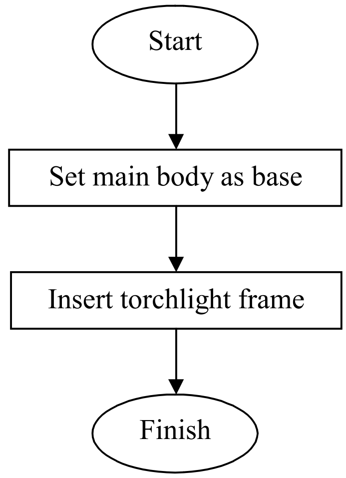
i. Sound System



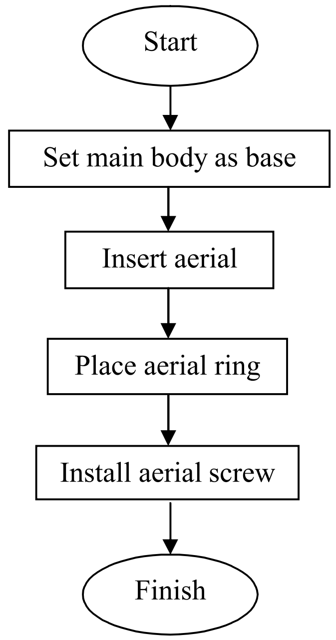
ii. Power System



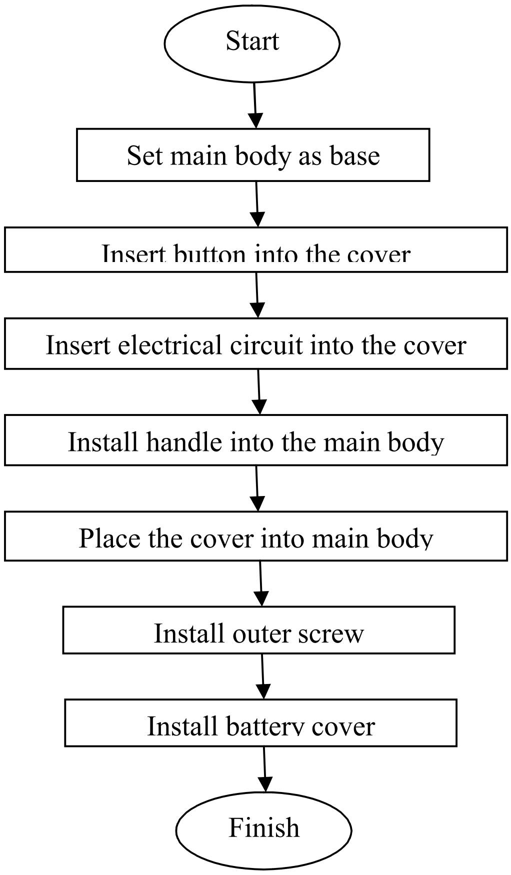
iii. Torchlight System



iv. Tuning System



v. Main Assembly



4.7 Application of Hitachi Assemblability Evaluation Method (AEM) on original product

In order to perform Hitachi assemblability evaluation method of the product, the product must be disassembled and the parts of the product are counted. The operation and penalty score for each part are shown in table 4.3 while the AEM evaluation score results as shown in table 4.4.

Table 4.3: The penalty score of original product

Part			Number of operation (m)	Summation Method			
Name	Count (n)	Operation		Total penalty (∑ Penalty)	M= 100 + ∑ Penalty	T=M*α (+15% add op)	T*n
cover	1	base	1	0	100	100	100
Speaker ring	2	down	2	0	100	100	200
Speaker cover	2	down	2	0	100	100	200
Speaker screw	2	down, turn	2	30	130	150	300
Speaker	1	down	1	0	100	100	100
Button cover	1	down	1	0	100	100	100
Button	1	horizontal	1	20	120	138	138
Torchlight frame	1	down	1	0	100	100	100
Electronic circuit	1	down, horizontal	1	20	120	138	138
Main body	1	base, F, down	1	40	140	161	161
Adapter pin	1	upward	1	30	130	150	150
Handle	1	upward	1	30	130	150	150
Outer screw	4	Down, turn	4	30	130	150	600
Inner	1	down	1	0	100	100	100

