“I/We hereby declared that I/we have read through this report
and found that it has comply the partial fulfillment for awarding the degree of
Bachelor of Mechanical Engineering (Design and Innovation)”

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DESIGN AND ANALYSIS OF OPTICAL MOUSE USING BOOTHROYD DEWHURST DFMA METHODOLOGY

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This report is submitted as partial
fulfillment of the requirement for the award of
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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references"

Signature : …………………………

Name : Khairul Aidil Bin Nordin

Date : …………………………

Especially to my beloved parents,
My lovely brothers,
My respectfully lecturers,
Also my faithfully friends,
Your prayers always with me every way that I went…

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ABSTRACT

This project is purpose to create technical research for undergraduate students which have high potential in technical paper publication. Throughout this project, an existing optical mouse will separated each part purpose to do analysis and to critique the assembly point of view. After done the analysis, by using the Boothroyd-Dewhurst method some of the part will eliminate or reduce and redesign remain part as possible and come out with the some conceptual design. To ensure the purpose is achieved, some of the important element must be consider, there are followed the scope of project such as, literature review of the DFMA. In this project, all the design drawing, drawn by using the CATIA software. Finally, the new design will be compared with the original design from aspect, assembly cost, assembly time, part quantity and design efficiency. Base on calculation, the result had been containing for manual analysis, the percentage of design efficiency is 67.2 %, and for software analysis, the percentage of design efficiency is 71%. For percentage of part quantity, the result is 60% for both analyses. The result for percentage of assembly time is 70.3% for manual analysis and 63.82% for software analysis. Mean while the percentage of assembly cost is 70.3% for manual analysis and 66.7% for software analysis. From the overall result, the result obtained in software and manual analysis was not much different. For example, in result of design efficiency, the different values in manual result and software result for existing design was not much different. For manual existing design efficiency the result is 0.134 and for software the result is 0.1305. This project has shown the correct method to design and analyze optical mouse using Boothroyd-Dewhurst DFMA methodology

ABSTRAK

Projek ini adalah bertujuan untuk mewujudkan penyelidikan teknikal bagi pelajar prasarana yang mempunyai potensi besar untuk penerbitan kertas teknikal. Di dalam projek ini, tetikus optic yang berada di pasaran sekarang dipilih dan akan diceraikan satu persatu untuk menjalakan analisis dan memberi sudut pandangan terhadap tetikus tersebut. Setelah menjalankan analisa dengan menggunakan kaedah “DFMA”, rekabentuk baru di cipta denggan mengeluarkan beberapa konsep rekabentuk untuk mempertingkat kan kos pembuatan dan mengurangkan bilangan pada rekabentuk lama. Untuk memastikan matlamat projek tercapai mengikut ruang lingkup yang bersesuaian, kajian ilmiah yang terdahulu dijadikan sebagai rujukan. Didalam projek ini juga, semua rekabentuk dilukis dengan menggunakan perisian “CAD” iaitu perisian CATIA. Dan akhir skali rekabentuk baru akan dibandingkan dengan rekabentuk sedia ada dari aspek kos pemasangan, kos pembuatan dan kecekapan pemasangan. Berdasarkan analisis yang dijalankan, hasil yang telah diperolehi untuk peratusan kecekapan rekabentuk adalah 67,2% untuk manual analisis, dan untuk analisis perisian, peratusan kecekapan rekabentuk adalah 71%. Untuk peratusan jumlah bahagian, hasilnya adalah 60% untuk kedua analisis. Keputusan untuk peratusan masa pemasangan adalah 70,3% untuk analisis manual dan 63,82% untuk analisis perisian. Sementara peratusan kos pemasangan adalah 70,3% untuk analisis manual dan 66,7% untuk analisis perisian. Dari hasil keseluruhan, hasilnya diperolehi dalam perisian dan analisis manual tidak jauh berbeza. Contohnya, dalam keputusan kecekapan rekabentuk, nilai-nilai yang berbeza pada hasil manual dan keputusan perisian untuk rekabentuk yang sudah ada tidak jauh berbeza. Untuk kecekapan rekabentuk manual yang ada hasilnya adalah 0,134 dan untuk perisian hasilnya adalah 0,1305.

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CHAPTER 1

INTRODUCTION

1.1 General

Design for Manufacturing (DFM) and design for assembly (DFA) are the integration of product design and process planning into one common activity. DFMA can define as "*a process for improving product design for easy to manufacture and low-cost assembly, focusing on functionality and on assimilability concurrently*."

The goal of designing for manufacturing and assembly (DFMA) is to design a product that is easily and economically manufacture and assembly. On the other words is to improve the design of the assembly, to reduce the adhesion such as welding operation necessary to end up with a finished product. The most common methods of improvements are reducing the number of times the part have to be reoriented, and eliminating any excess material without sacrifice the product quality (George A. Bekey, 1993).

The importance of design of designing for manufacturing and assembly is underlined by the fact that about 70% of manufacturing cost of a product (cost of materials, processing, and assembly) is determined by design decision, with production decisions (such as process planning or machine tool selection) responsible while decisions made during production only 20%. Further, decisions made of the product's cost, quality and manufacturability characteristics (Piere De Lit, 2003).

1.2 Objectives

The goals of this project are:

i. To design and analyze of optical mouse using Boothroyd-Dewhurst DFMA methodology.
ii. To compare of between existing product and proposed design.
iii. To improve the assembly efficiency of existing product and proposed design.

1.3 Scope Of The Project

To ensure the objectives are achieved, some of the important element must be considered. There are as follow:

i. Literature Review.
ii. Drawing of existing design using the CATIA.
iii. Analysis of existing design using Boothyord-Dewhurst DFMA.
iv. Conceptual design and Detail design for the modification of existing product drawn by using CAD.
v. Boothyord-Dewhurst DFMA analysis of the existing and proposed design.
vi. Comparison between existing and proposed design

1.4 Problem Statement

There are several significant problems regarding to the project that exists in the case study:

1. Maximum number of subassembly part which less or not functions
2. The cost price of the existing product high because using excessive raw material and more purchases part (such as screws) used.
3. Is difficult or complicated in assembly process.

CHAPTER 2

LITERATURE REVIEW

2.1 Designs for Manufacture and Assembly (DFMA)

A literature review is a body of text that aims to review the critical point of current knowledge on a particular topic. Base on literature review, it provides general up to date ideals, theoretical concept and applications related to this project. This literature review will go through those topics related to Design for Manufacturing and Assembly (DFMA), Design for Assembly (DFA) and Design for Manufacturing (DFM) where has become an important concurrent engineering imperative for cost effective product design. The basis of DFMA is a systematic procedure for analyzing product design based on the application of the application of quantifiable data. This chapter also explained the basic concept and method of Boothroyd Dewhurst DFMA. The method is described for effective integration of quantitative and qualitative materials, manufacturing and assembly process information during product design.

Modern production systems have introduced a broad range of technologies to help accelerate the manufacturing process, but it is now well recognized that many of the decisions that are made at the concept design stages have a major impact on the success of the final project. Hence, the term “design for manufacturing (DFM)” means the design for ease manufacture the product after assembly and term “design for assembly (DFA)” means the design for ease of assembly. Thus, to be effective in product design, the both term are often combined as Design for Manufacture and Assembly (DFMA). Buss et al. (2001) agreed with this point of view, saying that the DFMA allows bring the product design to be effective if the considerations of design related to the assembly and manufacturability of the product.

Design for manufacture and assembly, or DFMA it has become to known, is now a widely accepted technique and are use in many manufacturing industries around the world purpose to earn more profit. There are three goals in DFM (Xiaofan Xie, 2002):

i. Increase the quality of new produces during the developing period, including design, technology, manufacturing, assembly, service and so on.
ii. Decrease the cost, including the cost of design, technology, manufacturing, delivery, technical support, discarding and so on.
iii. Shorten the developing cycle time and increase productivity including the time of design, manufacturing preparing, and repeatedly calculation.

Examples now prove that DFMA analysis provides much greater benefit than a simple reduction in-assembly cost. In fact, it appears that DFMA is the key to very significant reduction in overall manufacturing cost.

DFMA is used to provide accurate cycle time and manufacturing costs at the conceptual stage of the design cycle. This enables engineers to make more informed decisions for design optimization before it is too late make any changes. A few of these simple principles are:

a) Minimize the number of part
b) Minimize the number of assembly operations
c) Improve access and visibility
d) Maximize part compliance
e) Apply modular designs principles
f) Mistakes-proof part

Commonly, the incentive for considering design for manufacture and assembly is the need for improved productivity and cost performance. It has become widely accepted that first step in assessing the feasibility of automated assembly is the consideration of the product design and making changes to make automation plausible.

Since all this done at the design stage, the result is the optimum product design and before too much time and money has wasted in unnecessary planning, tooling and perhaps actual production of eliminated parts (Mark Curtis, 1990).

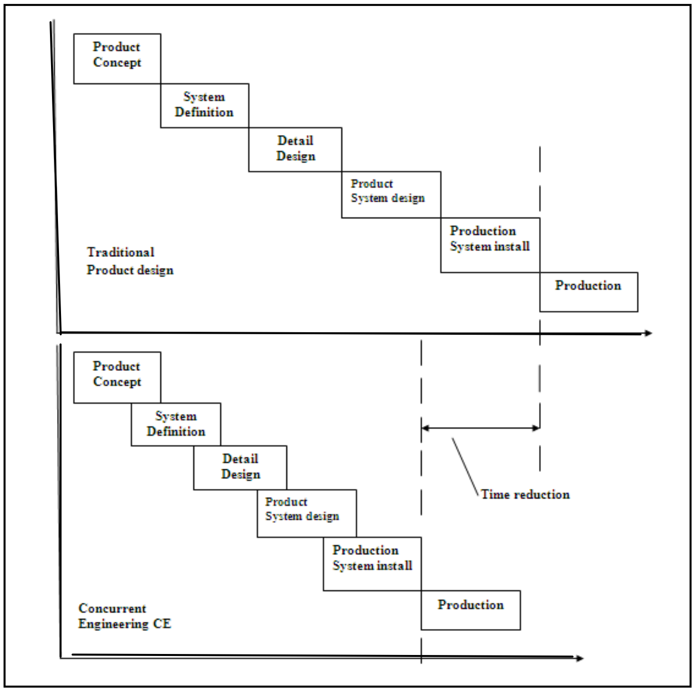


Figure 2.1: Traditional product development compared to concurrent engineering (Source: Stephen Eskilandar, 2001)

2.2 History and Background of Design for Assembly (DFMA)

In the 1960's and 70's various rules and recommendation were proposed in order to help designer consider assembly problems during the design process. Many of these rules and recommendations were presented together with practical examples showing how assembly difficult could be improved. However, it was not until the 1970's that numerical evaluation method were developed to allow design for assembly studies to be carried out on existing and proposed design.

The first evaluation method was developed at Hitachi and was called the Assembly Method (AEM). This method is based on the principal of "one motion for one part." For more complicated motions, a point-loss standard is used and the ease of assembly of the whole product is evaluated by subtracting points lost. The method was originally developed in order to rate assemblies for ease of automatic assembly.

Starting in 1977, Geoff Boothyord, supported by NSF grant at the University of Massachusetts, developed the design for Assembly (DFA) method; it is based on timing each of the handling and insertion motion which could be used to estimate the time for manual assembly of a product and the cost of assembling the product on an automatic assembly machine. Recognizing that the most important factor in reducing assembly costs was the minimization of the number of separate parts in a product, he introduced simple criteria which could be used to determine theoretically whether any of the parts in the product could be eliminated or combined with other parts. U.K. Unlike the Boothroyd Dewhurst method, the Lucas method is based on a "point scale" which gives a relative measure of assembly difficulty. Lucas DFA method definitely based on the parts count analysis stage with is known as terms "functional analysis".

Starting in 1981, Geoffrey Boothroyd and Peter Dewhurst developed a computerized version of the DFMA method which allowed its implementation in a broad range of companies. For this work they were presented with many awards including the National Medal of Technology. There are many manufacturing company of significant savings obtained through the application of DFA software. For example in 1981, Sidney Liebson, manager of manufacturing engineering for Xerox, estimated that this company would save hundreds of millions dollars through the application of DFA. In the 1988, Ford Motor Company credited the software with overall savings approaching $1 billion. In many companies DFA is a corporate requirement and DFA software is continually being adopted by companies attempting to obtain greater control over their manufacturing cost. John Allen (2006) from Celestica identified Boothroyd-Dewhurst's DFA soft as playing an important role in the early-stage review for manufacturing and assembly design.

Using DFMA software, product engineers assess the cost contribution of each part and then simplify the product concept through part reduction strategies. These strategies involve incorporating as many features into one part as is economically possible. DFMA software tools and services allow companies to develop product with fewer parts at lower cost and with higher quality than was previously possible. Table 2.1 shows the average reductions with using DFMA software where the result compiled from over 100 published case studies. The outcome of DFA software is a more elegant product with fewer parts that is both functionally efficient and easy to assemble. The larger benefits of DFA software are reduced part cost, improved quality and reliability, and shorter development cycles. A few achievements by using DFMA application is:

i. Create products that are functionally efficient and easier to assemble.
ii. Estimate assembly costs for alternative design.
iii. Reduce manufacturing and assembly costs.
iv. Shorten overall development time for your organization.

Table 2.1: DFMA Software Average Reductions
(Source: Boothroyd Dewhurst, Inc)

Item	Reduction (%)
Labor Costs	45
Part Count	54
Separate Fasteners	57
Weight	22
Assembly Time	60
Assembly Cost	45
Assembly Tools	73
Assembly Operations	53
Product Development Cycle	45
Total cost	50

2.3 Advantage of Applying DFMA

There were advantages of applying Boothroyd Dewhurst DFMA to product. The advantages as following (G. Boothroyd, P. Dewhurst, W. Knight 1994):

i. DFMA provides a systematic procedure for analyzing a design from view of assembly and manufacture. The procedure result more simple and more reliable product which less expensive.
ii. DFMA tools encourage dialogue between designer and manufacture engineers and other individual who involve. This means the teamwork is encouraged and benefite of simulation engineering can achieve.
iii. The saving in manufacture cost obtained by company after implemented DFMA.

2.4 Example How DFMA is Apply

The example in **Figure 2.2** showed proposed original design of motor drive in exploded view. The design showed the parts before analyze using DFMA method.

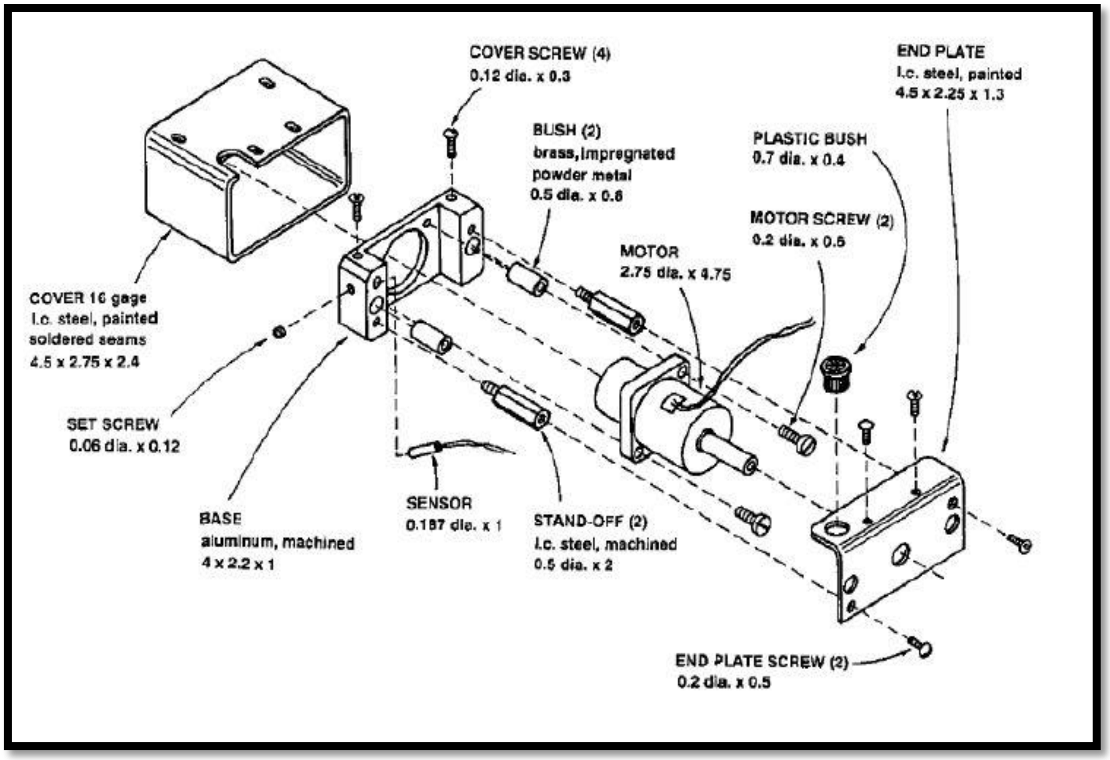


Figure 2.2: Proposed original design of Motor Drive assembly

(Source: Geoffrey Boothroyd, 1994)

Table 2.2: DFA analysis result

(Source: Geoffrey Boothroyd, 1994)

Parts	No.	Theoretical Part Count	Assembly Time (S)	Assembly Cost ($)
Base	1	1	3.5	2.9
Bushing	2	0	12.3	10.2
Motor Subassembly	1	1	9.5	7.9
Motor Screw	2	0	21	17.5
Sensor Subassembly	1	1	8.5	7.1
Set Screw	1	0	10.6	8.8
Standoff	2	0	16	13.3
End Plate	1	1	8.4	7
End Plate Screw	2	0	16.6	13.8
Plastic Bushing	1	0	3.5	2.9
Thread Leads	-	-	5	4.2
Reorient	-	-	4.5	3.8
Cover	1	0	9.4	7.9
Cover Screw	4	0	31.2	26
Total	19	4	160	133

$$\text{Design efficiency} = \frac{4 \text{ x } 3}{160} = 7.5\%$$

Table 2.2 shows the result of Design for Assembly (DFA) analysis for the motor drive assembly proposed design. The result for design efficiency is 7.5%.

