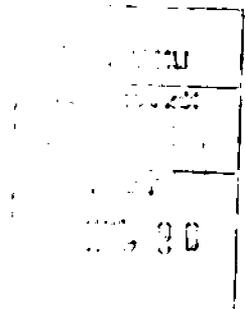


**REDESIGN OF RICE COOKER COMPONENT BY USING AN INTEGRATED
BOOTHROYD DEWHURST DFA AND AXIOMATIC DESIGN**

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ABSTRACT

In the early process for product design, the methodology of Design for Assembly (DFA) and its guidelines are very useful to engineers. Design for Assembly is a set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum of effort, time and cost. Axiomatic Design, AD is an engineering design theory that provides a framework to decision-making in the designing process. It will consider the customer needs which are very important in the product market today. The main objective of the project is to improve the assembly effectiveness by using integration of Boothroyd Dewhurst DFA method and Axiomatic Design techniques. Currently, a rice cooker consists of 37 components, where several components are difficult to assemble. So, this project provides the framework to redesign the current product in order to reduce the difficulty of assembly. The stage of the project is starting by gathering all information of the product and also determining the customer needs for the current product. After that, the current product is redesigned based on the analysis of DFA and Axiomatic Design which is aimed to increase the design efficiency, reduce total assembly time and cost of the product. The result of this project shows that design efficiency is increased from 22.0 % to 33.0 %. From the case studies result, this evaluation system is able to improve the design in terms of design efficiency, product time and cost.

ABSTRAK

Di dalam proses awal untuk merekabentuk produk, kaedah rekabentuk untuk pemasangan (DFA) dan garis panduannya adalah amat berguna kepada jurutera. Rekabentuk untuk pemasangan adalah satu garis panduan yang dibangunkan untuk memastikan produk yang direkabentuk supaya mudah dan berdaya saing untuk dihasilkan dan dipasang dengan minimum usaha, masa dan kos. Rekabentuk aksiomatis, AD adalah teori Kejuruteraan rekabentuk yang menyediakan rangka kerja untuk membuat keputusan di dalam proses merekabentuk. Ia akan mempertimbangkan kehendak pelanggan yang amat penting pada hari ini di dalam pasaran produk. Tujuan utama projek ini adalah untuk meningkatkan kecekapan pemasangan dengan menggunakan integrasi kaedah Boothroyd Dewhurst DFA dan teknik Rekabentuk Aksiomatis. Periuk nasi terdiri daripada 37 komponen, di mana sesetengah komponennya rumit untuk dipasang. Oleh itu, projek ini menyediakan rangka kerja untuk merekabentuk semula produk yang sedia ada yang bertujuan untuk mengurangkan kerumitan pemasangan. Peringkat permulaan projek ini bermula dengan mengumpul semua data tentang produk dan juga menentukan kehendak pelanggan mengenai produk sekarang. Selepas itu, produk yang sedia ada direkabentuk semula dengan berpandukan analisis daripada DFA dan Rekabentuk Aksiomatis dengan menyasarkan kepada meningkatkan kecekapan rekabentuk, mengurangkan jumlah masa dan kos untuk memasang sesuatu produk. Hasil keputusan projek ini menunjukkan, kecekapan rekabentuk meningkat daripada 22.0% kepada 30.0%. Daripada keputusan kes kajian, sistem penilaian ini adalah berupaya untuk memperbaiki rekabentuk pada istilah kecekapan rekabentuk, masa dan kos sesuatu produk.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter is discussed about the project background, the problem of the project, the objectives of the project and project scope of the project.

1.2 Project Background

Design for assembly (DFA) is defined as a process for improving product design for assemble ease, low-cost assembly and low assembly time. Often this is accomplished by reduced the number of parts in a product design. In the early process for product design, the methodology of DFA and it guidelines are very useful to engineers. This is because by implement the DFA method it will reduce the overall cost of product development through the DFA analysis with knowing the estimated of product assembly time and cost without made a product prototype. So that, it will help the engineers making a correct decision about decided where is a product that have good design in term of design efficiency and assemblability.

There are several systems being used in industry today, the most DFA quantitative is Boothroyd - Dewhurst DFA, Lucas DFA and Hitachi AEM. The three of this method are explained in chapter 2 about their methodology, advantages and drawback of each method. However, this project only discussed on the applying integration between product evaluation techniques, axiomatic design with Boothroyd Dewhurst DFA methodology. Axiomatic design is an engineering design theory that provides a framework to decision-making in the designing process. It will consider the customer needs which very important in the product market today.