spring negative terminal							
Outer positive terminal	1	down	1	0	100	100	100
Right spring	1	down	1	0	100	100	100
Left spring	1	down	1	0	100	100	100
Battery cover	1	horizontal	1	20	120	138	138
Aerial ring	2	Horizontal , F, G	2	100	200	230	460
Aerial	1	Horizontal , f	1	40	140	161	161
Aerial screw	1	Down, turn	1	30	130	150	150
Assy Effy	56%		**Assy time**	37.5T down		**∑T*n=**	3746

Table 4.4: The AEM evaluation score result

No	Part Name	Part Evaluation score, E_i	Assembly Cost, C (RM)	Assembly Time, (s)
1.	cover	100	0.0500	6.000
2.	Speaker ring	80	0.0833	6.000
3.	Speaker cover	80	0.0833	6.000
4.	Speaker screw	40	0.1500	18.000
5.	Speaker	100	0.0500	6.000
6.	Button cover	100	0.0500	6.000
7.	Button	80	0.0833	10.000
8.	Torchlight frame	100	0.0500	6.000
9.	Electronic circuit	90	0.0667	8.000
10.	Main body	60	0.1167	14.000
11.	Adapter pin	60	0.1167	14.000
12.	Handle	60	0.1167	14.000
13.	Outer screw	40	0.1500	18.000
14.	Inner spring negative terminal	100	0.0500	6.000
15.	Outer positive terminal	100	0.0500	6.000
16.	Right spring	100	0.0500	6.000
17.	Left spring	100	0.0500	6.000
18.	Battery cover	80	0.0833	10.000
19.	Aerial ring	43	0.1450	17.400
20.	Aerial	88	0.0700	8.400
21.	Aerial screw	40	0.1500	18.000
		$\sum E_i$=1641	**$\sum C$=1.7484**	**∑assy.time=209.8**

Product AEM score, E $= \dfrac{\sum \text{Part AEM score}, E_i}{\sum \text{No of part}}$

$E = \dfrac{}{} = \mathbf{78}$

Total assembly Cost, C = 1.7484

Total assembly time = 209.8 sec

4.8 Suggestion of improvement on original mini radio

Based on evaluation that has been done, the improvement suggestions of design changes of mini radio are proposed. Table 4.5 shows a description for the lowest assemblability evaluation score and the suggestion of improvement.

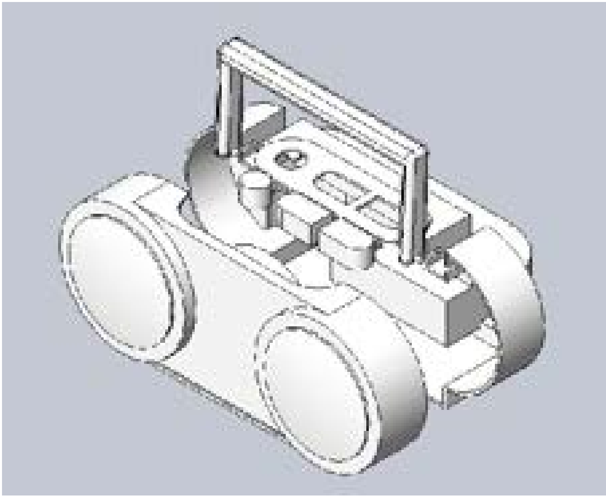
Table 4.5: Description of weak point and suggestion of improvement