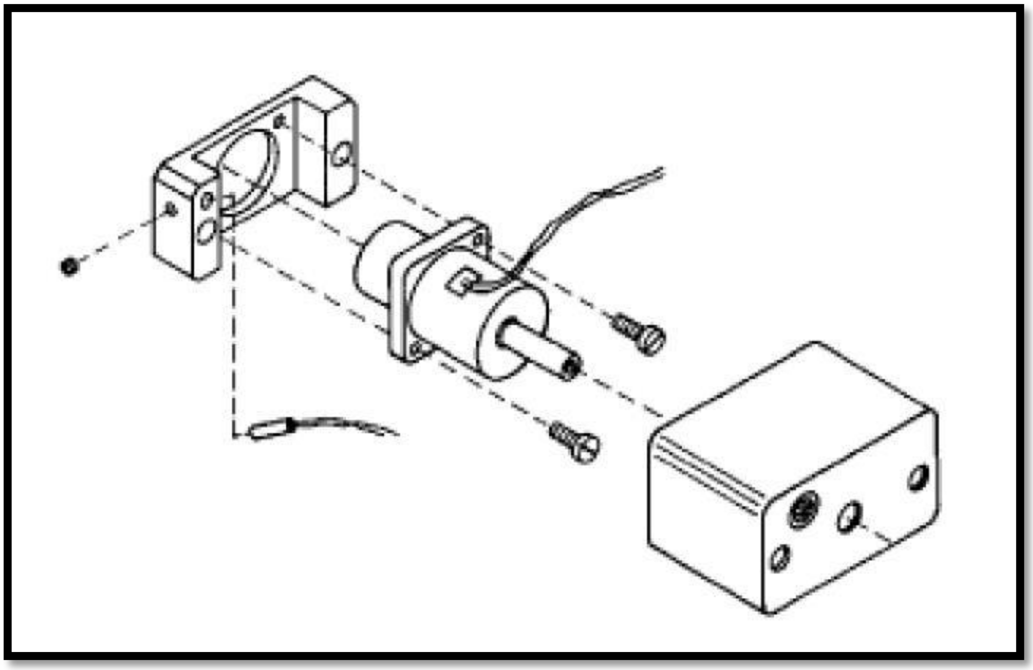


Figure 2.3: Redesign of Motor Drive assembly after DFA
(Source: Geoffrey Boothroyd, 1994)

The example in **Figure 2.3** showed redesign of motor drive in exploded view. The designs showed the parts after analyze using DFMA method. The number off part was reducing.

Table 2.3: Result after DFA analysis

(Source: Geoffrey Boothroyd, 1994)

Parts	No.	Theoretical Part Count	Assembly Time (S)	Assembly Cost ($)
Base	1	1	3.5	2.9
Motor Subassembly	1	1	4.5	3.8
Motor Screw	2	0	12	10
Sensor Subassembly	1	1	8.5	7.1
Set Screw	1	0	8.5	7.1
Thread Leads	-	-	5	4.2
Plastic Bushing	1	0	4	3.3
Total	6	4	46	38.4

$$\text{Design efficiency} = \frac{4 \text{ x } 3}{46.0} = 26\%$$

Table 2.3 shows the result for redesign of motor drive. The design efficiency result after DFMA analysis is 26%.

2.5 Overview of DFMA

The Design for Manufacturing and Assembly has the guidelines that use for ease of assembly and manufacture. There were categorizing between design for assembly and design for manufacture. The guidelines are the principle of all the DFMA method available and can generally used for product design and development.

2.5.1 Guideline for DFM

The following guidelines are the practice use in development the product by DFM (G. E. Dieter, 2000):

i. Minimize total number of parts by eliminate parts by combine the 2 or more parts in single piece of part. However, the combination should consider the difficulty and complexity of design should also reduce.
ii. Standardize components is use which available commercially.
iii. Use common parts across product lines, by usage of parts in more than one product will simplify the process operations.
iv. Part should design to be multifunctional, where it can fulfill more than one function. Therefore, the quantity of part in product is reducing.
v. The part should design for ease of fabrication whenever possible.
vi. Avoid tight tolerance. The high precisions of parts in fabrication are costly which need extra precision tooling and high skill worker. Therefore, the avoidances of the tight tolerance are required wherever possible.
vii. Avoid secondary operations on parts such heat treatment, polish, planting and other. The process use only if has functional reasons or is need for aesthetic purposes.
viii. Utilize the special characteristic of manufacture process. There were special designs features provide by many of process. As example the

polymers injection molding can provided with “built-in” color, as opposed to metal that need to be painted.

2.5.2 Rules for DFM

A list of the specific design rules as the following (J. George, 1986):

i. Space holes in machined, cast, molded or stamped parts so they can been make in one operation without tooling weakness. This means that there is a limit on how close holes may be spaced due to strength in thin section within hole.
ii. Avoid generalize statement on drawings, like “polish this surface” or “tool marks not permitted” which are difficult for manufacturing personnel to interpret. Notes on engineering drawings must specific and unambiguous.
iii. Dimension should make from specific surface or points on parts, not from points in space.
iv. Dimension should all be from single datum line rather than from variety of points to avoid overlap of tolerances.
v. The design should aim for minimum weight consistent with strength and stiffness required.
vi. Use the general purpose of tooling rather than special customizes tool wherever possible.
vii. Use generous fillets and radius on castings, molded, formed and machined parts.
viii. Part should be designed so that as many operations as possible can performed without reposition.

2.5.3 Basic DFA Guidelines

Each act of retrieving, handling, and mating a component is called an assembly operation. Each assembly operation takes time and has an associated cost. The assembly of components can from a significant part of the manufacturing cost of a product, especially when large quantities of component are involved. The use of guidelines on good design practice for manufacturing and assembly can help improve manufacturing and assembly efficiency, thereby reduce the time and costs. Here are some basic guidelines for DFA. Generally, start with a concept design and then go through each of these guidelines, decide whether or not it is applicable, and the modified the concept to satisfy the guideline. There is no guarantee that a given guideline will apply to a particular design problem (George E. Dieter. 2000):

i. Minimize part count by incorporating multiple functions into single part.
ii. Modularize multiple parts into single subassemblies.
iii. Assemble in open space, not in limited spaces with never hide important components.
iv. Make parts such that it is easy to identify how they should be oriented for insertion.
v. Prefer self-locating parts.
vi. Standardize to reduce part variety.
vii. Maximize part symmetry
viii. Design in geometric or weight polar properties if nonsymmetrical.
ix. Eliminate tangle parts.
x. Color code parts that are different but shaped similarly.
xi. Prevent nesting of parts; prefer stacked assemblies.
xii. Provide orienting features on non-symmetries.
xiii. Design the mating features for easy insertion.
xiv. Provide alignment features.
xv. Insert new parts into an assembly from above.
xvi. Eliminate re-orientation of both parts and assemblies.
xvii. Eliminate fasteners.

xviii. Place fasteners away from obstructions; design in fastener access.

xix. Deep channels should be sufficiently wide to provide access to fastening tools; eliminate channels if possible.

xx. Provide flats for uniform fastening case.

xxi. Ensure sufficient space between fasteners and other features for a fastening tool.

xxii. Prefer easily handled parts

.

The process of manual assembly is divided into 2 separate areas (G. Boothroyd et. al, 1994):

i. Handling – acquiring, orienting and moving of part

ii. Insertion and fastening – mating a part to another part or group of parts.

2.5.3.1 Design Guideline for Part Handling

Generally, for ease the part handling, the factors should consider are:

i. Design parts that have end-to-end symmetry and rotational about axis of insertion. If thus cannot be achieved, try to design parts having maximum possible symmetry.

ii. Design parts that in those instances where the part cannot be make symmetric are obviously asymmetric.

iii. Provide features that will prevent jamming of parts that tend to nest or stack when stored in bulk.

iv. Avoid features that will allow tangling of parts when stored in bulk.

v. Avoid parts that stick together or are slippery, delicate, flexible, very small or very large or that hazardous to the handler (i.e.; parts that are sharp, splinter easily, etc)

2.5.3.2 Design Guideline for Insertion & Fastening

For the ease of the handling and insertion designer should attempt to:

i. Design so that there is little or no resistance to insertion and provide chamfers to guide insertion of two mating parts. Generous clearance should be provide and with care must be take to avoid clearances that will result a tendency for parts to jam or hang-up during insertion.
ii. Standardize by using common parts, processes 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.
iii. Use pyramid assembly – provide for progressive assembly about one axis of reference. Generally it is best assemble from above.
iv. Avoid where possible for holding parts down to maintain their orientation during manipulation of subassembly or during the placement of another part. If holding down required, design part to secure as soon as possible after has been inserted.

2.6 DFMA Method

There were several designs for assembly method available to support product development. Sackett and Holbrook (1988) reported of twelve commercially available DFMA methods as **Table 2.4.**

Table 2.4: The available commercial DFMA method
(Source: Stephen ESkilandar, 2001)

DFMA method	Authors	Country origin
Assemblability Evaluation Method (AEM)	Ohashi Yano	Japan
Boothyord-Dewurst DFMA	Boothyord Dewhurst	USA
A designer guide optimize the assemblability of the product design (DGO)	Hock	USA
Lucas Method	Miles Swift	UK
ASSEMBLY	DeWinter machiels	Belgium
Assembly Oriented Product Design (AOPD)	Bassler Warnecke	Germany
Assembly System (ASSYST)	Arpino Grppeti	Italy
Assembly View	Sturges	USA
Design for Assembly Cost-effectiveness	Yamagiwa	Japan
Product and System Design for Robust Assembly	Davisson	USA
The DFA House	Rampersad	The Netherlands

There were two approaches of evaluation philosophies in DFA are the qualitative and quantitative evaluation. The qualitative defined as evaluation criteria that used to decide whether the product does fit a certain assembly process or not. The evaluating requirement themselves give information about the preferred solution that will fit the assembly process (Stephen ESkilandar, 2001).

Quantitative evaluation defined as evaluating a product and being given the answer that it takes how much second to assembly process. Quantitative evaluation does not given explicit information about the preferred solution for the assembly process.

For this research, the focused will be the Boothyord-Dewhurst DFMA method. The details information will be discuss later. For all the methods available, generally the guidelines are merely the same for each other's. The differences are on the methodologies approaches on each method. The evaluations on the design of the parts is count either by qualitative or quantitative.

2.7 Various DFMA Method

Various researchers have proposed method of evaluating the efficiency of product design from the perspective of product assembly. DFMA consist of three popular methods which is Boothroyd Dewhurst method, Lucas method and Assembly evaluation method. All of these method have their same mission which is to the design team in simplifying the product structure, to reduce manufacturing and assembly cost, and to quantify the improvements. But they their own techniques which is (Mital. A, 2007):

i. The Boothyord Dewhurst method: this method seeks to reduce the number of parts by a consideration of manual handling and manual insertion time.
ii. The Lucas method: Analysis is carried out in three sequences stages-functional, fitting and feeding.
iii. The Assembly evaluation method: This method aims to facilitate design improvements by identifying weakness in the design at the earliest stage in the process by using an assemblability evaluation score and assembly cost ratio.

2.7.1 The Lucas Method

The Lucas DFA evaluation method was developing by University of Hull with collaboration with Lucas Organizations. These methods use the quantitative evaluation. The method is based on ‘assembly sequence flowchart’ (ASF). The method consists to assign the score to potential assembly problem due to design. The procedure of the method is shown in **Figure 2.7.1.** As the design specification arise, the product analyze whether it’s unique or whether there are similarities and therefore opportunities for standardize of components, and simplify assembly process. Function analysis is carried out according to the category functions. The assembly analysis is be differentiate by term of “handling” for the manual assembly operations and “feeding” when part handle automatic (H J Bullinger and M Richter, 1991).

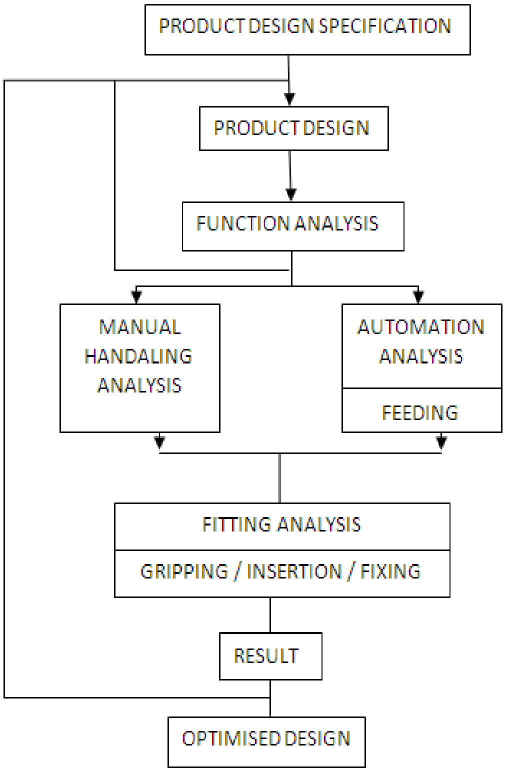


Figure 2.4: The Lucas DFMA procedure

(Source: H J Bullinger and M Richter, 1991)

2.7.1.1 The Evaluating procedure

The system feature of three assimilability score, which are; design efficiency, feeding/handling and fitting ratio. The evaluation is carried out by the following procedure:

i. Functional analyses carried out by rules of value operation are categorized due to the functional importance. Each operation or activities are categorized as either an A (essential) part or a B (non-essential) parts. Then the design efficiency is derived from the ratio of essential part to total part (A/(A+B)). Design efficiency should exceed 60% as by suggestion to aim.

ii. Feeding or handling analysis; depend on manual or automatic assembly. Each component is examined with respect to a knowledge base, and the user determines a feeding index. The feeding/handling ratio is the feeding index total divided by the number of essential components. The feeding index has a threshold of 1.5 indicating that any greater score be considered for redesign for feeding. The feeding ratio is the ratio of feeding index total to number of essential components, and has its own threshold of 2.5.

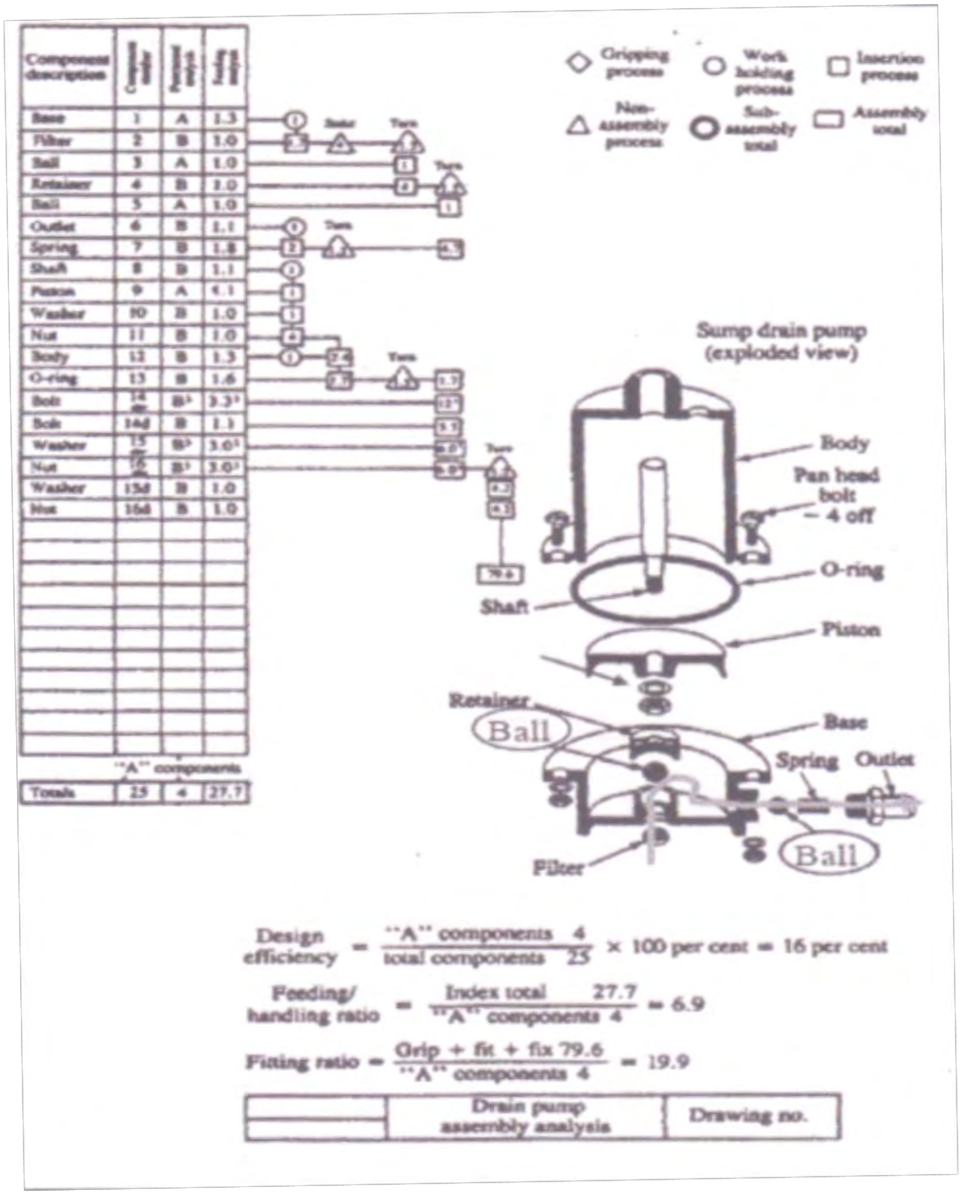
iii. The fitting analysis is carried out to derive the fitting ratio. Fitting analysis follows the same formula as feeding, utilizing a knowledge base, determining a fitting index, and finally a fitting ratio. Each symbol in the ASF contains a penalty factor. The sum of these factors is the fitting index in the fitting ratio. These score can then be compared to thresholds or values established for previous design.

2.7.1.2 Improvement of Design

The improvement of the product is done by either eliminate all ‘B’ part or combine with ‘A’. The high index parts should be redesigned according to the evaluation criterion.

2.7.1.3 The Lucas DFA Evaluation Example

Figure 2.5 and **Figure 2.6** show how the Lucas method shows design efficiency and the feeding/handling and fitting ratios and how redesigning a product can improve them. The first Drain Pump design at **Figure 2.5**, shows a poor design efficiency of 4 essential parts out of 25 (16%).



Component description	[illegible]	[illegible]	[illegible]
Base	1	A	1.3
Filter	2	B	1.0
Ball	3	A	1.0
Retainer	4	B	1.0
Ball	5	A	1.0
Outlet	6	B	1.1
Spring	7	B	1.8
Shaft	8	B	1.1
Piston	9	A	4.1
Washer	10	B	1.0
Nut	11	B	1.0
Body	12	B	1.3
O-ring	13	B	1.6
Bolt	14	B^{3}	3.3^{3}
Bolt	14d	B	1.1
Washer	15	B^{3}	3.0^{3}
Nut	16	B^{3}	3.0^{3}
Washer	15d	B	1.0
Nut	16d	B	1.0
		"A" components	
Totals	25	4	27.7

Design efficiency = "A" components 4 / total components 25 × 100 per cent = 16 per cent

Feeding/handling ratio = Index total 27.7 / "A" components 4 = 6.9

Fitting ratio = Grip + fit + fix 79.6 / "A" components 4 = 19.9

	Drain pump assembly analysis	Drawing no.

Figure 2.5: Lucas evaluation method on existing design

(Source: Redford Alan and Jan Chal, 1994)

The second design illustrated in **Figure 2.6**, reduces the number of parts to 6 with a resulting design efficiency of 66%. A visual comparison between the two ASFs shows that the redesign is much simpler to assemble. This is reflected in the difference between the two Fitting Ratios (4.0 for the redesign compared to 19.9 for the original).