The case study of this project is focused on Pensonic rice cooker. The analysis is aim to evaluated the assemblability in term of reduce the number of parts in order to ease the assembly.

1.3 Problem Statement

Currently, rice cooker consists of 37 components that including screw and rivet. While to assemble the component of rice cooker there have problems that occur such as difficult to assemble the component because of having the different types and size of fasteners. As a result, it will increase the cost in term of manufacturing process and assembly time.

1.4 Project Objectives

The objectives of this project are:

1. To improve the design by integrated the Boothroyd Dewhurst DFA method and Axiomatic Design techniques.
2. To make comparative analysis between current design and proposed design in term of assembly effectiveness.

1.5 Project Scope

In order to achieve the objectives the following scope of project are performed:

1. Literature review of DFA Boothroyd-Dewhurst, Lucas DFA, Hitachi Assembly Evaluation Method and Axiomatic Design.
2. Information gathering of rice cooker with:
 - a) Find out the part function for each car door component.
 - b) Dimensioning the current design using the manual measured.
 - c) Modelling the 3D current design using the Solidworks software.
3. Analysis of current design using integration of Axiomatic Design and Boothroyd-Dewhurst DFA.
4. Proposed the best design and also make analysis for proposed design. Make comparative analysis between current design and proposed design using Boothroyd Dewhurst, Inc. software in terms of design efficiency, total assembly time and cost.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is aimed to discuss about DFA methodologies and its guideline. The advantages and drawback among of DFA techniques are also discussed. Product evaluation, axiomatic design also discussed to find out their method that has been used in this thesis.

2.2 Design for Assembly (DFA)

Assembly is a key in manufacturing activity. DFA is general term for a set of process, which guides the designer in making assembly-related decisions. Design for Assembly means the design of the product for ease of assembly (Boothroyd and Dewhurst, 2002). To ensure the product design achieved the DFA objective, there should be considered at all stages of the design process especially in the early stages that give a lot of benefit:

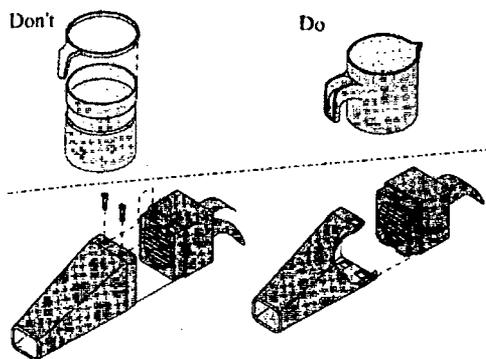
- i. minimizing the amount of assembly required by a product
- ii. reducing the cost of manufacturing process
- iii. increasing the productivity and quality

Good design is contains of fewer parts that take less time to assemble, thereby it will reduce the assembly costs.

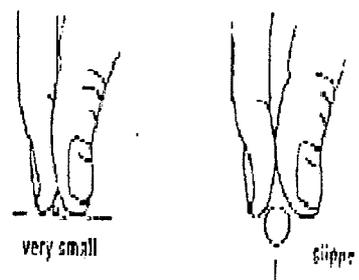
2.3 DFA Guidelines and Principles

The most basic approach to design for assembly by applies the design guidelines in the product design. The purpose of the design guidelines is to impose discipline and rigor on the design process (Henry W., 1999). DFA guidelines can be summarized as following below (Otto and Wood, (2001); Boothroyd *et al.*, 2002):