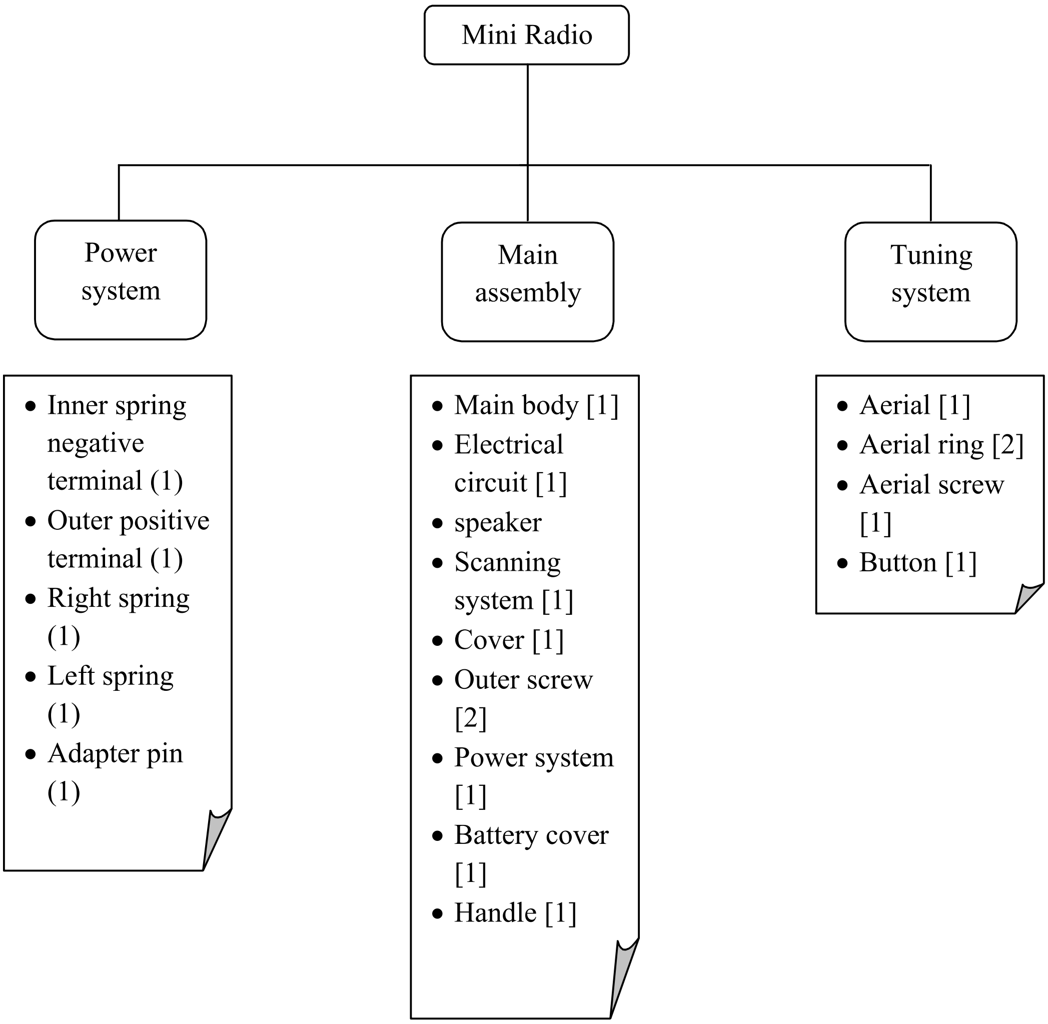
Part No.	AEM Score	Description weak point	Suggestion of improvement design
4.	40	This part related to part number 1 and 2. Screws are needed to fasten the speaker cover and speaker ring with cover.	The screw can be eliminated by combining the speaker cover and speaker ring with cover.
10.	60	This part is also the one of main part in mini radio. This part has a low AEM score due the too many sequence of assembly operation such as need to hold the part more than one next operation.	No need to do modification on the current part.

11.	60	This part related to part number 10 where this part is attached to the main body.	No need to do modification on the current part because adapter pin is important part to supply power beside battery.
12.	60	This current design looks perfect and the operation also not effected too much on AEM scoring.	No need modification on this current design.
13.	40	This part is related to the part number 10 which is main body where 4 screws are needed to fasten the main body with the cover.	Eliminate two screws and change the screw with the snap fit.
19.	43	This part is related to the part number 20 and 21. This part is difficult to handle because of size and o-ring type.	No need to do modification on current design.
21.	40	This part related to the part number 19 and 20 which is aerial ring and aerial. This part is needed to fasten the aerial with aerial ring.	No need to do modification on the current design.