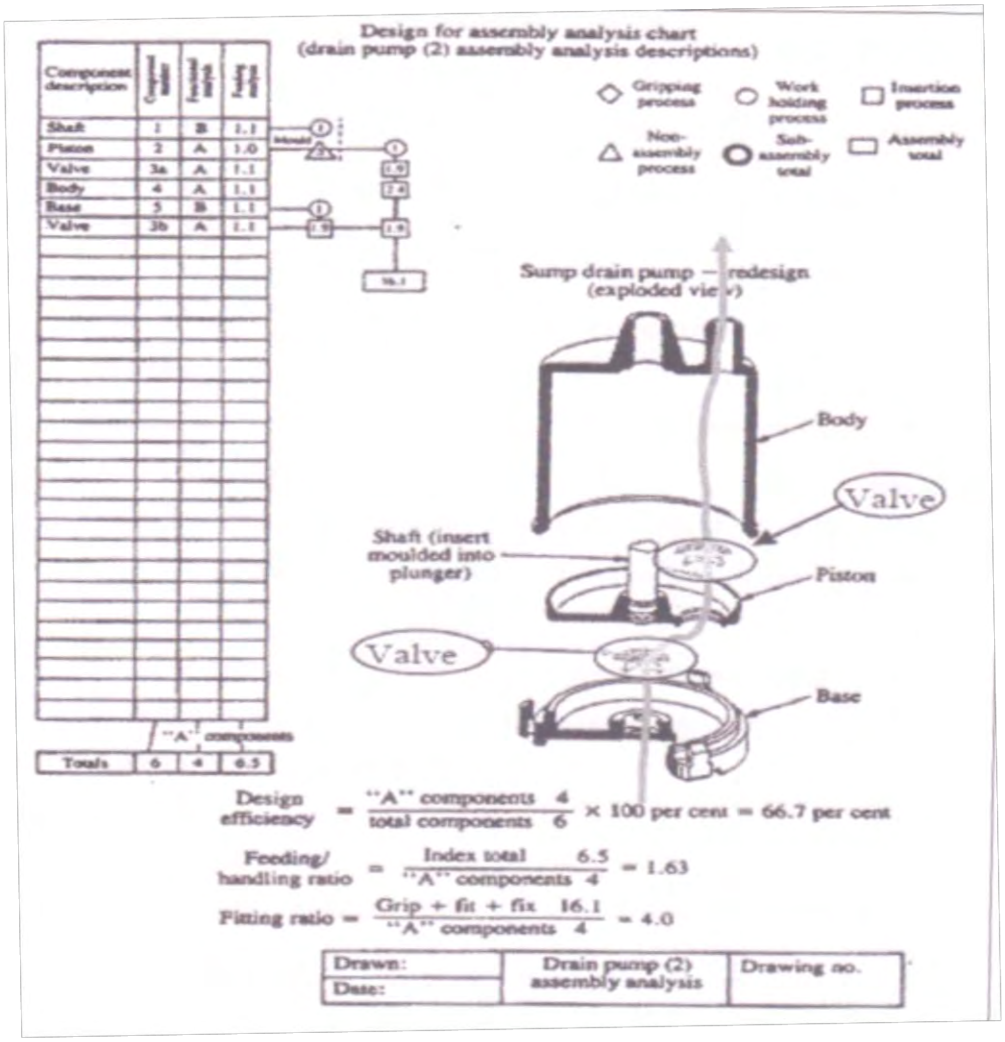


Figure 2.6: Lucas evaluation method on redesign product

(Source: Redford Alan and Jan Chal, 1994)

The redesign has reduced the number of components by getting rid of the bolt, washer and nut. These happen to attribute the higher feeding analysis scores (and fitting) to the total (this makes sense because these tend to be difficult to assemble in reality). As a consequence the feeding and handling ratio has reduced from 6.9 to 1.63.

2.7.2 Assembly Evaluation Method (AEM)

The Assemblability Evaluation Method (AEM), is develop by Hitachi as a result of trying to develop an automatic assembly system for tape recorder mechanism (Hashizume et al., 1980). After years of improvement, Miyakawa (1990) presented the ‘new’ Assembly Evaluation Method from Hitachi. The improvements were e.g. the improvement assembly cost estimate accuracy for individual parts. This methodic formally known as Hitachi’s AEM.

The method does not distinguish manual, automatic or robotic assembly. The reasons are the method is most beneficial when used in early conceptual stage and the manufacturing methods not decide yet.

The method improve design by identify “weakness” in early design process using two indicator. An assemblability index is calculated by summarizing the scores for all parts.

The indicators used in AEM for product evaluation are:

i. Assembly evaluation score, “E”.
  - Asses the design by determine difficulties of assembly operation or design quality.

ii. Estimate assembly cost ratio, “K”.
  - Used as relative index that compared the redesign to the estimated assembly cost of original design.

Analysis procedures start by preparations, which involve collecting data of the design detail. Then the operation analysis is conduct by determine an assembly sequence and the categorizing each part according to “standard operation”. The total assemblability evaluation score individual tasks, divided by the number of tasks. With the evaluation index judgment, the improvement will consider for part reductions. The product’s design been improved by concentrate on evaluation score. As per **Figure 2.6**, the figure mentions the flow procedure of AEM,

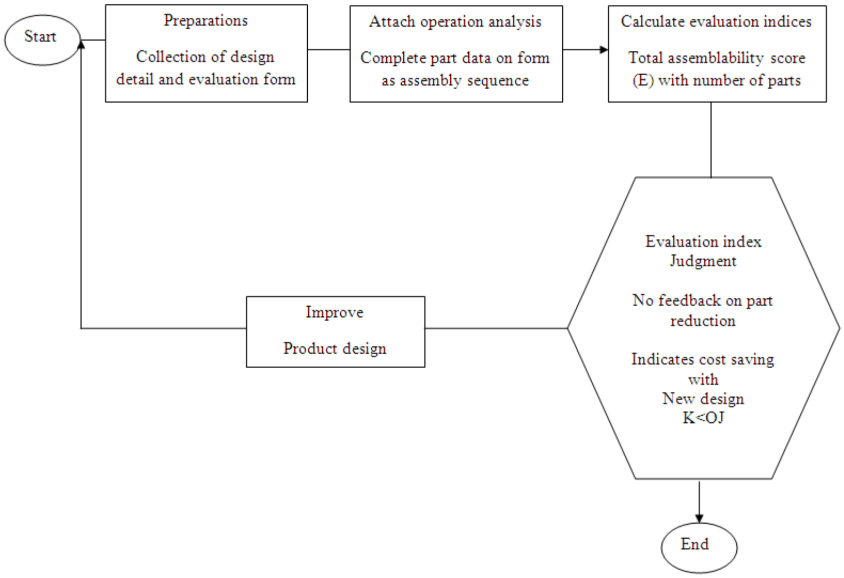


Figure 2.7: The Hitachi’s AEM procedure

(*Source: http://www.ami.ac.uk/ami4813_dfx/u03/s01/index.asp*)

2.7.2.1 The Evaluation Procedure

The Hitachi AEM procedures are as per following sequence (R. Alan and J. Chal, 1994):

i. The analysis start by determine and categorized the assembly task sequence according by standard operation, that approximately 20 standard assembly task.

ii. All the parts tasks are receiving the penalty score, which subjects to difficulty of the assembly. The ideal operations are rewarded 100 points, which receive zero on penalty score. The score of 100 points represents the assembled with only downward motions.

iii. All score for the parts will summarize, then modify it by attach coefficients and subtracted from the best score.

iv. The totals then divided by the total number of parts. This may be able to consider a measure of design efficiency where a score of 100 would represent a perfect design.

v. Then the cost ratio, k is estimated continuously by compared to current assembly cost ratio with new design.

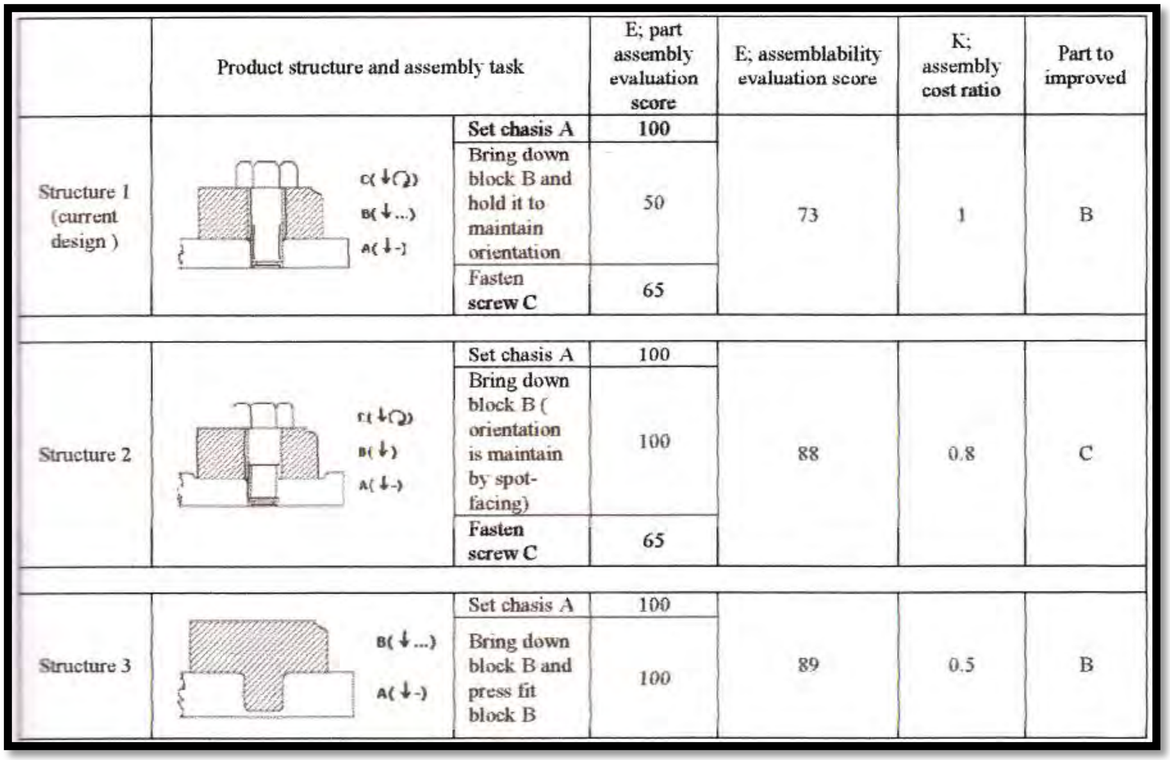
vi. Hitachi consider that an overall score E of 80 and higher is acceptable and overall assembly cost ratio K of 0.7 or greater is acceptable.

2.7.2.2 Improve of design

To redesign the product, the assemblability evaluation score, E is used as guide. However in certain cases, high score of ‘E’ can be achieve by having many simple components and the ‘K’ score will show the increasing due to parts increase.

2.7.2.3 The Hitachi’s AEM Method Example

The following **Figure 2.8** is the example of assemblability evaluation and improvement of part.



	Product structure and assembly task		E; part assembly evaluation score	E; assemblability evaluation score	K; assembly cost ratio	Part to improved
Structure 1 (current design)	C(↓↻) B(↓...) A(↓-)	**Set chasis A**	**100**	73	1	B
		Bring down block B and hold it to maintain orientation	50			
		Fasten **screw C**	65			
Structure 2	C(↓↻) B(↓) A(↓-)	Set chasis A	100	88	0.8	C
		Bring down block B (orientation is maintain by spot-facing)	100			
		Fasten screw C	65			
Structure 3	B(↓...) A(↓-)	Set chasis A	100	89	0.5	B
		Bring down block B and press fit block B	100			

Figure 2.8: Assemblability evaluation and improvements

(Source: Redford Alan and J. Chal, 1990)

As illustrated in **Figure 2.8**, the structure 1 shows an assembly task of the current design. The assembly evaluation score is 73, after sum of part score and divided by number of operation, 3. The result in product assemblability evaluation score is 73 is below than acceptable score of 80. The improvement designs shown in structure 2, which improvement on part by remove the holding. It must spot-facing the chassis down. This gives assemblability evaluation score, E as 88; the assembly cost ratio, K as 0.8 the structure 3, the bolt is removed and block attached to chassis by using press fit. The assemblability evaluation score, E is 89; the assembly cost ratio is 0.5. The significant improved of the of the cost ratio because the reduced number of parts.

2.7.3 The Boothroyd – Dewhurst Method

Boothyord Dewhurst method design for manufacture and assembly is the well-known DFMA method that applicable for industry. The Boothyord-Dewhurst DFMA develops by Geoffrey Boothyord and Peter Dewhurst since 1982. The methods generally applied in industry particularly U.S industry. The methodology is well known for the industry especially US industry. The term "DFMA" is actually a trademark for Boothyord Dewhurst Inc. (BDI) the companies have created and develop the DFMA concept that used for their product development, the DFMA software system.

The manual systematic evaluation method using the quantitative evaluation method also introduce by BDI. The studies measure the effect of symmetric, size, weight, thickness, and flexibility of manual assembly. The method perform by analyze base on two ways; elimination possibility and ease of assembly possibility.

2.7.3.1 Evaluation Procedure

All parts for product are evaluated according to the geometrical, assembly time, the theoretical part and operation cost. The information is used to calculate the design efficiency.

Theoretical part is the element to determine the possibility to eliminate or combine the parts. The theoretical part determine by answering the question (G.Boothyord, P.dewhurt, W.Knight. 1994):

i. Does the part move relative to other already assembled parts when the product working normally?
ii. Does the part have to be of other material or isolated from other already assembled parts? Only acceptable for fundamental material.
iii. Does the part has to be separate from other already assembled parts because assembly or disassembly of other parts otherwise be impossible.

For the question, which the answer for all is “no”, then the part can be considered for eliminate or integration.

For the geometrical properties analysis of the difficulty, handling and the insertion while assembly. The difficulty of handling and insertion then given the code according to matrix provide by Boothyord Dewhurst. The codes and subsequent times are used to determine a number of metric:

i. Assembly time (TM) is determining by summing the handling and insertion times.
ii. Assembly cost (CM) is proportional to TM by a factor that accounts for wage and overheads

Then the design efficiency is calculated is defined as the ideal assembly time divided by the estimated time. The ideal assembly time is given 3NM, where the 3 represents a handling time of 1.5 seconds and insertion time 1.5 second, for an ideal component. The estimated assembly time is TM

$$\textbf{Design Efficiency} = \frac{3 \text{ x NM}}{\text{TM}} \qquad \ldots \text{ Equation (1)}$$

2.7.3.2 Improvement of Product

For redesigning the parts is indicating by low value of design efficiency. For the parts elimination, the theoretical parts not necessary should be eliminating. For part with high assembly time should be redesign to better assembly operation that can shorter the assembly time.

2.7.3.3 Boothyord – Dewhurst DFMA Example

The example of the Boothyord – Dewhurst method is illustrated in **Figure 2.9** and **Table 2.5** that show the original evaluation. For the redesign evaluation is illustrated in **Figure 2.10** and **Table 2.6**. The product for evaluation is sub-assembly part that use in construction of gas flow meter. On **Figure 2.9**, original design, the efficiency acquire is 0.077. Then for new design which acquire design efficiency of 0.428. The design efficiency increased for new design. Based on the number of theoretical part, the redesign product has reduced the quantity of part from 8 to 2.

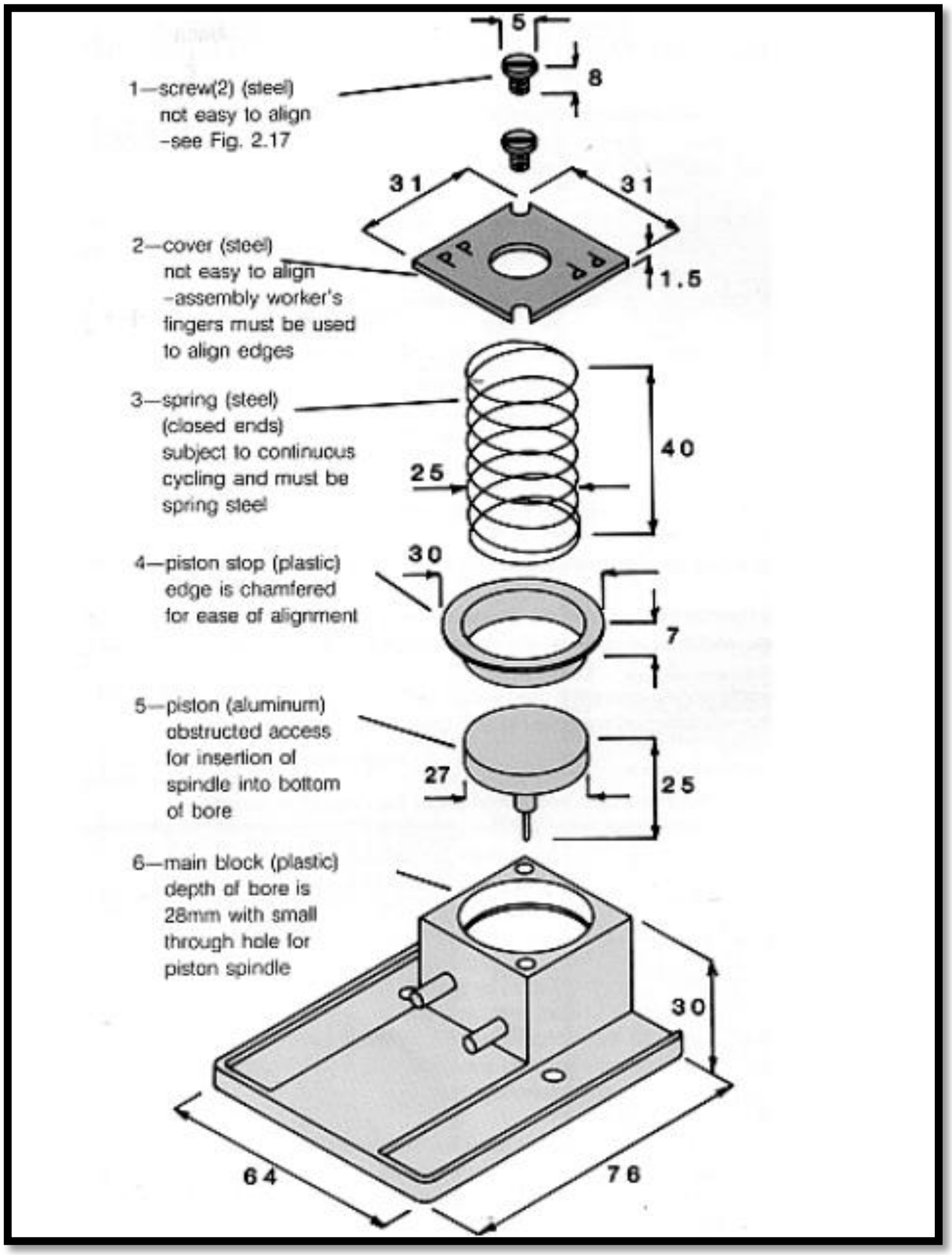
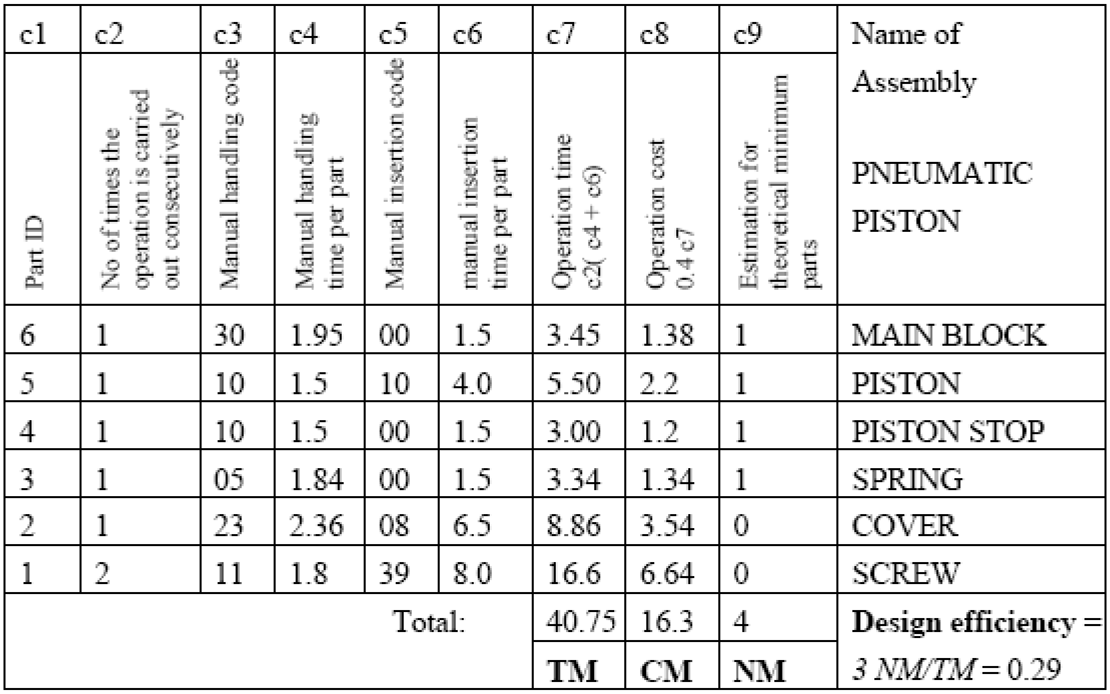