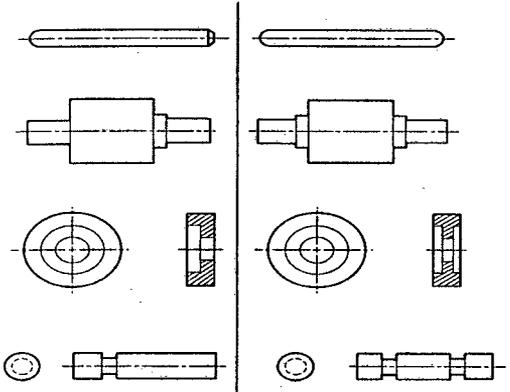
- i. Minimize the number of parts and levels assembly and simplify product complexity by eliminating unnecessary parts and combining parts if possible. (see Fig. 2.1(a))
- ii. Design parts that have reasonable weight means the parts not too heavy or too light because it will effect the time to handling. (see Fig. 2.1 (b))
- iii. Design parts that have end-to-end symmetry and rotational symmetry about the axis of insertion to avoid need for extra orienting and motions. (see Fig. 2.1(c))
- iv. If symmetry cannot be achieved, attempt to design parts having the maximum possible symmetry and provide asymmetrical features that can be facilitate easily orienting the parts.
- v. Design parts that have chamfers to avoid resistance or jamming while to insertion of two mating parts. (see Fig. 2.1 (d))
- vi. Standardize by using common parts, process and methods across all models and even across product lines to permit the use of higher volume processes that normally result in lower product cost. (see Fig. 2.1 (e))
- vii. Design parts to prevent tangling. For example when using spiral springs, avoid open ends and when using rings, make the gap small. Part tangling may cause difficult to handle such as slippery. (see Fig. 2.1 (f))
- viii. Reducing or eliminate the use of fasteners in design by using the concept of fitting parts.



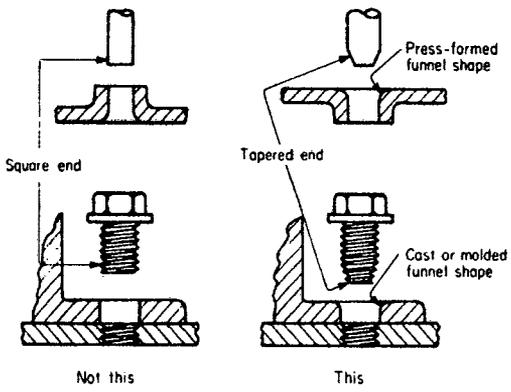
(a) Minimize part count



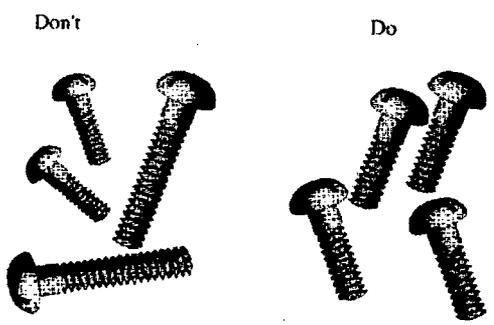
(b) Design parts that have reasonable weight and size



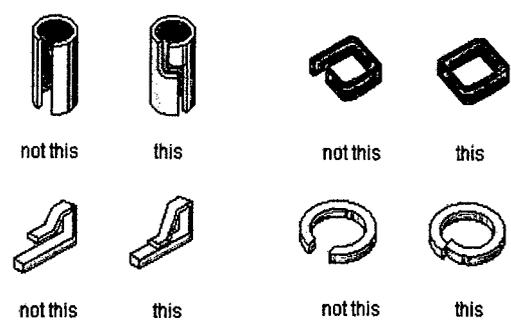
(c) maximize part symmetry



(d) Provide chamfer



(e) Standardize the part



(f) Avoid the part that have tangling

Figure 2.1: Design guidelines (Otto and Wood, 2001, Boothroyd *et al.*, 2002)

2.4 Various Method of DFA

Designs for assembly procedures are guidelines that guide the designer to implement DFA in real practice. Three of the better-known quantitative evaluation techniques has been used in industry are Boothroyd-Dewhurst (USA), Lucas (UK) and Hitachi (Japan). The recommendations suggested by the DFA methodologies can be summarized into the following below (Hung, 1995):

- i. Eliminate the part. Parts such as screw, nut and spring are usually considered to be eliminated as much as possible.
- ii. Combine the part with it mating part. This is due to recommendation of the Boothroyd's three criteria.
- iii. Simplify the assembly operations. This includes consideration of the structure of product and designs each component.

2.4.1 Boothroyd Dewhurst DFA

Design for assembly (DFA) that formulated by Boothroyd and Dewhurst are one of the most widely DFA methodologies which is used on productivity improvement through product design in term of assembly ease and reduce assembly time. Boothroyd and Dewhurst DFA methodology has been recognized as a very useful tool in increasing competitiveness by reducing the part number of components, simplifying the product design structure and improving product design reliability. The procedure for analyzing product for manual assembly Boothroyd and Dewhurst method is summarized as following below (Henry W., 1999):

- i. Obtain the best information about the product or assembly. Useful items include engineering drawing, exploded three-dimensional views, an existing version of the product, or prototype.
- ii. Take the assembly apart. Assign an identification number to each item as it is removed. Initially, treat subassemblies as parts and then analyze them as assemblies later.