4.9 Product Tree for improved design

The improvement design of mini radio has been divided into 3 subsystems for an easy analysis as shown in product tree below.

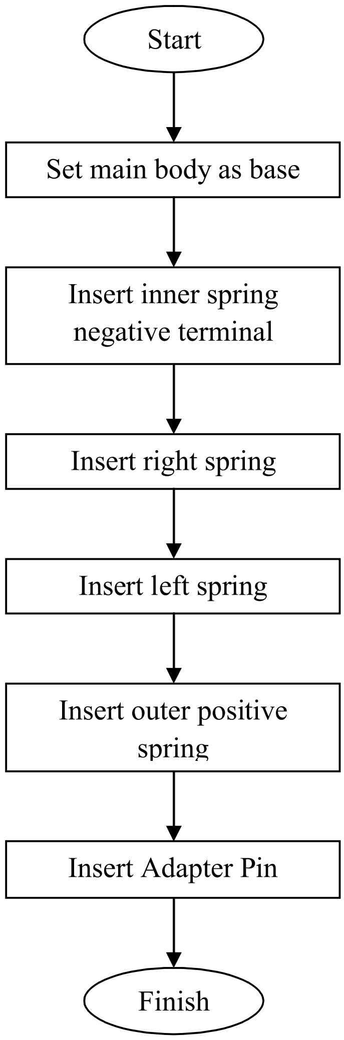




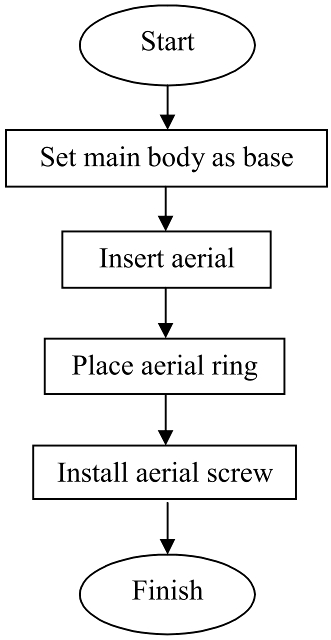
4.10 Product assembly operation sequence for improvement design

The product assembly operation sequence for improvement design must be identified in order to perform a new analysis to get the data.

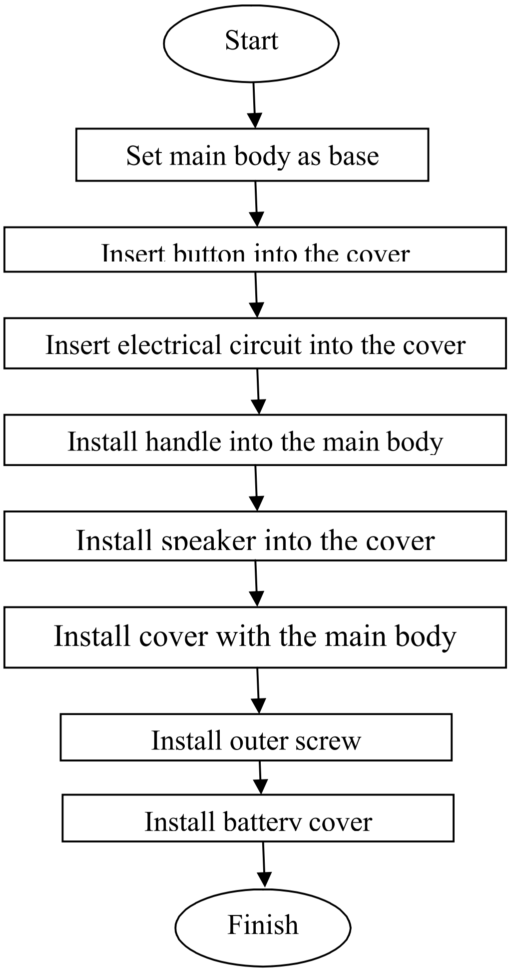
i. Power system



ii. Tuning system



iii. Main Assembly



4.11 Application of Hitachi Assemblability Evaluation Method (AEM) on improvement designs

Based on improvement suggestion, the penalty score and assemblabilty evaluation method (AEM) to be determined and evaluate once again so that comparison of score can be made between current design and improvement design. The results of penalty score for improvement design are shown in table.