Figure 2.9: A piston-assembly design

(Source: Redford Alan and J. Chal, 1990)

Table 2.5: Evaluating the design efficiency of Piston

(Source: Redford Alan and J. Chal, 1990)



c1	c2	c3	c4	c5	c6	c7	c8	c9	Name of Assembly PNEUMATIC PISTON
Part ID	No of times the operation is carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	manual insertion time per part	Operation time c2(c4 + c6)	Operation cost 0.4 c7	Estimation for theoretical minimum parts	
6	1	30	1.95	00	1.5	3.45	1.38	1	MAIN BLOCK
5	1	10	1.5	10	4.0	5.50	2.2	1	PISTON
4	1	10	1.5	00	1.5	3.00	1.2	1	PISTON STOP
3	1	05	1.84	00	1.5	3.34	1.34	1	SPRING
2	1	23	2.36	08	6.5	8.86	3.54	0	COVER
1	2	11	1.8	39	8.0	16.6	6.64	0	SCREW
					Total:	40.75	16.3	4	**Design efficiency =**
						TM	**CM**	**NM**	*3 NM/TM* = 0.29

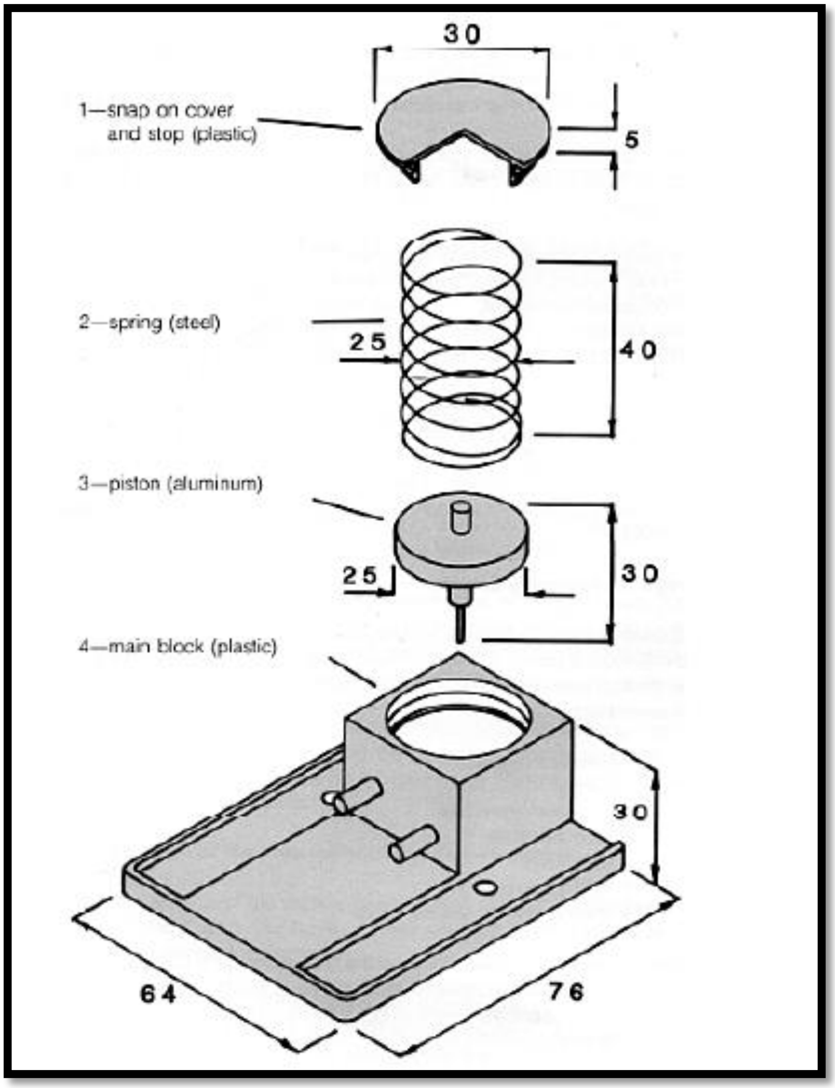
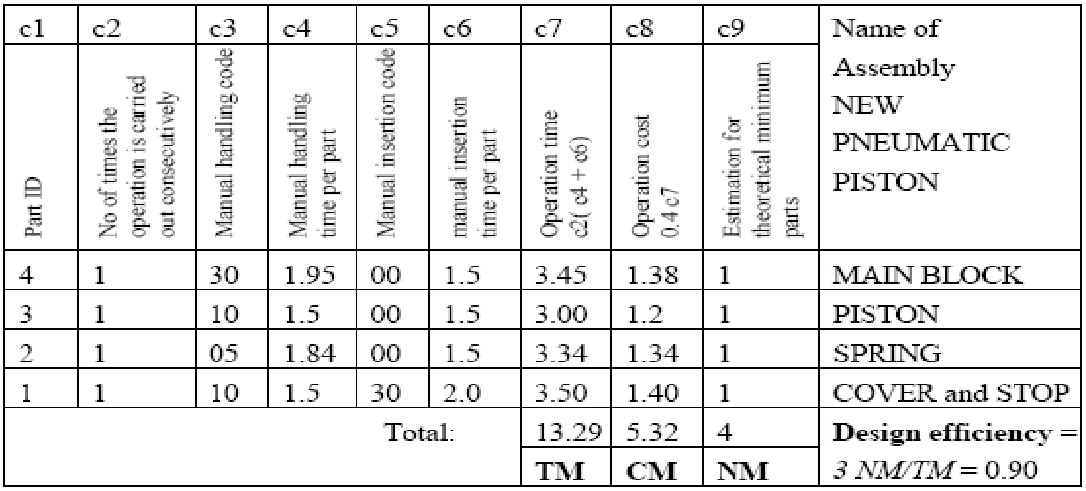


Figure 2.10: An improved piston design

(Source: Redford Alan and J. Chal, 1990)

Table 2.6: Evaluating the design efficiency of the re-designed piston

(Source: Redford Alan and J. Chal, 1990)



c1	c2	c3	c4	c5	c6	c7	c8	c9	Name of Assembly NEW PNEUMATIC PISTON
Part ID	No of times the operation is carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	manual insertion time per part	Operation time c2(c4 + c6)	Operation cost 0.4 c7	Estimation for theoretical minimum parts	
4	1	30	1.95	00	1.5	3.45	1.38	1	MAIN BLOCK
3	1	10	1.5	00	1.5	3.00	1.2	1	PISTON
2	1	05	1.84	00	1.5	3.34	1.34	1	SPRING
1	1	10	1.5	30	2.0	3.50	1.40	1	COVER and STOP
Total:						13.29	5.32	4	**Design efficiency =** *3 NM/TM* = 0.90
						TM	**CM**	**NM**	

2.8 SUMMARY

Design for manufacture and assembly (DFMA) is the practice of designing products with manufacturing in mind so they can be designed in the least time with the least development cost; make the quickest and smoothest transition into production; be assembled and tested with the minimum cost in the minimum amount of time; have the desired level of quality and reliability; and satisfy customers needs and compete well in the marketplace.

DFMA considers manufacturing issues early to shorten product development time and ensure smooth transitions to manufacturing, thus, accelerating time-to-market. DFMA reduces costs since products can be quickly assembled from fewer standard parts. Parts are designed for ease of fabrication and commonality with other designs. This, in turn, means a broader product line can be created by assembling common "building blocks" modules into new products.

All the methodologies in the literature review are same motive with the project. All the guideline in the literature review can give more efficiency result at the end project.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, project methodology will illustrate what and how methods that have been used for this project until get the result. This project is start with the project plan and project design. This project also has two parts which is the first part is the analyze and evaluate the current product (optical mouse) using Boothyord – Dewhurst Method and the second part is the come out with the proposed design by improved the existing design and redesign each part in the product and evaluate the new design with Boothyord – Dewhurst Method.

In this chapter also carried out in order achieve the objective of the project and ensure the project is follows as the scope. For the project certain stage has been determine. The process flow of the project as illustrated in flow chart as shown in **Figure 3.1**.

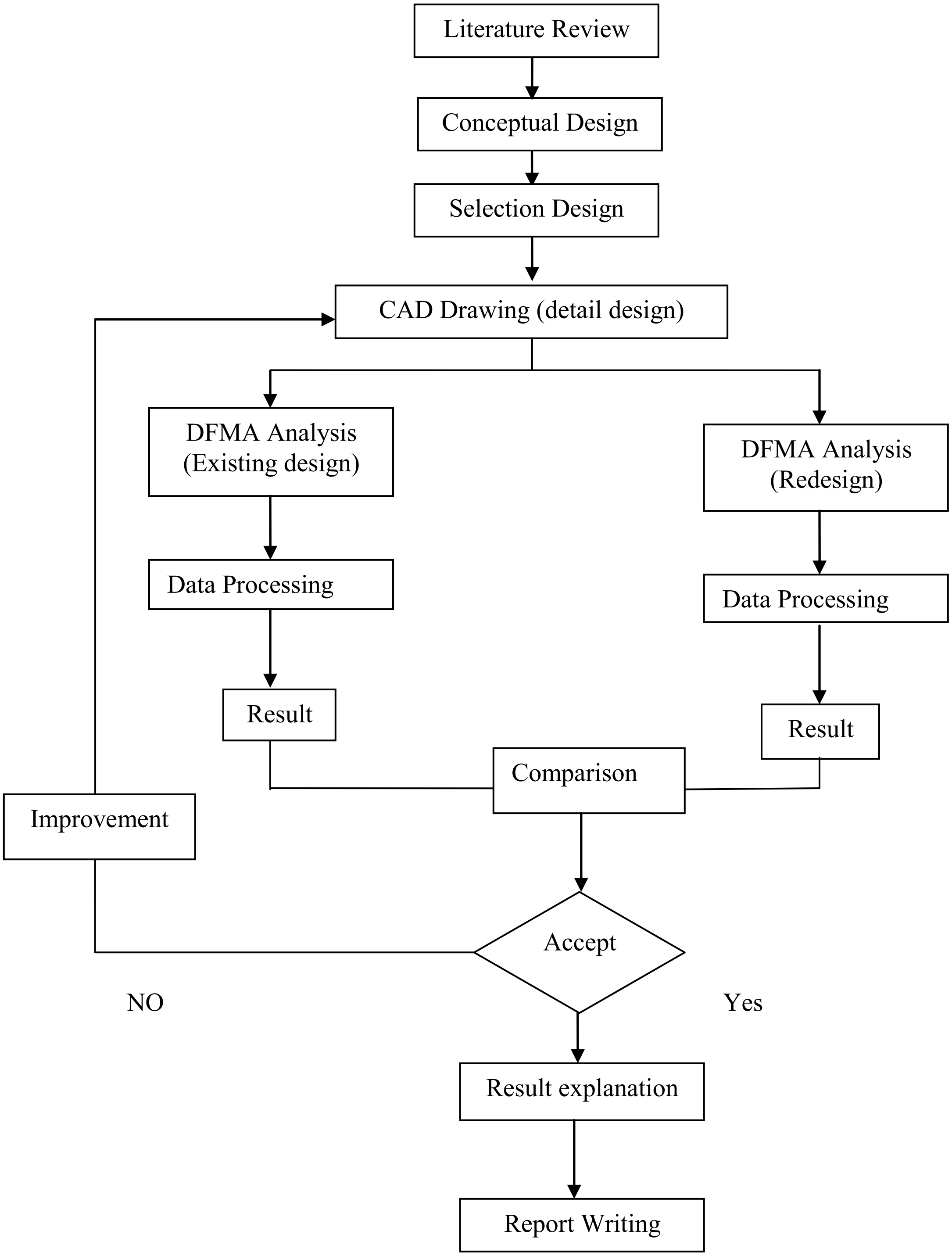


Figure 3.1: Project Flow Chart.

3.2 Literature Review

The literature review is the process of collecting information based on a given title. The information is collected through two types of source, which is primary source and secondary source. The primary sources are those that are gathered from discussions with lecturer. The secondary data or information collections are searched out from books, case studies, thesis, journals, reports and the internet.

3.3 Conceptual Design

The concept design is based on the improvement of the existing design. The existing design will go through disassemble and assemble operation for several times. For each part, the evaluation is made to determine the current design efficiency. Then from the process, come out with two or three proposed designs of the conceptual design. The concept design develops in order to achieve the objective, for ease of assembly and manufacturing.

3.4 Selection Design

From the conceptual of design, one of the three proposed designs will be chosen to go through the Boothroyd Dewhurst DMFA analysis to determine the best result of the criteria by following the scope and objective of the project. After sketching the concept of design is done, all the drawing needs to be analyzed and the best concept will be chosen. If the concept needs to change, the concept will be re-designed until the best concept is selected. Following that, detail drawing of the concept will be drawn in this project.

3.5 CAD Drawing (Detail Design)

For the CAD drawing in this project, the detail design will be drawn using CATIA V5R19 software and the detail design will be explained through the existing design and the selected design. The drawing includes the part of the optical mouse, the assembled drawing, and the exploded drawing. Before starting with the detailed design of the concept that has been selected, overall dimension must be determined because it will be easier to draw the detail design afterwards.

3.6 DFMA Analysis

After CAD drawing process, the project will continuous with the Boothroyd Dewhurst DFMA analysis manual and simulation. For the manual DFMA the procedure must follow the step below (Geoffrey Boothroyd 1991):

i. Obtain design details
    - Engineering drawings, or Exploded 3-D views, or Existing product, or Prototype

ii. Take assembly apart (or imagine doing so) -- assigning identification to each part as it is removed.
    - Consider sub-assemblies as parts, and analyze them separately (recursively).

iii. Begin re-assembly of the product. Start with the part with the highest identification number, going all the way up to the part 1.
    - Fill up the assembly worksheet as you go along.