- iii. Reassemble the product starting with the part having the highest identification number. As each part is added to the assembly, analyze its ease of handling and insertion and use the three questions to decide if it is a candidate for elimination or combination with other parts
- iv. Redesign the assembly using the insights gained from the analysis. Analyze the new design by repeating step 1 through 4 and gage improvements by comparing design efficiencies between current and modified design. Iterate until satisfied.

The Boothroyd and Dewhurst DFA analysis is basically completed in 6 steps. The flow chart of Boothroyd and Dewhurst DFA analysis is shown in Figure 2.2:

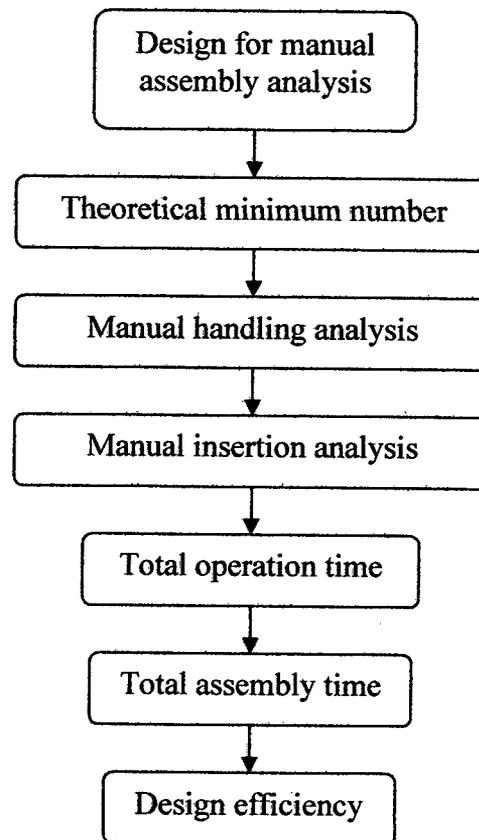


Figure 2.2: Boothroyd and Dewhurst DFA analysis (Boothroyd *et al.*, 2002)

As an illustration Figure 2.2 the analysis is starting with defined the theoretical minimum number. The purpose is to define each part in assembly as a necessary part or candidate to be eliminated or to be combined with other part. Each part in assembly must answer the three following question below (Boothroyd *et al.*, 2002):

- i. During operation of the product, does the part move relative to all other parts already assembled? For example in the internal combustion engine operation, the piston must move relative to the engine block. So that, the piston as a necessary part because of movement or motion the other part.
- ii. Must the part be of a different material, or be isolated from all other parts already assembled? For example, handle cooking ladle as an insulator that are made from different material such as wooden or plastic because of to protect from the heat.
- iii. Must the part be separate from all other parts already assembled because otherwise necessary assembly or disassembly of other parts would be impossible?

If the answer “yes” to at least one of the following three questions above for a part, the part are the theoretical minimum number. Otherwise if the answer “no”, the part are the candidate to eliminate or combine with other part. The second step is manual handling analysis on each part. This analysis is used to define the estimated time for handling the part according the weight, thickness, end-to-end part symmetry and rotational part about the axis. The third step is manual insertion analysis that used to estimate the insertion time for each part according the resistance and alignment during insertion and how the part is secured such as the part secured using snap fit or mechanical tools. Then forth and fifth step is calculated the total operation time and the total assembly time. The formulated is following below:

$$\text{Total operation time in second} = T_h + T_i \quad (2.1)$$

where; T_h = handling time

T_i = insertion time

$$\text{Total assembly time (sec)} = \Sigma \text{ total operation time of each part} \quad (2.2)$$

The last step is calculated the design efficiency. The design efficiency is obtained by using the formula below (Boothroyd et al, 1994)

$$\text{Design efficiency, } E_{ma} = \frac{N_{min} \times T_a}{T_{ma}} \quad (2.3)$$

where; N_{min} = theoretical minimum number of parts

T_a = basic assembly time = 3 second

T_{ma} = estimated time to complete the assembly of the product

2.4.2 Lucas – Hull DFA

The Lucas DFA methodology is similar to the Boothroyd – Dewhurst DFA. It is developed in the early 1980's by cooperation of the Lucas Organization and the University of Hull in U.K. Lucas DFA method is based on a "point scale" which gives a relative measure of assembly difficulty. Lucas DFA method evaluated the product design process based on three steps: function analysis, handling analysis and fitting analysis. The relations of these three steps are shown in figure. The objectives of Lucas DFA are (Lucas and Hull, 1990):

- i. Reducing parts counts.
- ii. Ensuring feasible assembly process at minimum cost.
- iii. Achieving reliable and efficient automatic assembly.
- iv. Highlights areas for future consideration when business environments permit.
- v. Standardization of components, assembly sequence and methods across a range of related products.