Table 4.6: Penalty score for improvement design

Part			Number of operation (m)	Summation Method			
Name	**Count (n)**	**Operation**		**Total penalty (∑ Penalty)**	**M= 100 + ∑ Penalty**	**T=M*α (+15% add op)**	**T*n**
cover	1	Base	1	0	100	100	100
Speaker	1	Down	1	0	100	100	100
Button	1	Horizontal	1	20	120	138	138
Electronic circuit	1	down, horizontal	1	20	120	138	138
Main body	1	base, F, down	1	40	140	161	161
Adapter pin	1	Upward	1	30	130	150	150
Handle	1	upward	1	30	130	150	150
Outer screw	2	Down, turn	2	30	130	150	300
Inner spring negative terminal	1	down	1	0	100	100	100
Outer positive terminal	1	down	1	0	100	100	100

Right spring	1	down	1	0	100	100	100
Left spring	1	down	1	0	100	100	100
Battery cover	1	horizontal	1	20	120	138	138
Aerial ring	2	Horizontal , F, G	2	100	200	230	460
Aerial	1	Horizontal , f	1	40	140	161	161
Aerial screw	1	Down, turn	1	30	130	150	150
Assy Effy	62.8%		**Assy time**	25.5T down		**∑T*n=**	2546

Table 4.7: The AEM evaluation result

No	Part Name	Part Evaluation score, E_i	Assembly Cost, C (RM)	Assembly Time, (s)
1.	cover	100	0.0500	6.000
2.	Speaker	100	0.0500	6.000
3.	Button	80	0.0833	10.000
4.	Electronic circuit	90	0.0667	8.000
5.	Main body	60	0.1167	14.000
6.	Adapter pin	60	0.1167	14.000
7.	Handle	60	0.1167	14.000
8.	Outer screw	88	0.1500	18.000
9.	Inner spring negative terminal	100	0.0500	6.000
10.	Outer positive terminal	100	0.0500	6.000
11.	Right spring	100	0.0500	6.000
12.	Left spring	100	0.0500	6.000
13.	Battery cover	80	0.0833	10.000
14.	Aerial ring	43	0.1450	17.400
15.	Aerial	88	0.0700	8.400
16.	Aerial screw	40	0.1500	18.000
		$\sum E_i$=1289	**$\sum C$=1.3984**	**∑assy.time=167.8**

$$\text{Product AEM score, } E = \frac{\sum \text{Part AEM score, } E_i}{\sum \text{No of part}}$$

$$E = \frac{}{} = 80.6$$

Total assembly Cost, C = 1.3984

Total assembly time = 167.8 sec

4.12 Comparison between current design and improvement design

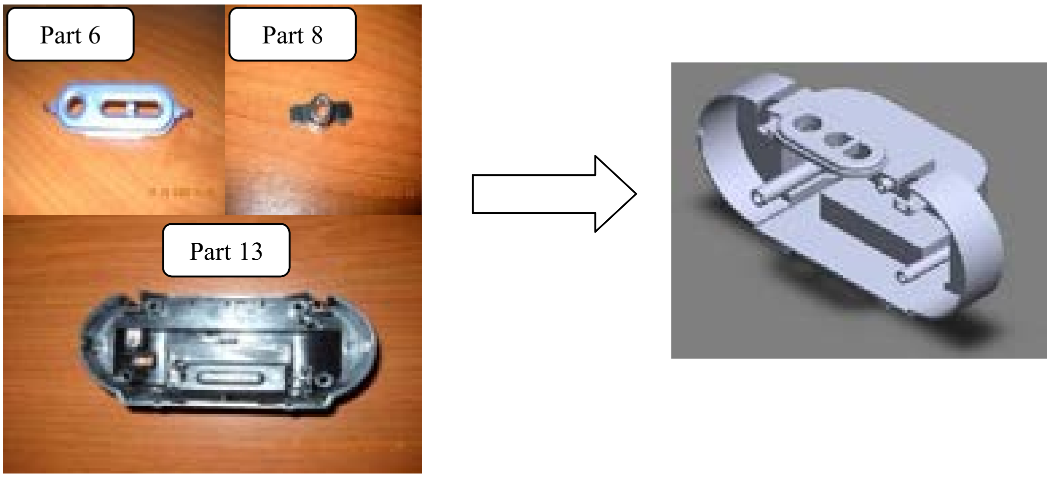
The improvement design was compared with current design in term of assembly efficiency, product score, assembly cost and also assembly time by using application Hitachi assembly evaluation method (AEM). Table 4.8 shows the comparison between current design and improvement design.