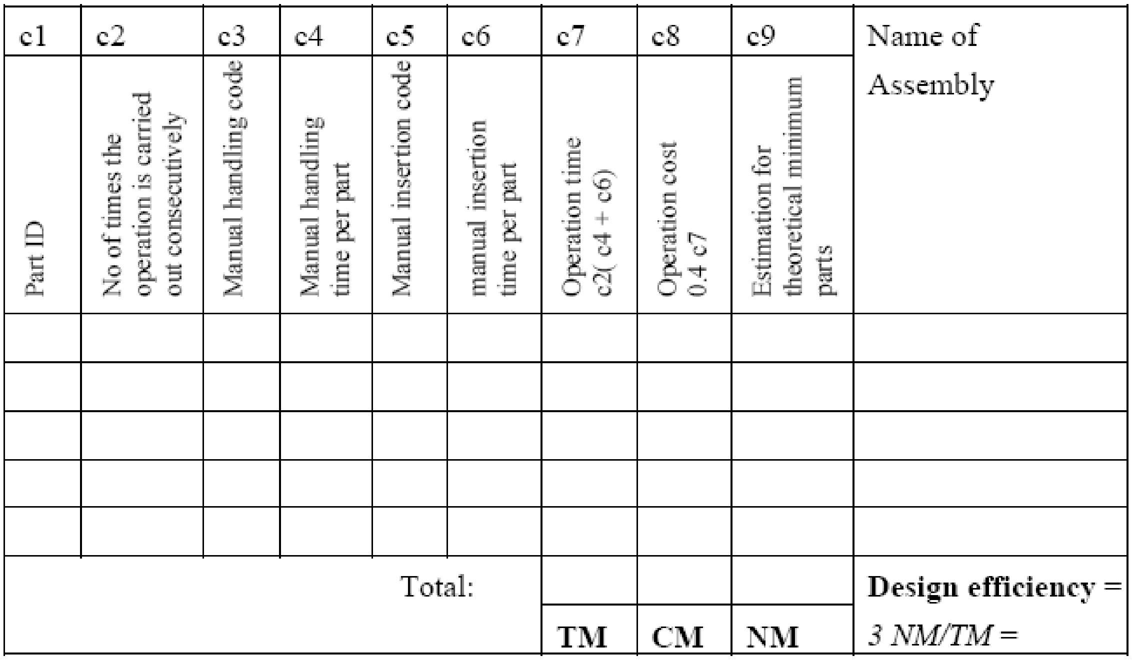
The method requires that the product is assembled one part at a time. In reality, assembly workers use both hands and often assemble two parts in a step. However, a change in the assembly procedure will correspondingly change the assembly time for the ideal product -- thereby keeping the efficiency constant.

iv. Compute the design efficiency, given as:

- EM = 3 x NM / TM

Table 3.1: Table for computation of Design efficiency

(Source: Redford Alan, J. Chal, 1990)



c1	c2	c3	c4	c5	c6	c7	c8	c9	Name of Assembly
Part ID	No of times the operation is carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	manual insertion time per part	Operation time c2(c4 + c6)	Operation cost 0.4 c7	Estimation for theoretical minimum parts	
					Total:				**Design efficiency =**
						TM	**CM**	**NM**	*3 NM/TM =*

3.6.1 Alpha and Beta symmetric

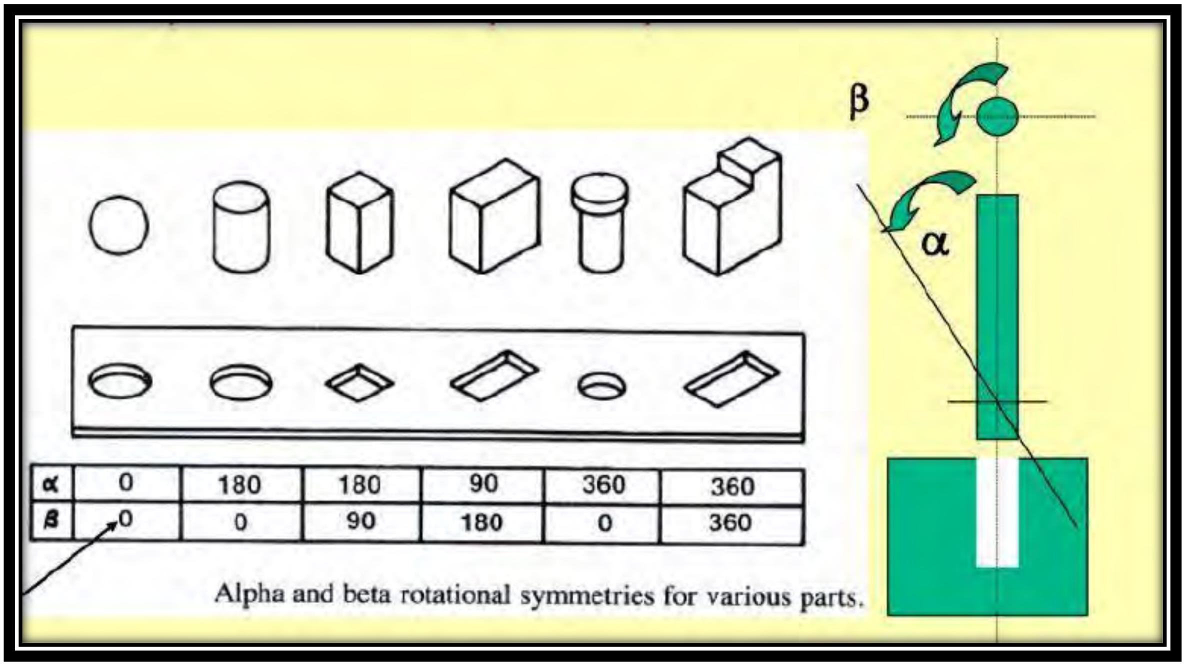
One of the principal geometrical design features that affects the times required to grasp and orient a part is its symmetry. Assembly operations always involve at least two component parts: the part to be inserted and the part or assembly (receptacle) into which the part is inserted. Orientation involves the proper alignment of the part to be inserted relative to the corresponding receptacle and can always be divided into two distinct operations:

i. Alignment of the axis of the part that corresponds to the axis of insertion.

ii. Rotation of the part about this axis

It is therefore convenient to define two kinds of symmetry for a part:

i. Alpha symmetry: depends on the angle through which a part must be rotated about an axis perpendicular to the axis of insertion to repeat its orientation.
ii. Beta symmetry: depends on the angle through which a part must be rotated about the axis of insertion to repeat its orientation.



α	0	180	180	90	360	360
β	0	0	90	180	0	360

Alpha and beta rotational symmetries for various parts.

Figure 3.2: Alpha & Beta rotational symmetric guideline
(Source: Geoffrey Boothroyd 1991)

3.6.2 Design Guideline for Part Handling

Generally, for ease the part handling, the factors should consider are:

vi. Design parts that have end-to-end symmetry and rotational about axis of insertion. If thus cannot be achieved, try to design parts having maximum possible symmetry.

vii. Design parts that in those instances where the part cannot be make symmetric are obviously asymmetric.
viii. Provide features that will prevent jamming of parts that tend to nest or stack when stored in bulk.
ix. Avoid features that will allow tangling of parts when stored in bulk.
x. Avoid parts that stick together or are slippery, delicate, flexible, very small or very large or that hazardous to the handler (i.e.; parts that are sharp, splinter easily, etc)

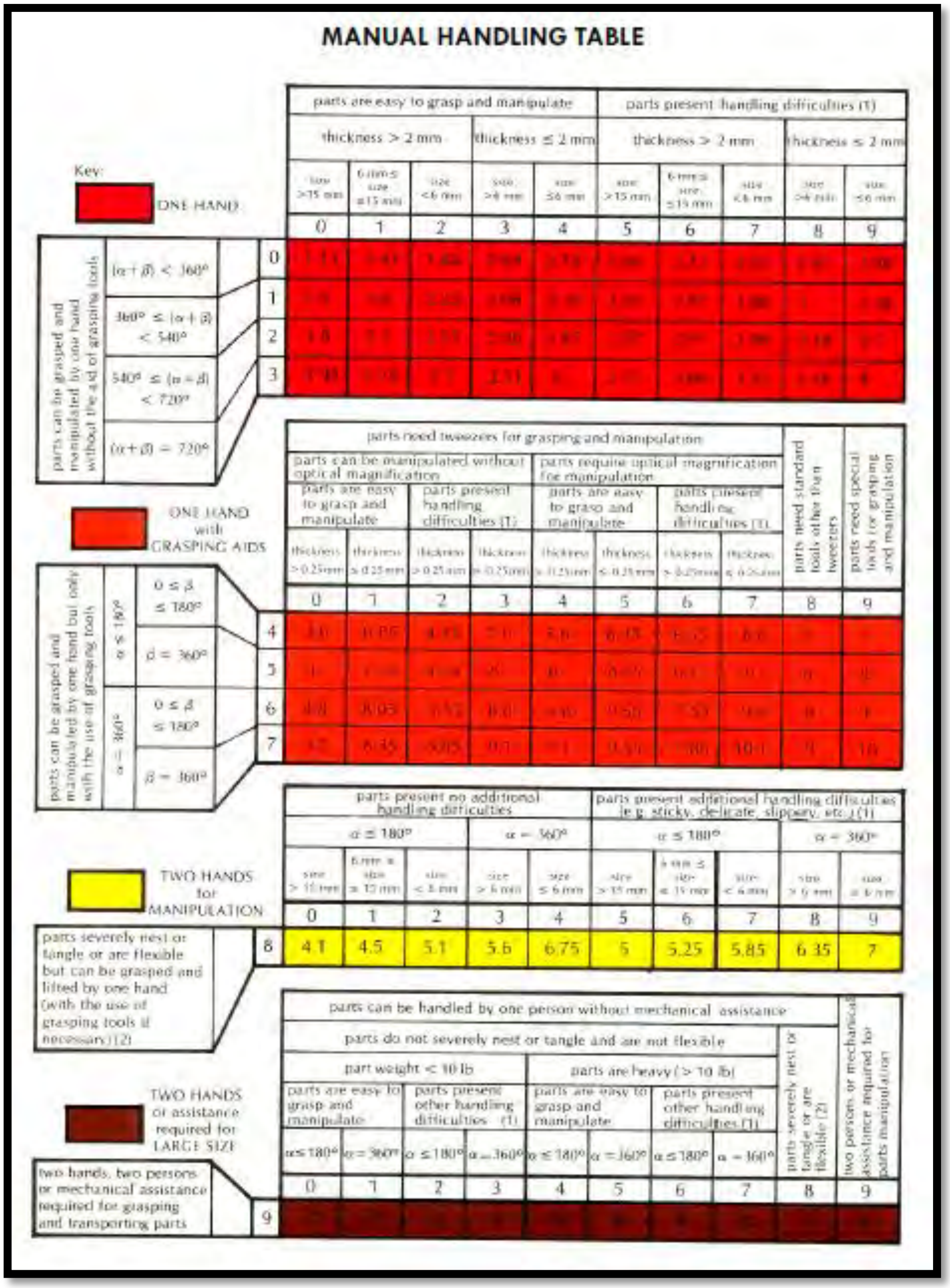
3.6.3 Design Guideline for Insertion & Fastening

For the ease of the handling and insertion designer should attempt to:

v. Design so that there is little or no resistance to insertion and provide chamfers to guide insertion of two mating parts. Generous clearance should be provide and with care must be take to avoid clearances that will result a tendency for parts to jam or hang-up during insertion.
vi. Standardize by using common parts, processes 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.
vii. Use pyramid assembly – provide for progressive assembly about one axis of reference. Generally it is best assemble from above.
viii. Avoid where possible for holding parts down to maintain their orientation during manipulation of subassembly or during the placement of another part. If holding down required, design part to secure as soon as possible after has been inserted.

Table 3.3: Manual Handling

(Source: Geoffrey Boothroyd, 1994)



MANUAL HANDLING TABLE

Key:

🟥 ONE HAND

🟥 ONE HAND with GRASPING AIDS

🟨 TWO HANDS for MANIPULATION

🟫 TWO HANDS or assistance required for LARGE SIZE

			parts are easy to grasp and manipulate					parts present handling difficulties (1)				
			thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
			size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of grasping tools	(α+β) < 360°	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	360° ≤ (α+β) < 540°	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	540° ≤ (α+β) < 720°	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	(α+β) = 720°	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

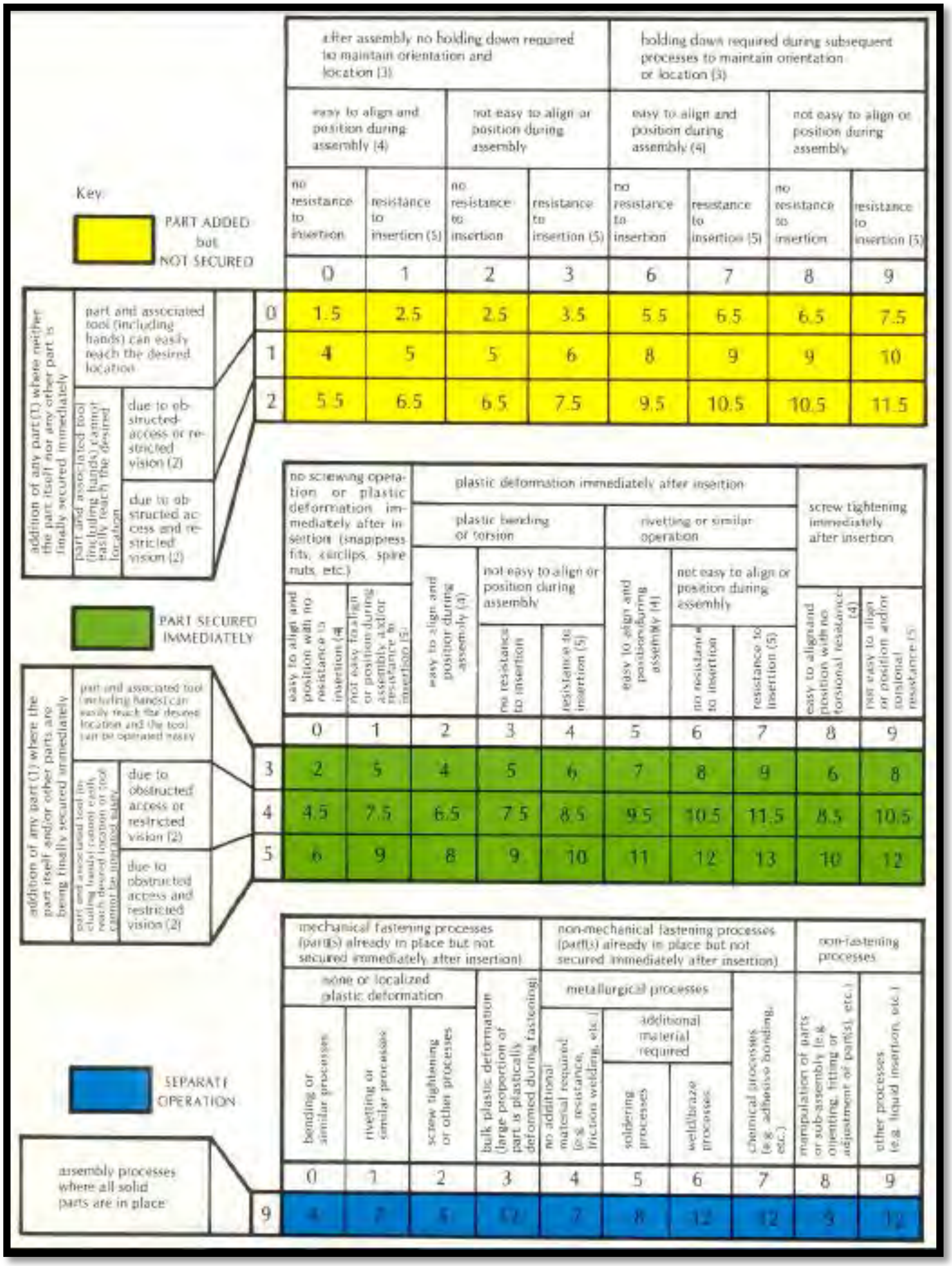
				parts need tweezers for grasping and manipulation								parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
				parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
				parts are easy to grasp and manipulate		parts present handling difficulties (1)		parts are easy to grasp and manipulate		parts present handling difficulties (1)			
				thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm		
				0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α ≤ 180°	0 ≤ β ≤ 180°	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
		β = 360°	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
	α = 360°	0 ≤ β ≤ 180°	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		β = 360°	7	5.1	8.35	5.85	9.1	7.1	9.85	7.85	10.1	9	10

		parts present no additional handling difficulties					parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
		α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
		size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm
		0	1	2	3	4	5	6	7	8	9
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

		parts can be handled by one person without mechanical assistance									two persons or mechanical assistance required for parts manipulation
		parts do not severely nest or tangle and are not flexible								parts severely nest or tangle or are flexible (2)	
		part weight < 10 lb				parts are heavy (> 10 lb)					
		parts are easy to grasp and manipulate		parts present other handling difficulties (1)		parts are easy to grasp and manipulate		parts present other handling difficulties (1)			
		α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°		
		0	1	2	3	4	5	6	7	8	9
two hands, two persons or mechanical assistance required for grasping and transporting parts	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3.4: Manual Insertion

(Source: Geoffrey Boothroyd, 1994)



Key:

🟨 PART ADDED but NOT SECURED

				after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
				easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
				no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
				0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location		0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location	due to obstructed access or restricted vision (2)	1	4	5	5	6	8	9	9	10
		due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

🟩 PART SECURED IMMEDIATELY

				no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
						plastic bending or torsion			rivetting or similar operation				
							not easy to align or position during assembly			not easy to align or position during assembly			
				easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
				0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily		3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily	due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
		due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

🟦 SEPARATE OPERATION

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screw tightening or other processes	bulk plastic deformation (large proportion of part is plastically deformed during fastening)	no additional material required (e.g. resistance, friction welding, etc.)	soldering processes	weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	12	7	8	12	12	9	12

3.7 Comparison

After application of Boothroyd Dewhurst methods on the design, it is important to carry out comparing and evaluating the design efficiency with the existing design and proposed design. After coming out with the comparison, the proposed design analysis should be less then than existing design in order to improve the design efficiency, it will also effect on time to assemble.

CHAPTER 4

DFMA ANAYSIS FOR EXISTING PRODUCT

4.1 Introduction

The product case study is carried out to apply the Boothyord-Dewhurst DFMA method. The Boothyord-Dewhurst DFMA method has developed the systematic system that used for ease of assembly and manufacture. Therefore, the case study on the existing product can show the applications of the method.

4.2 Product Description

The Egg Shape optical mouse is the chosen as an existing design for Boothroyd Dewhurst DFMA method. The product description is as follows:

Product: Egg Shape Optical Mouse (SY-177)
Dimension: 86.5mm: W x 65mm: D x 46mm: H
Material: Plastic (Polyethylene)

Figure 4.1: Optical Mouse

Figure 4.2: Top cover of Optical Mouse

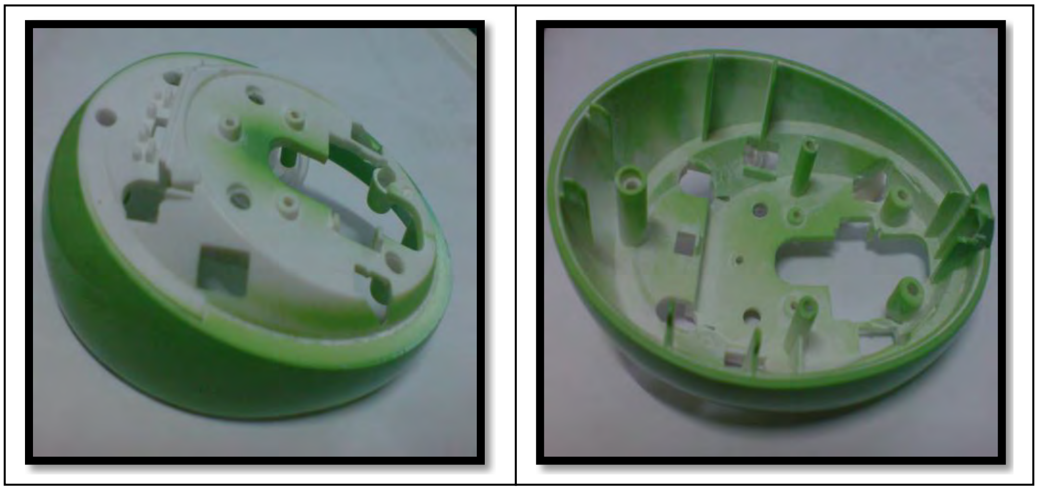


Figure 4.3: Middle cover of Optical Mouse

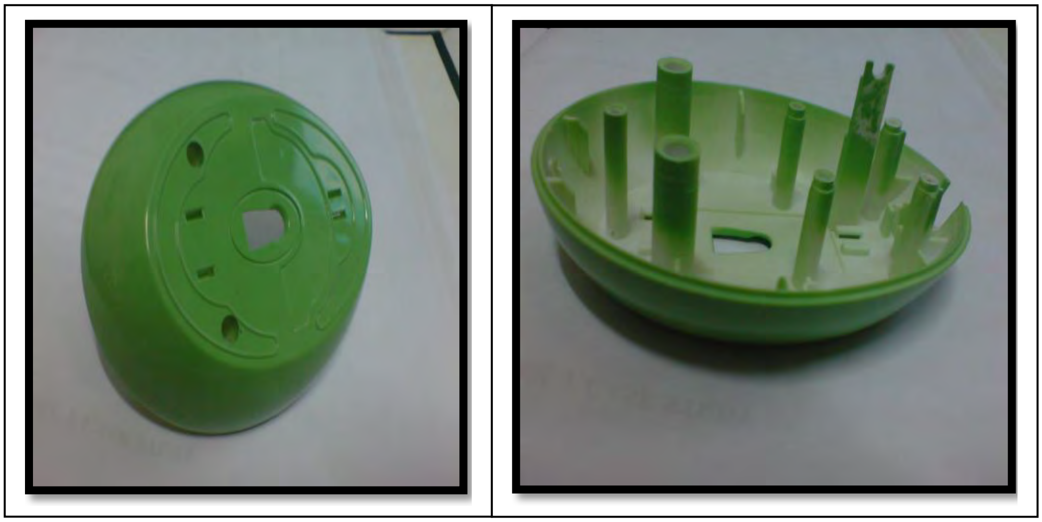


Figure 4.4: Bottom cover of Optical Mouse

Figure 4.5: Scroll Wheel with rubber

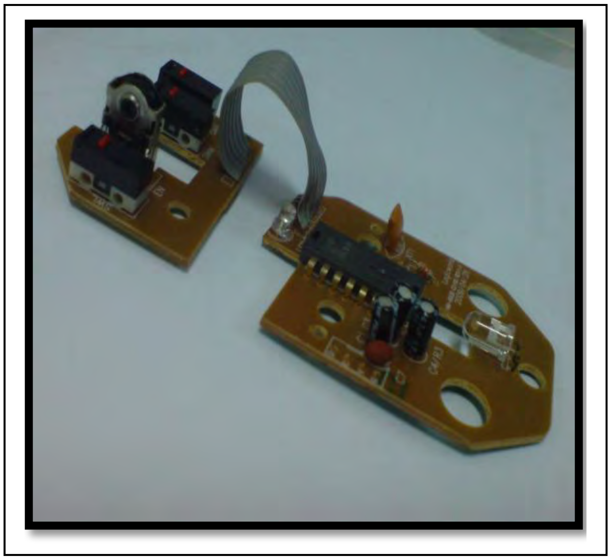


Figure 4.6: Printed circuit board (PCB) of optical Mouse

4.3 Analysis of the existing product (Manual)

The product has gone through a disassemble process to define the assembly process sequence carried out for the product. **Figure 4.7** shows the CAD drawing of the exploded view for the disassembled product.