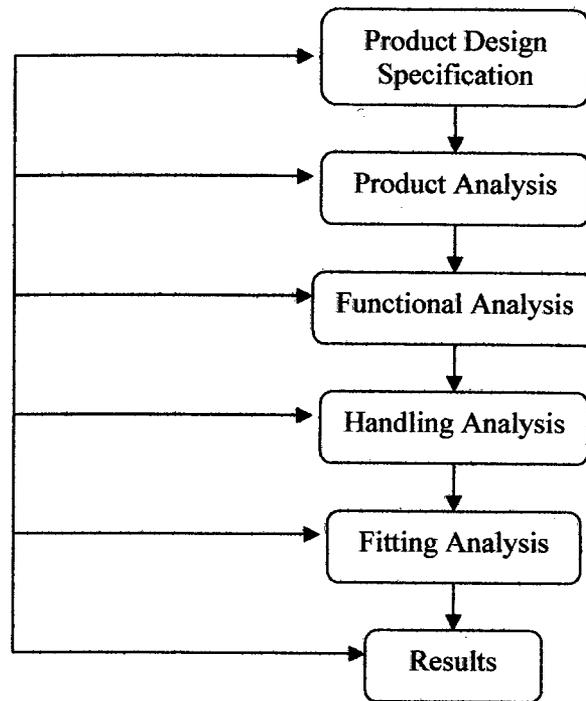


Figure 2.3: Lucas DFA analysis (Lucas and Hull, 1990)

In this paper, only manual assembly is considered. The Lucas DFA evaluation procedure is shown in Figure 2.3 and every step of procedures can be explaining the following below (Lucas and Hull, 1990):

- i. Product Design Specification (PDS) – PDS is document that lists all the needs, both customer and business, that the product must satisfy if it is to be entirely successful.
- ii. Product Design – The objective is to maximized tooling utilization and minimize the tooling variation by using common parts within and across the range of the products, to eliminated the tooling duplication by assemble in the same direction and to minimize the handling tool by applying the common feeding features on the larger component.
- iii. Functional Analysis - The parts of the product are reviewed only for their function in this analysis which is divided into two categorized. Firstly is 'A' part that means the number of essential parts such as drive shaft, adjusting screws etc and secondly is 'B' part that means the number of non-essential parts such as fasteners, locators etc. The analysis indicated design efficiency that can be calculated as:

$$E_d = \frac{A}{(A+B)} \times 100\% \quad (2.4)$$

When designing the new product, value of design efficiency should be more than 60%. If the value of design efficiency is less than 60%, it should iterate back to the PDS.

- iv. Handling Analysis - The analysis considers how components and subassemblies manufactured in various place, are going to be presented to the point of assembly. Handling analysis scores the parts based on the performance in three areas:
- a. The size and weight of the parts – If the size of parts very small the parts may difficult to handle and need required specialized tools such tweezers, optical etc. If parts is large or heavy, there need one more person or using lifting tool such as car wheel to handle it.
 - b. Parts characteristics – Part delicate, tangling, sharp or abrasive, nesting etc it may occur handling problem during assembly.
 - c. The orientation of the parts – The symmetrical and rotational parts affect the assembly time.

The handling analysis indicated the handling ratio that defined as:

$$\text{Handling Ratio} = \frac{(\text{Total Relative Handling Cost})}{(\text{Number of Essential Components})} \quad (2.5)$$

For each part, the individual handling index is calculated. The handling index target for a part is 1.5. If the index is greater than 1.5, the part should be considered for redesign. The value of handling ratio should be less than 2.5 is accept and the opposite must be iterate back to the PDS.