Table 4.8: Comparison current design and improvement design

	Current Design	**Improve Design**
Assembly Efficiency	56%	62.8%
Product AEM score, *E*	78	80.6
Total Assembly Cost, C	1.7484	1.3984
Total Assembly Time	209.8	167.8

From table 4.8, it can be conclude that by applying the Hitachi Assembleability Evaluation Method (AEM), the total number of part is decreased from 21 to 16. The total time per product is decreased from 209.8 second to 167.8 second. It is because of eliminating the part and also reducing number of screw.

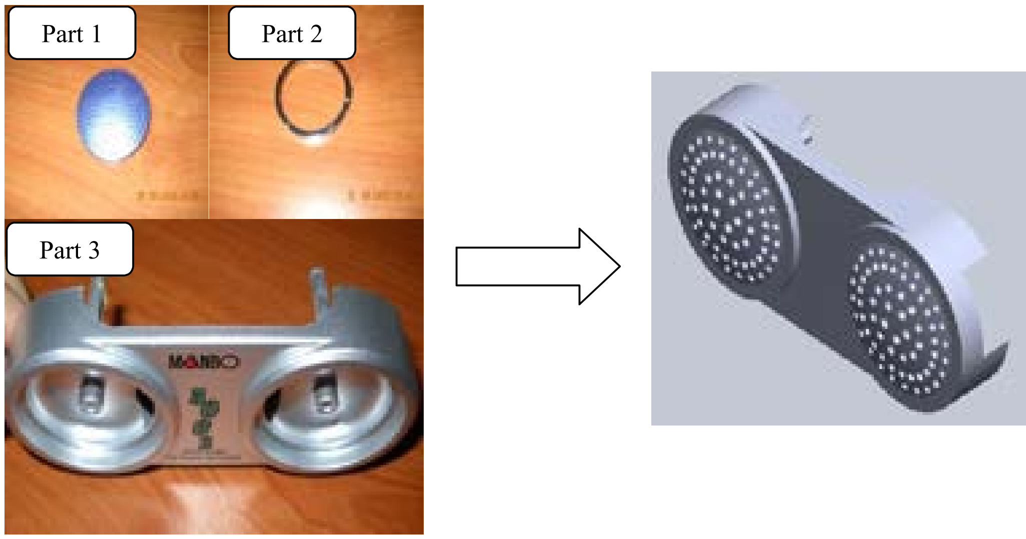
4.13 Figure of before and after modification



Before After

Figure 4.22: Button cover, torchframe and main body (before and after)

Figure 22 shows the comparison between two main body, button cover and torchlight frame. Before design improvement the button cover and the torch frame need to assemble together with main body. This part can be eliminate and become one part with main body. The part are not neccesary part and the material for the parts are same which made by plastic, therefore it easy to eliminate the part and join it as one part. The advantage of eliminating this part can help reduce the time of assembly and also the number of part for product itself.



Before After

Figure 4.23: speaker cover, speaker ring and cover (before and after)

Figure 23 shows the comparison between two cover, speaker cover and speaker ring. Before design improvement the speaker ring need to be attach with the cover to locate the speaker cover easily before fasten it using screw. The parts can be eliminate and combine as one part as shown in improvement design because the material for the speaker ring and speaker cover are same with the cover which is plastic and speaker ring is not a necessary part for this product. By combine this parts number 1 and 2 with part number 3 can help reducing the penalty for the operation and also time. Beside that, the advantage of combining all the parts become one part is screws are not required to be fasten with speaker cover and cover and it can help in reducing the operation assembly sequence by eliminating the screws.