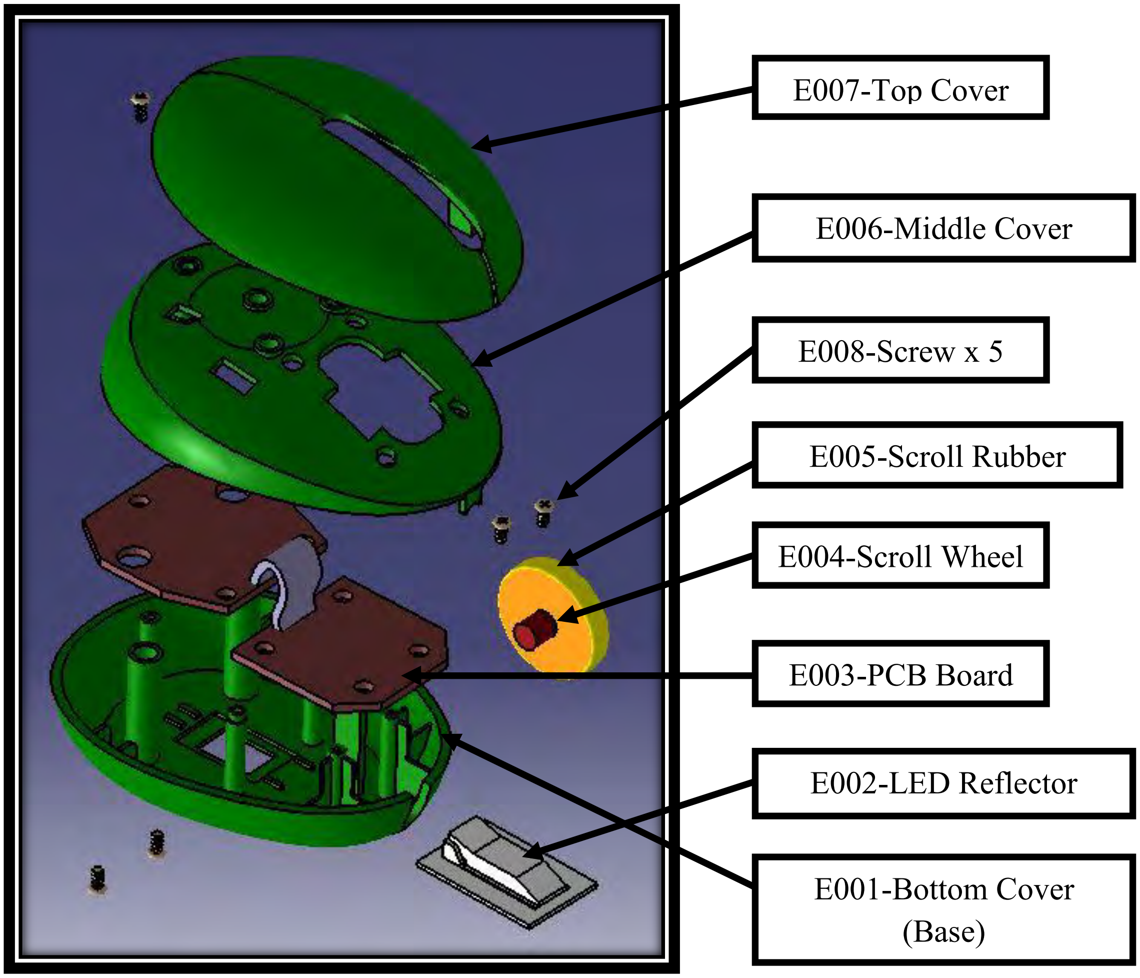


Figure 4.7: Disassembly view for Optical Mouse

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4.3.1 Assembly Flow Chart

After disassemble process, a flow chart for product was constructed to identify the process assembly of the product.

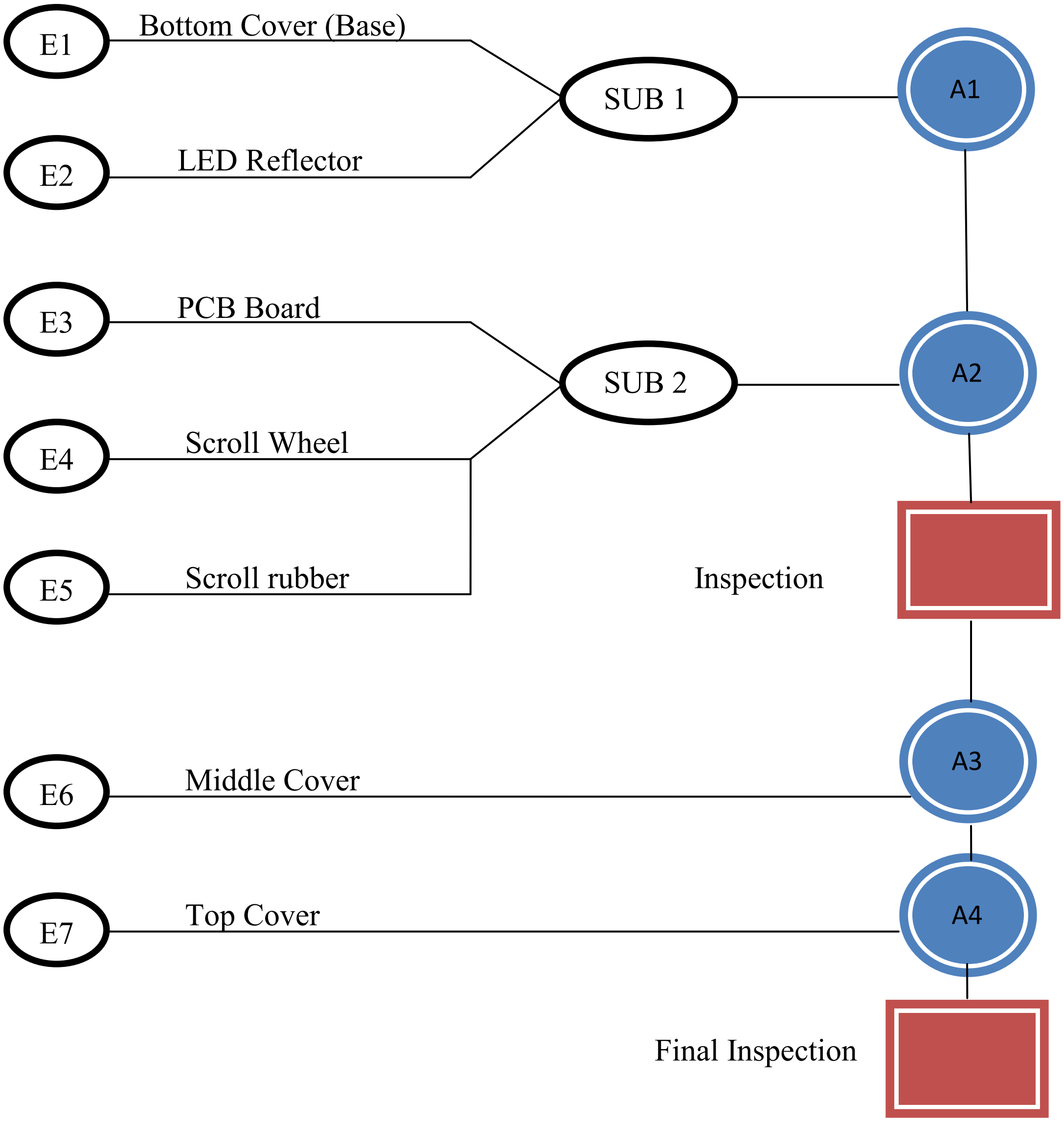


Figure 4.8: Assembly Process Flow for Existing Design

From the flow chart in **Figure 4.8**, the process assembly of the product is:

A1 - Be full of sub-assembly 1. Assemble LED Reflector (E002) to Bottom Cover (base) (E001).

A2 - Be full of sub-assembly 2. Place in the Scroll Rubber (E005) on the Scroll Wheel part (E004) in slot on the PCB board (E003).

🟥 - The parts will be inspected.

A3 - After complete inspection of parts in assembly 1 and assembly 2, assemble Middle Cover (E006) to continue the process assembly. The parts will be connected by using screw.

A4 - To complete the process assembly of the product, assemble the Top Cover (E007) to parts in assemble 3. And the parts are connected by using screws.

🟥 - The parts will go through final inspection.

4.3.2 The Process and Material Selection

The selection of appropriate manufacturing process based on matching in the required attributed of part and process capabilities. Most component parts are not produced only with single process but require the sequence of different processes to achieve the required attributes. Combinations of various processes are necessary because the application of a single process is hard to achieve a result of the finished part attributes.

The manufacturing process can be categorized in three groups; primary process, primary/secondary processes, and tertiary process. Primary process used in reproducing the raw materials for manufacturing. The primary/secondary processes, is the process that can generate shape of part, form features of part. The tertiary consist of the finishing processes.

For the stage, process flow of the each part for the product must be constructing. Process flow considered the manufacturing process, selection for the material, and so on. **Figure 4.9** to **Figure 4.15** is the process flow of each part.

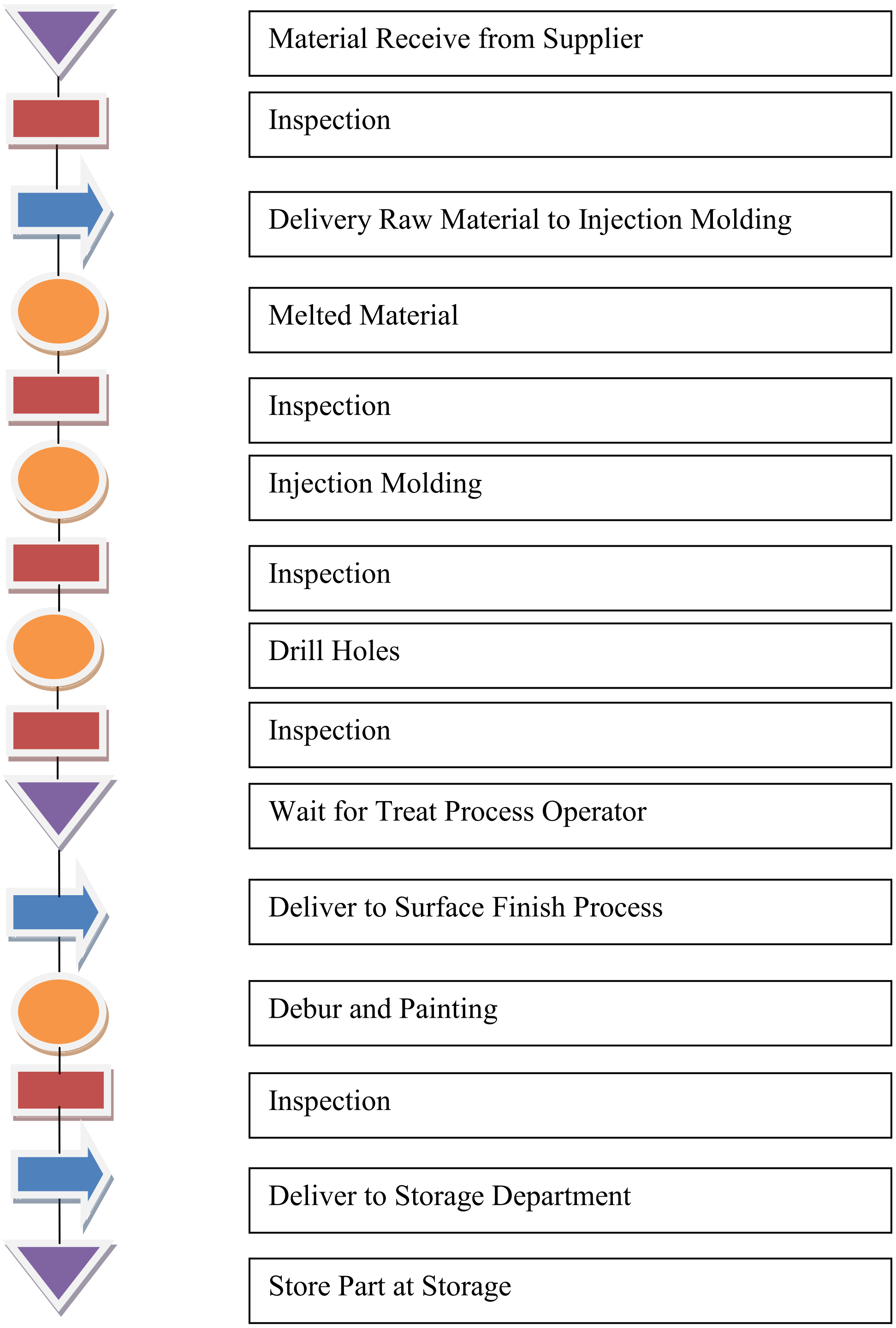


Figure 4.9: Process Flow for Bottom Cover (Base)