- v. Fitting Analysis – The analysis is made up of 3 sections: Gripping, Insertion and Fixing. This analysis indicated the fitting ratio is given by:

$$\text{Fitting Ratio} = \frac{(\text{Total Relative Fitting Cost})}{(\text{Number of Essential Components})} \quad (2.6)$$

The value of fitting ratio should be less than 2.5 to acceptable. Otherwise if the value of fitting more than 2.5, it should iterate back to the PDS.

2.4.3 Hitachi Assemblability Evaluation Method

This method developed by Miyakawa and Ohashi in the late 1970 as part Hitachi desire for products, which could be efficiently assembled by automation. The main objective is to facilitate design improvements by identifying ‘weaknesses’ in the design at the earliest possible stage in the design process, by the use of two indices:

- i. Assemblability evaluation score ratio (E), used to assess design quality by determining the difficulty of operations
- ii. Assembly cost ratio (K) used to project elements of assembly cost

The assembly process is analyzed using 20AEM elements. The total assemblability evaluation score for the product is defined as the sum of the assemblability scores for the individual tasks, divided by the number of tasks. This may be considered to be a measure of design efficiency where a score of 100 would represent a perfect design. Hitachi consider that an overall score E of 80 is acceptable and overall assembly cost ratio K less than 0.7 is acceptable.

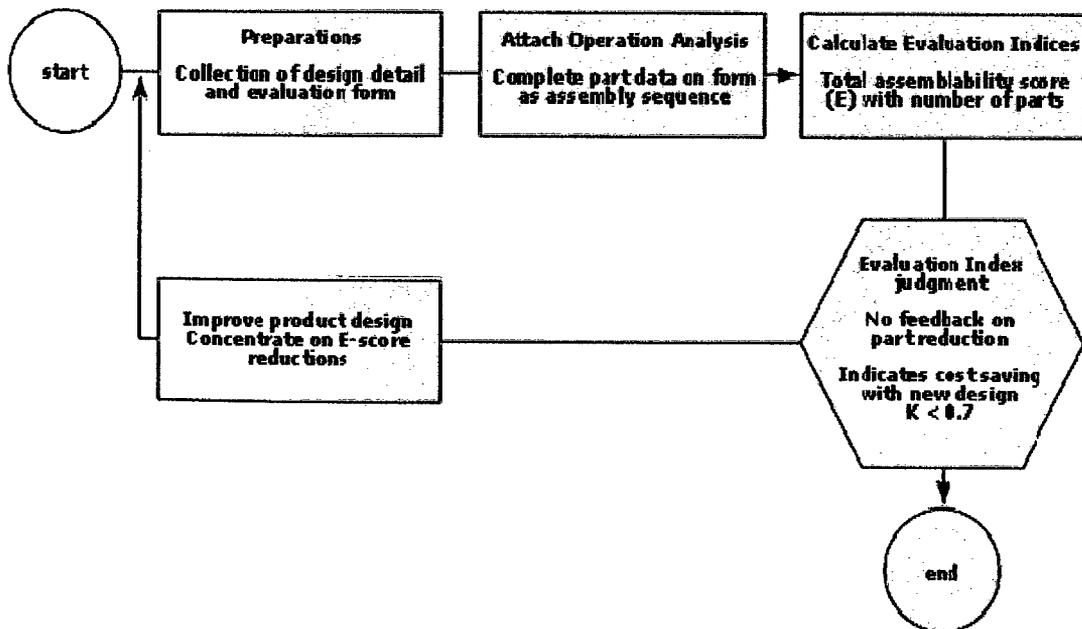


Figure 2.4: Framework of Hitachi analysis

2.4.4 Comparing the Various DFA Method

The comparison between three DFA methods:

i. Boothroyd and Dewhurst DFA

Advantages

It is very suitable for the redesign product based on design efficiency and the part that required high assembly time to assembly and unnecessary should be redesign or eliminate.

Disadvantages

Does not show the evaluation of the whole assembly sequence and also no support on how to redesign the evolution shows the poor results.

ii. Lucas / Hull DFA

Advantages

It is very suitable in develop new product design based on design efficiency and also evaluated the part based on functional, handling and fitting analysis.

Disadvantages

The function analysis does not show the reason why the part should exist and it is also no support on how to redesign the evolution shows the poor results.

iii. Hitachi Assemblability Evaluation Method (AEM)

Advantages

It is analyzes the assembly operations of each component of the product.

Disadvantages

Only focuses on the insertion and fastening process and neglected the handling process. It is also no support on how to redesign the evolution shows the poor results.