4.14 Conclusion

The evaluation result show improvement of the product has increased the product score, *E* from 78 to 80.6 and also has increased the assembly efficiency of the product itself from 56 percent to 62.8 percent. The numbers of part are reduced from 21 parts to 15 parts only. The parts that have been eliminated are part number part 1, 2, and 3. Parts have been eliminating by combining this 3 parts become one part. By eliminating this part, number of screw also can be eliminated. Besides that, these three parts are made from same material which plastic. The parts that also have been eliminated are part number 6, 8 and also part number 13. These three parts also have been eliminated by combining it and become one part. The reason of combining these parts are the part made from same material which plastic and not necessary parts.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter summarized the conclusion and recommendation for the overall objective on this final year project about design for assembly and application using Hitachi Assemblability Evaluation Method (AEM).

5.2 Conclusion

The mini radio study is presented from a set of consumer products purposely to develop a creative design. From this project, the number part of mini radio can be reducing by using application of Hitachi Assemblability Evaluation Method (AEM). Design for Assembly using Hitachi Assemblability Evaluation Method can help in reducing operation cost, assembly time and in the same time can improve the quality of product itself by evaluate the AEM score of each part if the product and also the AEM score for the product. Design for Assembly and application using Hitachi Assemblability method give a new design to mini radio from 21 parts to 15 parts. Hitachi Assemblability Evaluation Method (AEM) has shown that the current product can be improved. The assembly efficiency for this product has increased from 56 percent to

62.8 percent. Design for Assembly by using Hitachi Assembly Evaluation Method (AEM) also encourage dialogue between designers and manufacturing engineers and other individuals who play a part in determining final product costs during the early stages of design. This means that teamwork is encouraged and the benefits of simultaneous or concurrent engineering can be achieved.

5.3 Recommendation

For further research, Design for Assembly should be widely studied in order to mastered concept of design for assembly especially on Hitachi Assemblability Evaluation Method (AEM) because this method application is very restricted in Hitachi Ltd. This can be done by:

- Sharing knowledge and information on this method by publishing journal or technical report for public.
- Software to calculate the score also should be publishing to the public so that, other researcher and institution can use for their research or learning process.
- In order to make the data more concrete and accurate, this method can be implemented by doing a real assembly in industry.
- Apply this method on product that contains a lot of component so that the researcher can get a clear view and distinguish about percentage of improvement especially on assembly efficiency and also product AEM score.
- Get the exact assembly sequence operation from manufacturer so that the penalty for each operations can be easily determined are more accurate.
- Get the exact data such as total cost of assembly, total time of assembly and total labour cost from the manufacturer so that comparison between current design and improvement design can be made easily and more effective.

APPENDIX A

Final Year Project 1 Gantt chart

Project Activities		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Literature study	Planning														
	Actual														
Product Selection	Planning														
	Actual														
Identify problem	Planning														
	Actual														
Define objective and scope of study	Planning														
	Actual														
Setup framework	Planning														
	Actual														
Report preparation	Planning														
	Actual														
Presentation preparation	Planning														
	Actual														
FYP 1 presentation	Planning														
	Actual														
Report & logbook submission	Planning														
	Actual														

APPENDIX B

<u>Final Year Project 2 Gantt chart</u>

Project Activities		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
3D modeling current design	Planning	■	■												
	Actual	■	■												
3D modeling alternative design	Planning		■	■											
	Actual		■	■	■	■	■	■	■	■					
Analysis using Hitachi AEM	Planning				■	■									
	Actual				■	■	■	■							
Index Evaluation judgment	Planning						■	■							
	Actual						■	■	■	■					
Result and discussion	Planning							■	■						
	Actual										■				
conclusion	Planning									■	■				
	Actual										■				
Report preparation	Planning										■	■			
	Actual											■	■	■	
Presentation preparation	Planning												■	■	
	Actual													■	
FYP 2 presentation	Planning														■
	Actual														■
Final report submission	Planning														■
	Actual														■

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