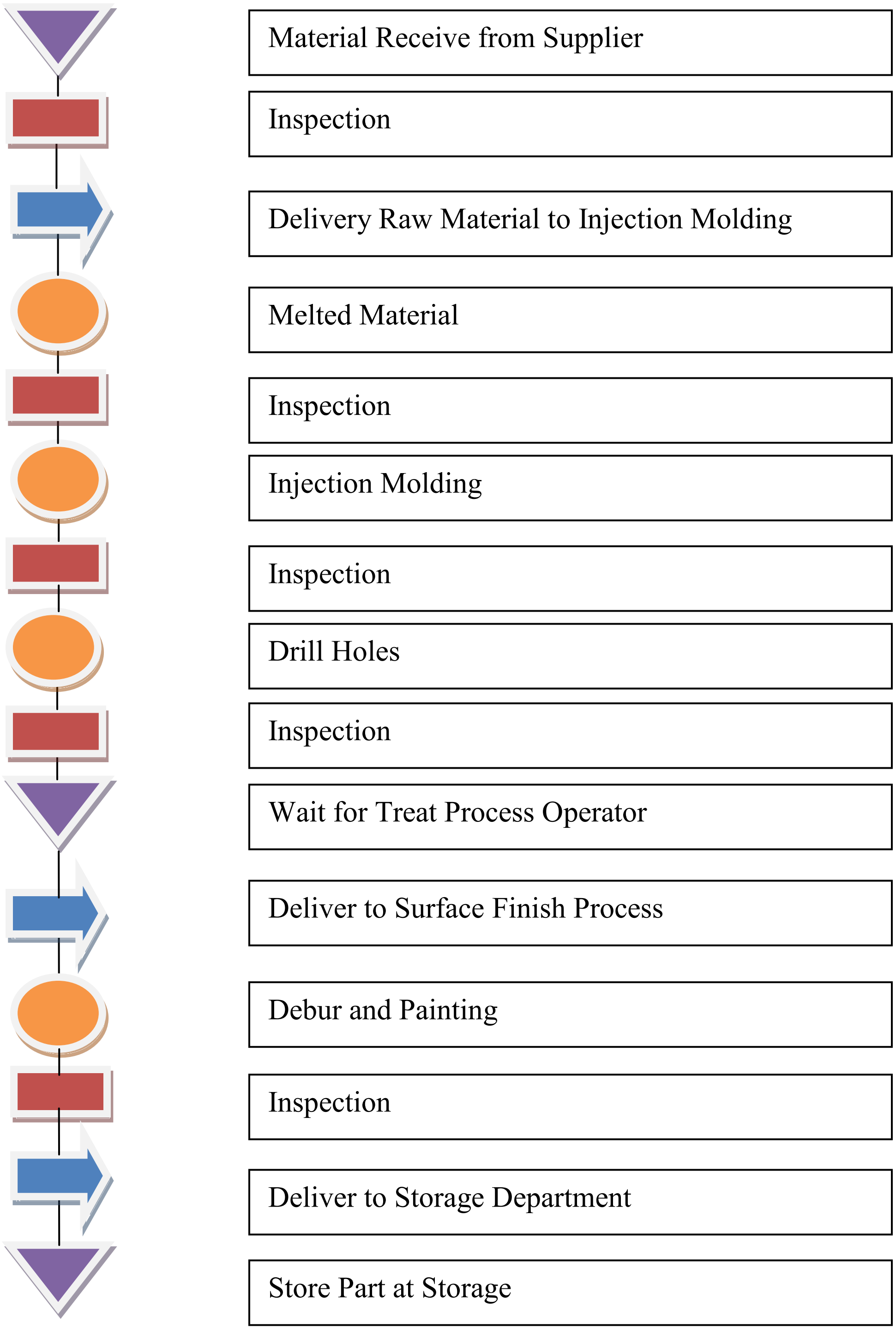


Figure 4.10: Process Flow for LED Reflector

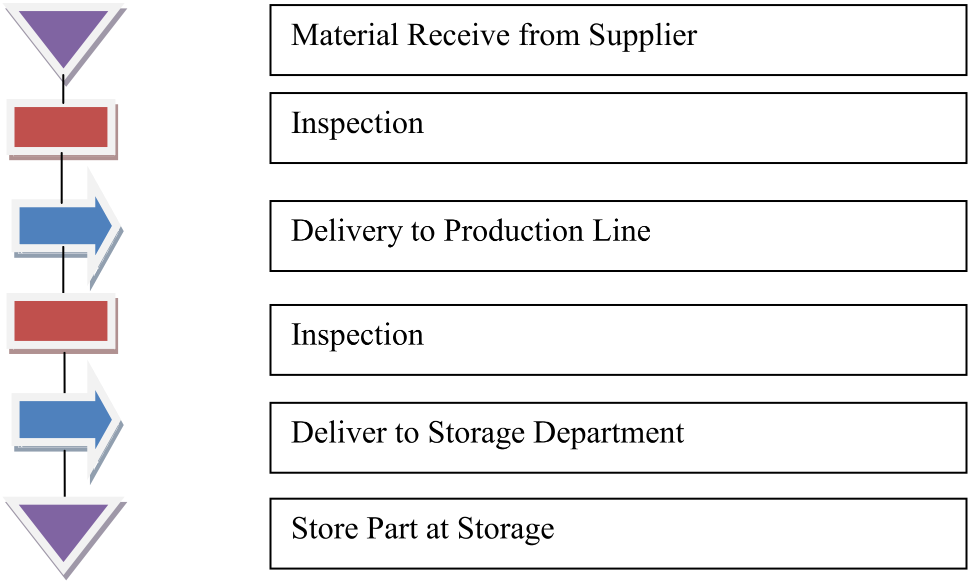


Figure 4.11: Process flow for PCB Board

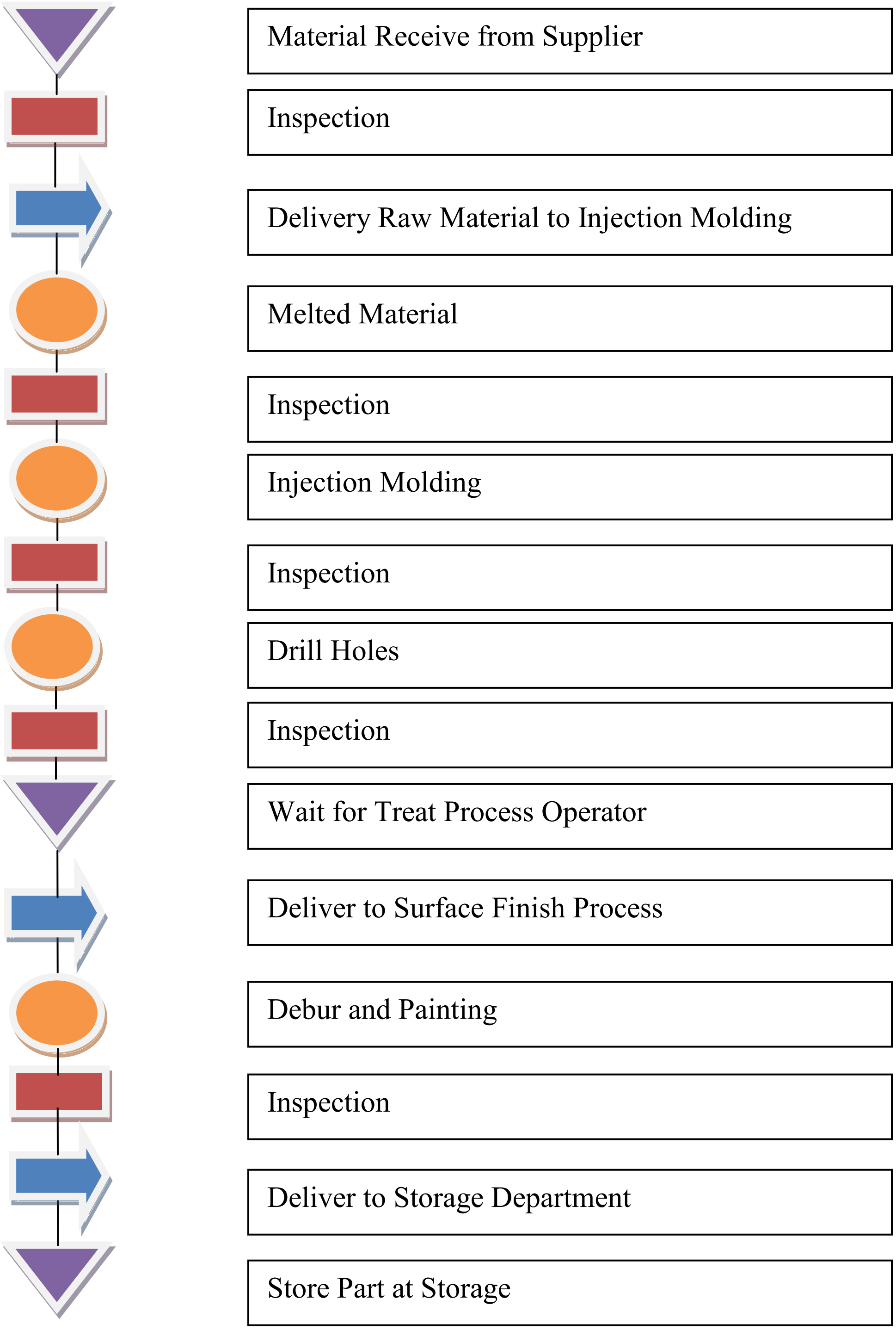


Figure 4.12: Process Flow for Scroll Wheel

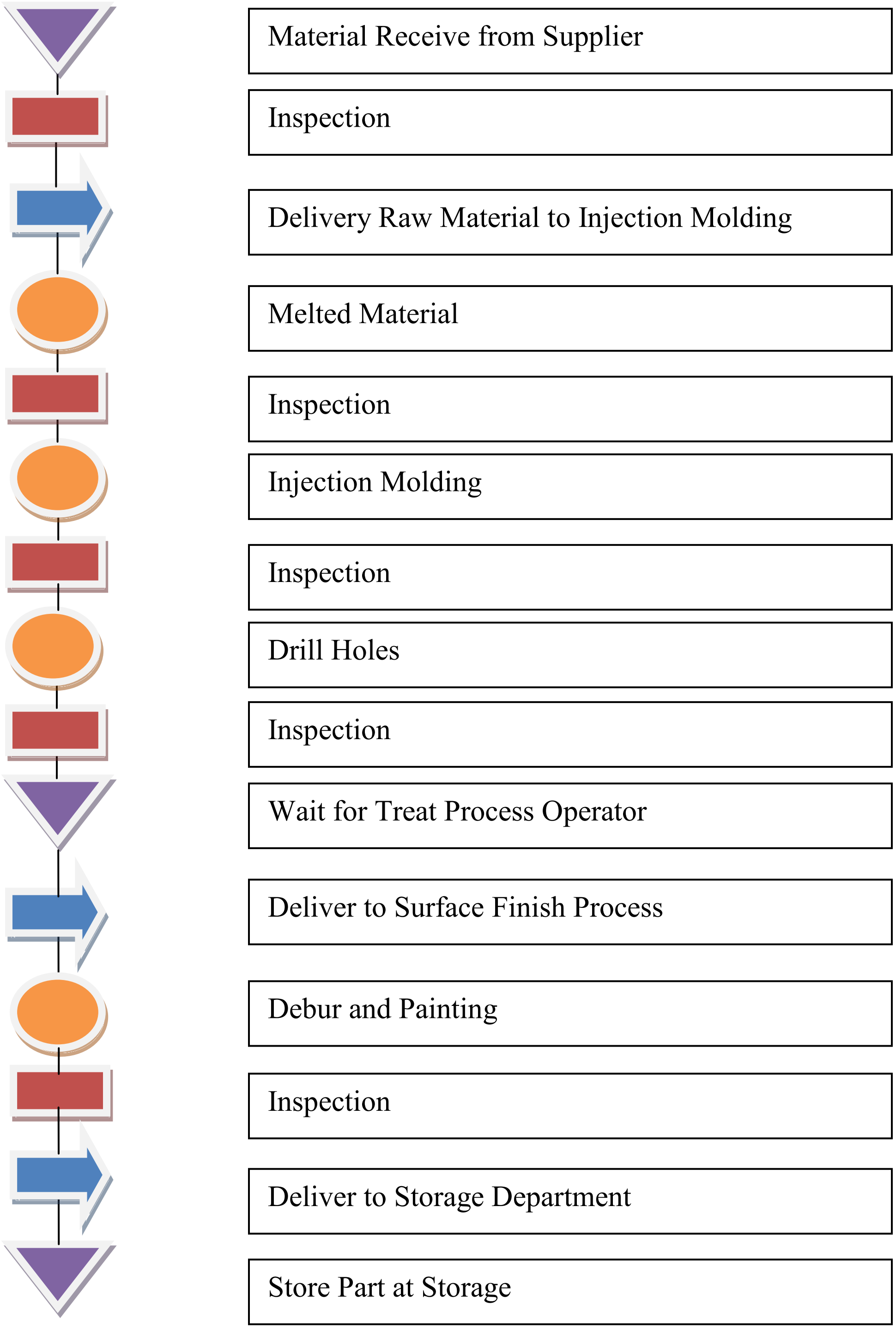


Figure 4.13: Process Flow for Middle Cover

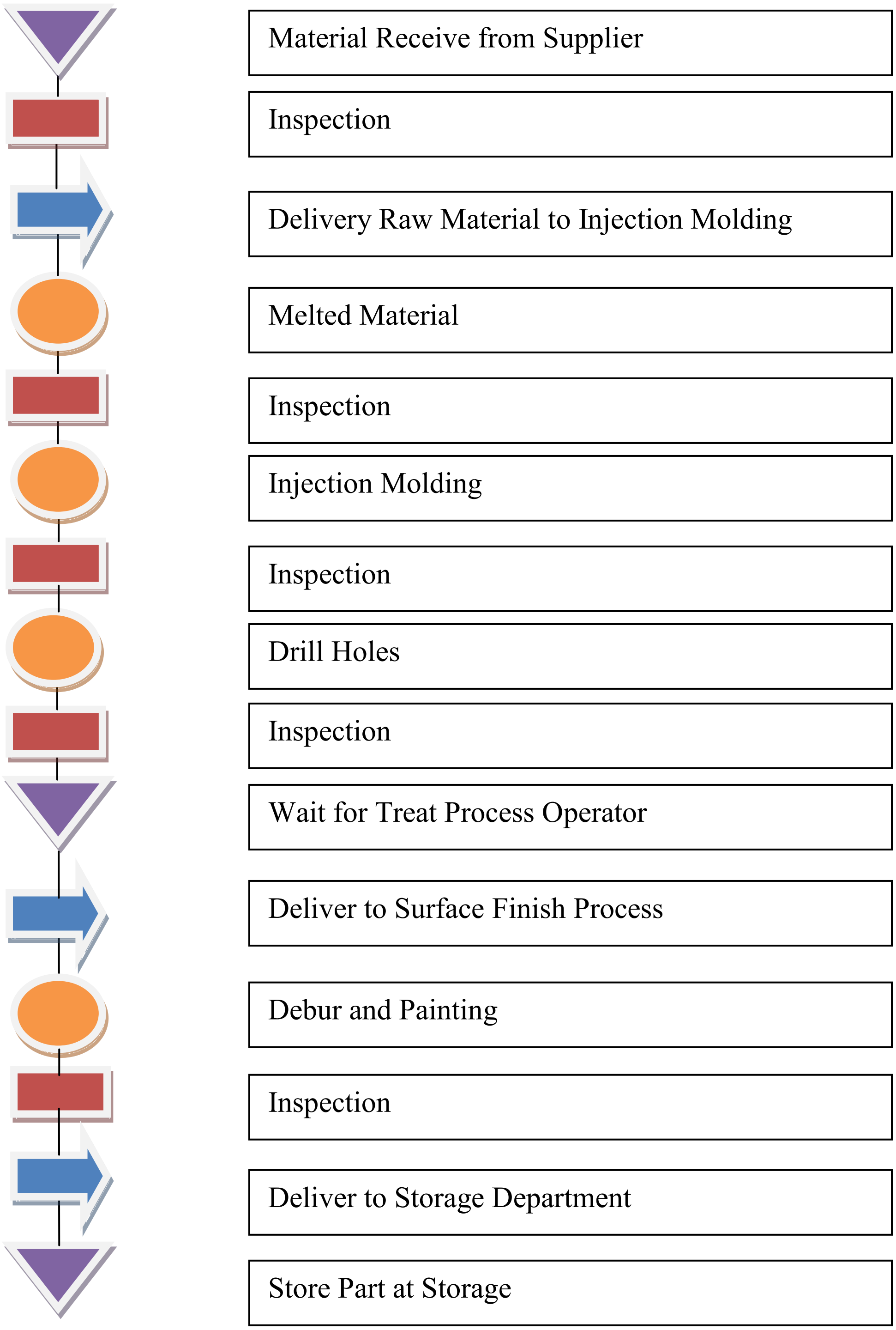


Figure 4.14: Process Flow for Top Cover

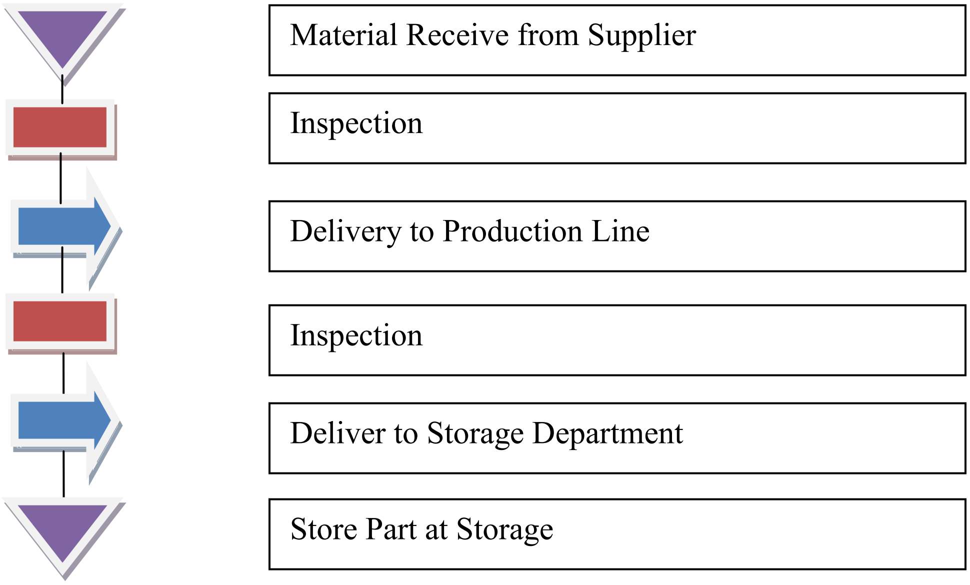


Figure 4.15: Process Flow for Scroll Rubber

From the process flow chart above **Figure 4.9 to Figure 4.15**, the symbol represent for the each process. The orange circle sign is a symbol of the operation of parts. The red square sign correspond to inspection process. The blue arrow shape, the sign represent the process of transportation, and the triangle purple sign is a symbol of storage or a delay process.

4.3.3 Theoretical Part

Theoretical part is the element to determine the possibility to eliminate or combine the parts. All the parts are to be determined whether it is theoretical part or not. The theoretical part determine by answering the question:

i. Does the part move relative to other already assembled parts when the product working normally?
ii. Does the part have to be of other material or isolated from other already assembled parts? Only acceptable for fundamental material.
iii. Does the part has to be separated from other already assembled parts because assembly or disassembly of other parts otherwise be impossible.

Table 4.1: Theoretical part & non-theoretical part for existing design

Part No.	Part Name	Material	Movement	Separation	Theoretical Part Count
E001	Bottom Cover (Base)	No	No	Yes	✓
E002	LED reflector	Yes	No	Yes	✓
E003	PCB Board	Yes	Yes	Yes	✓
E004	Scroll Wheel	Yes	Yes	Yes	✓
E005	Scroll Rubber	No	No	No	x
E006	Middle Cover	No	No	No	x
E007	Top Cover	No	No	No	x
E008	Screw	No	No	No	x

From the table, which the answer is "no", the part can be considered for elimination or integration.

4.3.4 Alpha and Beta symmetric

Alpha and Beta symmetric is one of the principal geometrical design features that affects the times required to grasp and orient a part is its symmetry.

Table 4.2: Alpha & Beta of Optical Mouse part

Part No.	Name Part	Alpha	Justification	Beta	Justification
E001	Bottom Cover (Base)	360	Consider LED Reflector attach on the body.	360	Consider LED Reflector attach on the body.
E002	LED reflector	360	Due to the shape of LED	360	Due to the shape of LED
E003	PCB Board	360	consider the position of electronic component	360	Consider the position of electronic component
E004	Scroll Wheel	360	Consider the position of the scroll	0	Symmetric shape
E005	Scroll Rubber	0	Symmetric shape	360	Consider the position of the scroll.
E006	Middle Cover	360	Due to the shape of middle cover	360	Due to the shape of middle cover
E007	Top Cover	360	Due to the shape of top cover	360	Due to the shape of top cover
E008	Screw	360	Consider screw attach on the body.	360	Consider screw attach on the body.

4.3.5 Handling and Insertion Time

From **Table 4.1** and **Table 4.2**, the value of total assembly time can be defined. Thus the efficiency also can be defined by 3 multiplied with the total theoretical minimum part and divided by total operation time refer **Equation 1**. **Table 4.3** shows all the process during to define all the value.

Table 4.3: Analyze Handling and Insertion Time

Part ID n0.	**No. or Item**	**Manual Handling Code**	**Manual Handling Time Per Part**	**Manual Insertion Code**	**Manual Insertion Time Per Part**	**Operation Time (Second)**	**Operation Cost (Per Second)**	**Figure For Theoretical Minimum Part**	**Name Of Assembly**
E001	1	30	1.95	00	1.5	3.45	0.00276	1	Bottom Cover
E002	1	30	1.95	00	1.5	3.45	0.00276	1	LED Reflector
E003	1	83	5.6	01	2.5	8.1	0.00648	1	PCB Board
E004	1	10	1.5	03	3.5	5	0.004	1	Scroll Wheel
E005	1	10	1.5	03	3.5	5	0.004	0	Scroll Rubber
E006	1	83	5.6	38	6	11.6	0.00928	0	Middle Cover
E007	1	83	5.6	38	6	11.6	0.00928	0	Top Cover
E008	5	12	2.25	38	6	41.25	0.033	0	Screw
					Total	**89.45**	**0.07156**	**4**	
						TM	**CM**	**NM**	

From **Table 4.3** of part analysis, the total of the parts for optical mouse is 8. The total assembly time for existing optical mouse is 56.45 second and total assembly cost for existing optical mouse is 0.04516 cents/sec. The corresponding assembly cost is 0.0008 cent per second, which count RM2.88 per hour, RM23.08 per day, and RM600.00 per month for 8 hours work time per day.

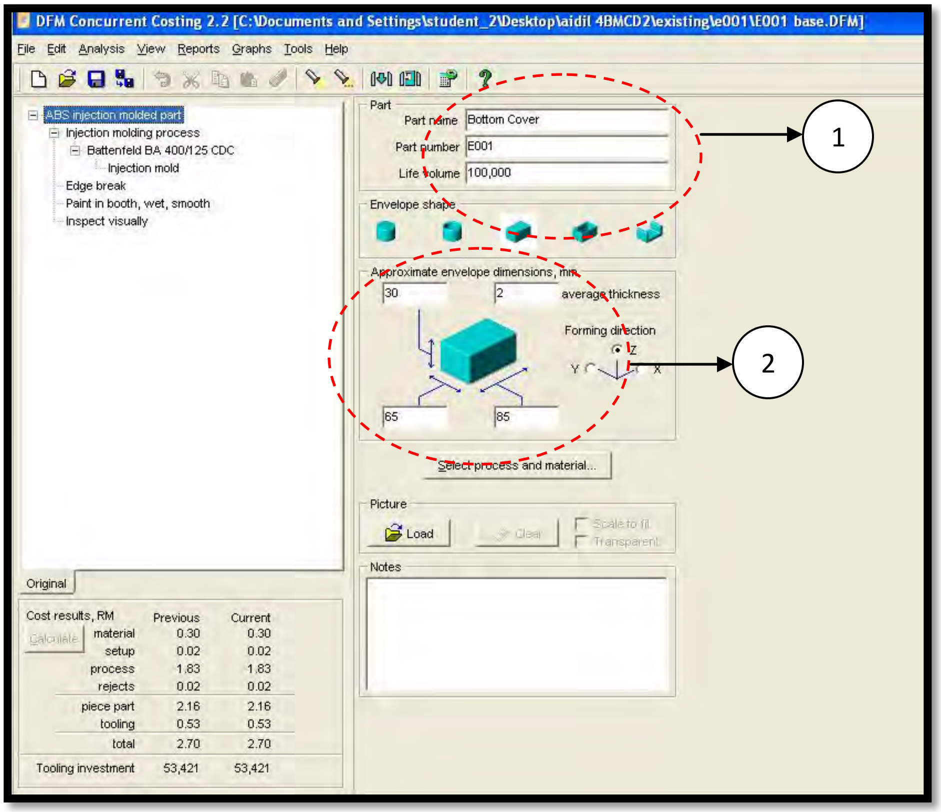
Design Efficiency = 3 x NM / TM x 100%

Design efficiency = $\frac{3 \text{ x } 4}{89.45} = 13.4\%$

4.4 Analysis of the existing product (DFMA Software)

DFMA software is a combination of two complementary tools, Design for Manufacture (DFM) and Design for Assembly (DFA). By using the DFM software, the product cost of manufacturing can be defined. DFM software also can provide an easy method for comparing analysis of manufacturing processes and material selection. Meanwhile DFA software is used to reduce the complexity of a product by consolidating parts into elegant and multifunctional designs resulting in significant cost saving.

4.4.1 Design for Manufacture (DFM)



DFM Concurrent Costing 2.2 [C:\Documents and Settings\student_2\Desktop\aidil 4BMCD2\existing\e001\E001 base.DFM]

- ABS injection molded part
  - Injection molding process
    - Battenfeld BA 400/125 CDC
      - Injection mold
  - Edge break
  - Paint in booth, wet, smooth
  - Inspect visually

Part

Part name: Bottom Cover

Part number: E001

Life volume: 100,000

Approximate envelope dimensions, mm: 30, 65, 85

2 average thickness

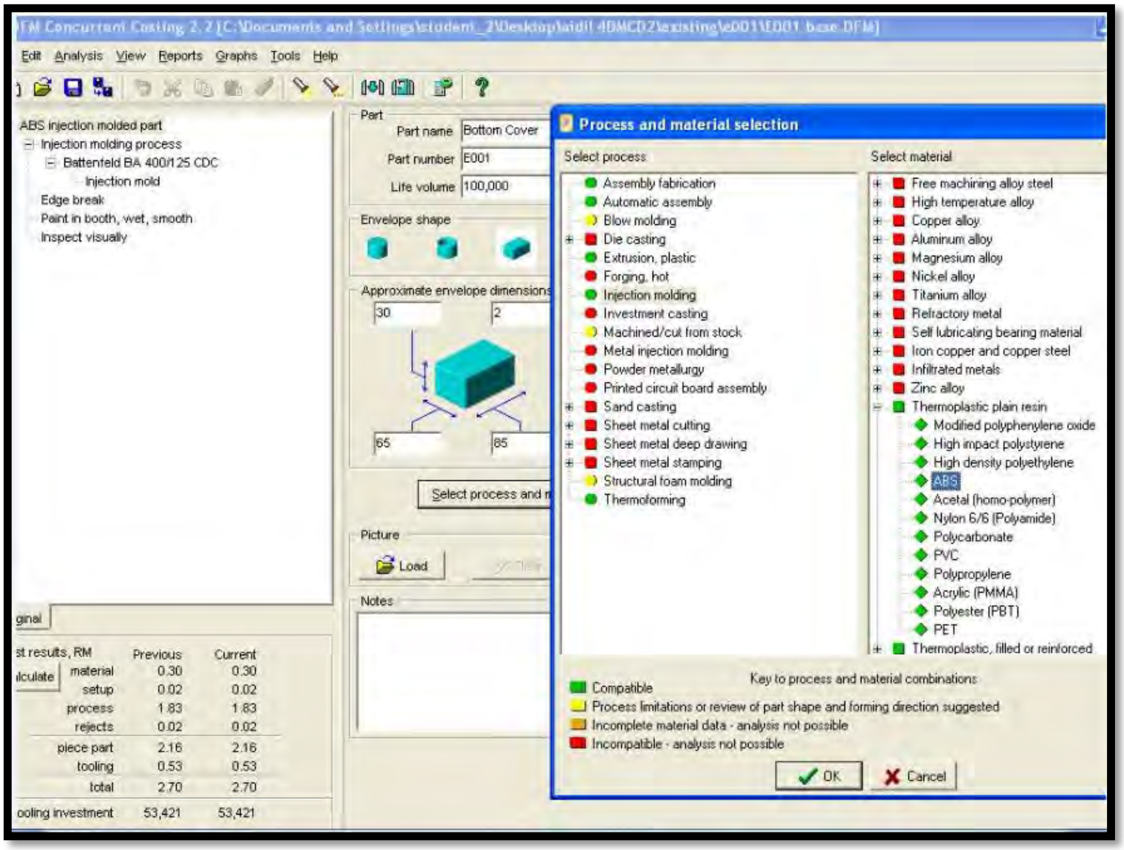
Forming direction: ● Z ○ Y ○ X

Original

Cost results, RM	Previous	Current
material	0.30	0.30
setup	0.02	0.02
process	1.83	1.83
rejects	0.02	0.02
piece part	2.16	2.16
tooling	0.53	0.53
total	2.70	2.70
Tooling investment	53,421	53,421

Figure 4.16: Example DFM Software for Bottom Cover Part

Figure 4.16 is an example process to analyze the cost for bottom cover part manufacturing process. At part number 1, the part name and part number is inserted in the columns specified. For part number 2, sizes for bottom cover part need to be inserted in the columns specified.



Part name: Bottom Cover
Part number: E001
Life volume: 100,000

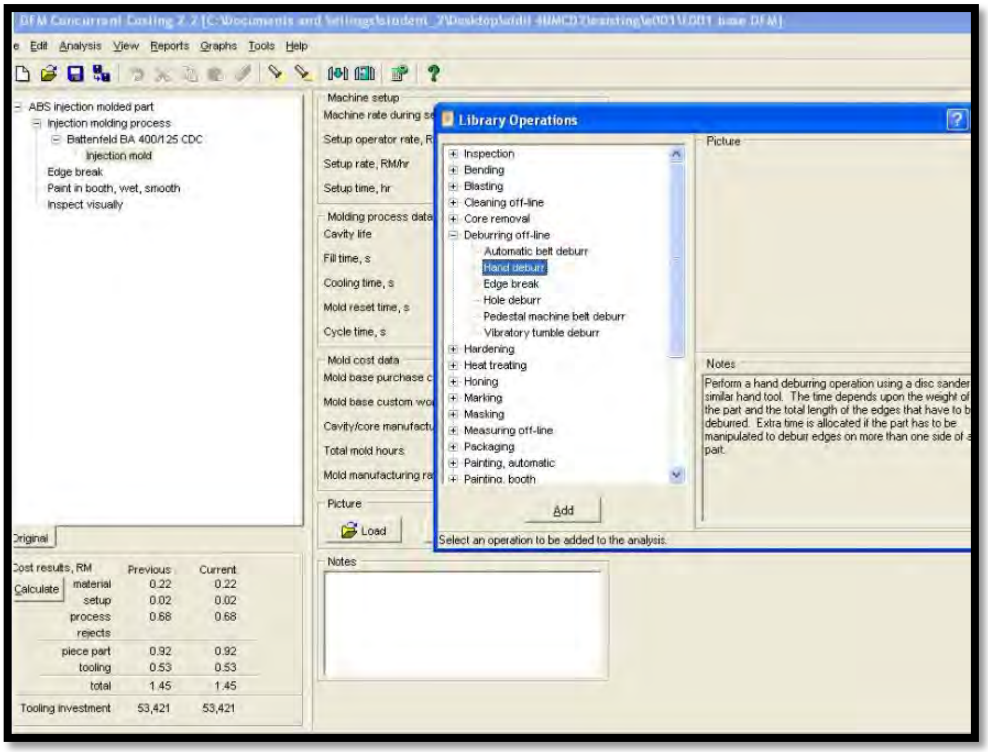
Approximate envelope dimensions: 30, 2, 65, 85

st results, RM	Previous	Current
material	0.30	0.30
setup	0.02	0.02
process	1.83	1.83
rejects	0.02	0.02
piece part	2.16	2.16
tooling	0.53	0.53
total	2.70	2.70
ooling investment	53,421	53,421

Key to process and material combinations
- 🟩 Compatible
- 🟨 Process limitations or review of part shape and forming direction suggested
- 🟧 Incomplete material data - analysis not possible
- 🟥 Incompatible - analysis not possible

Figure 4.17: Process and Material Selection

Figure 4.17 shows a visual after inserting the part name, part numbers, and size, identify the process and material. For the bottom cover, injection molding process and ABS plastic has been selected.



ost results, RM	Previous	Current
material	0.22	0.22
setup	0.02	0.02
process	0.68	0.68
rejects		
piece part	0.92	0.92
tooling	0.53	0.53
total	1.45	1.45
Tooling investment	53,421	53,421

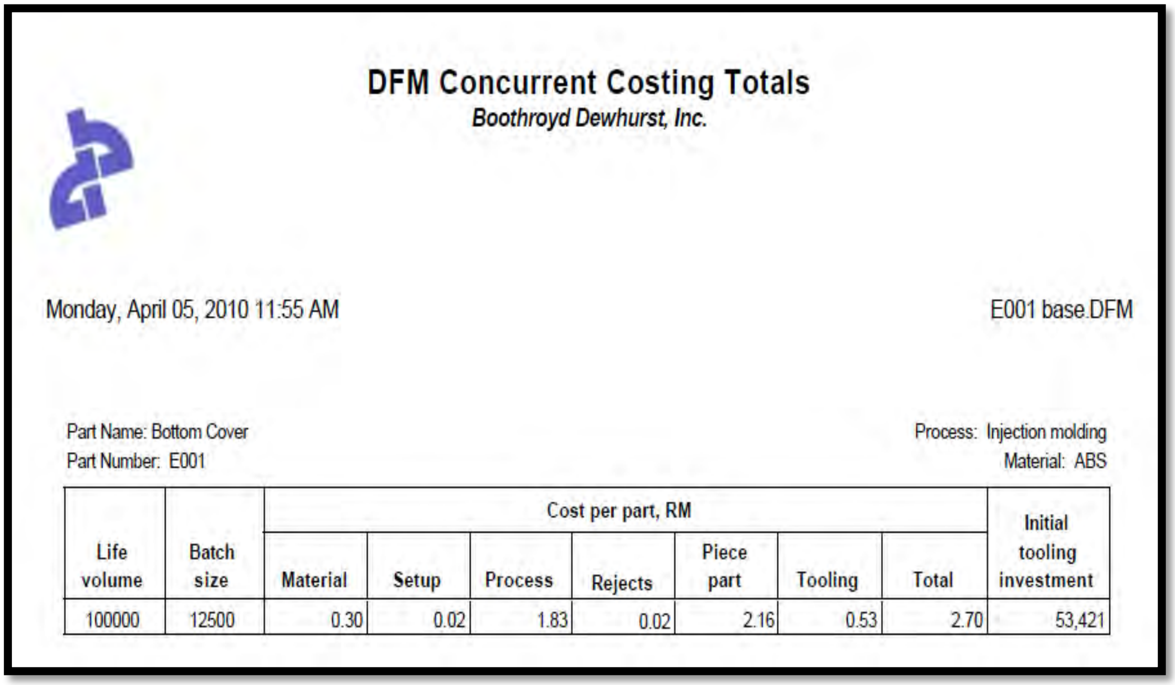
Perform a hand deburring operation using a disc sander similar hand tool. The time depends upon the weight of the part and the total length of the edges that have to b deburred. Extra time is allocated if the part has to be manipulated to debur edges on more than one side of a part.

Select an operation to be added to the analysis.

Figure 4.18: Add Process

After process and material has been selected, the additional processes on the parts need to be inserted. For the bottom cover for example, the additional process that have been inserted are deburing process, painting process and inspection process. The manufacturing total cost of this part is RM2.70.

Table 4.4: DFM Software Concurrent Costing Totals



DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 11:55 AM

E001 base.DFM

Part Name: Bottom Cover
Part Number: E001

Process: Injection molding
Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.30	0.02	1.83	0.02	2.16	0.53	2.70	53,421

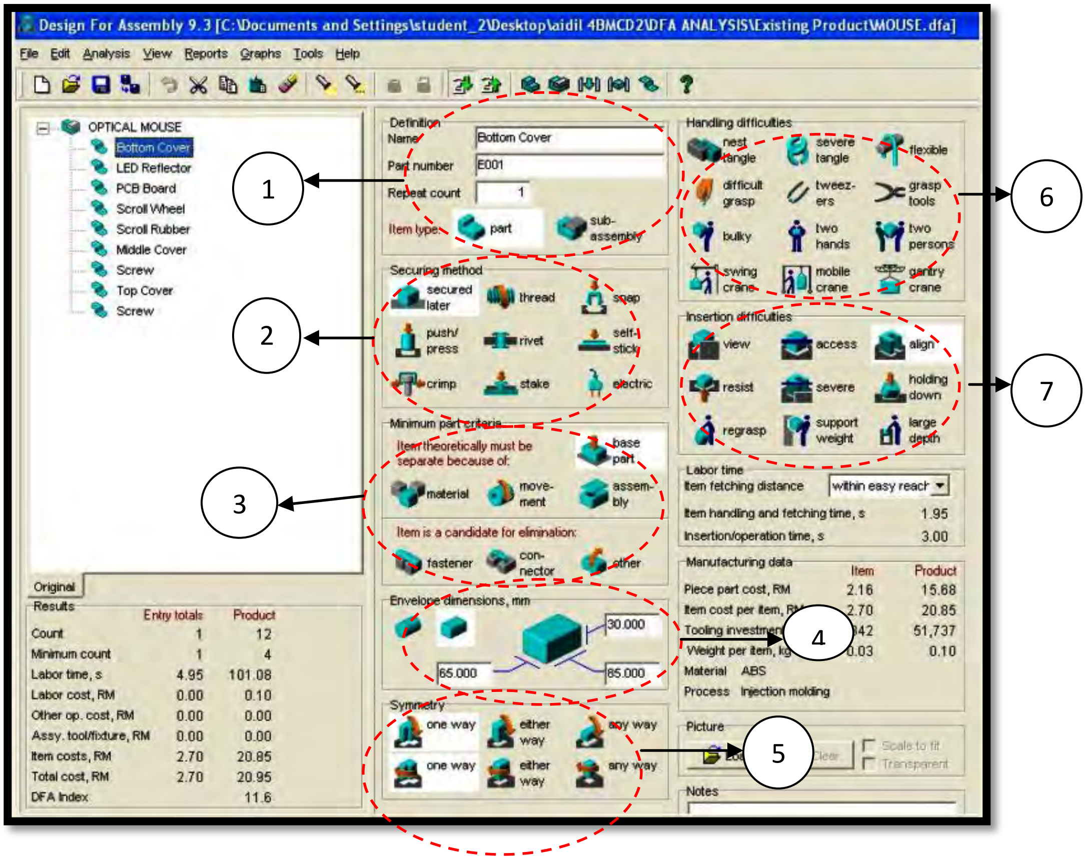
Table 4.4 had shown the example DFM concurrent Costing Totals result for each part. For figure above, the result for cost per part in RM is used for bottom cover. The total cost per part was obtained from the addition of material cost, setup cost, process cost, rejected part cost, and tooling cost. The total of cost for bottom cover is RM2.70.

Table 4.5: Totals Costing per Part of each part

Part No.	**material cost (RM)**	**setup cost (RM)**	**process cost (RM)**	**Rejects (RM)**	**tooling cost (RM)**	**total cost (RM)**
E001	0.3	0.02	1.83	0.02	0.53	2.7
E002	0.02	0.02	1.14	0.01	0.72	1.9
E003	0.04	0.02	1.67	0.01	0.77	2.51
E004	0.11	0.02	1.57	0.01	1.08	2.79
E005	0.02	0.02	1.49	0.01	0.82	2.35
E006	0.3	0.02	1.83	0.02	0.53	2.7
E007	0.23	0.02	1.43	0.01	0.73	2.42
E008	0	0	0.69	0	0	0.7
					Total	18.07

Table 4.5 shows the total costing per part for each part. For part E001 the total cost is RM2.70, for E002 is RM1.90, for part E003 the total cost per part is RM2.51. Meanwhile, for the parts E004, E005, E006, E007, and E008, the result of total costing per parts are RM2.79, RM2.35, RM2.70, RM2.42, and RM0.70 respectively. Thus, the total costing for all parts is RM18.07.

4.4.2 Design for Assembly (DFA)



Design For Assembly 9.3 [C:\Documents and Settings\student_2\Desktop\aidil 4BMCD2\DFA ANALYSIS\Existing Product\MOUSE.dfa]

Name: Bottom Cover
Part number: E001
Repeat count: 1

30.000
65.000
85.000

Labor time
Item fetching distance: within easy reach

Item handling and fetching time, s	1.95
Insertion/operation time, s	3.00

Manufacturing data

	Item	Product
Piece part cost, RM	2.16	15.68
Item cost per item, R	2.70	20.85
Tooling investmen	342	51,737
Weight per item, kg	0.03	0.10

Material ABS
Process Injection molding

Results

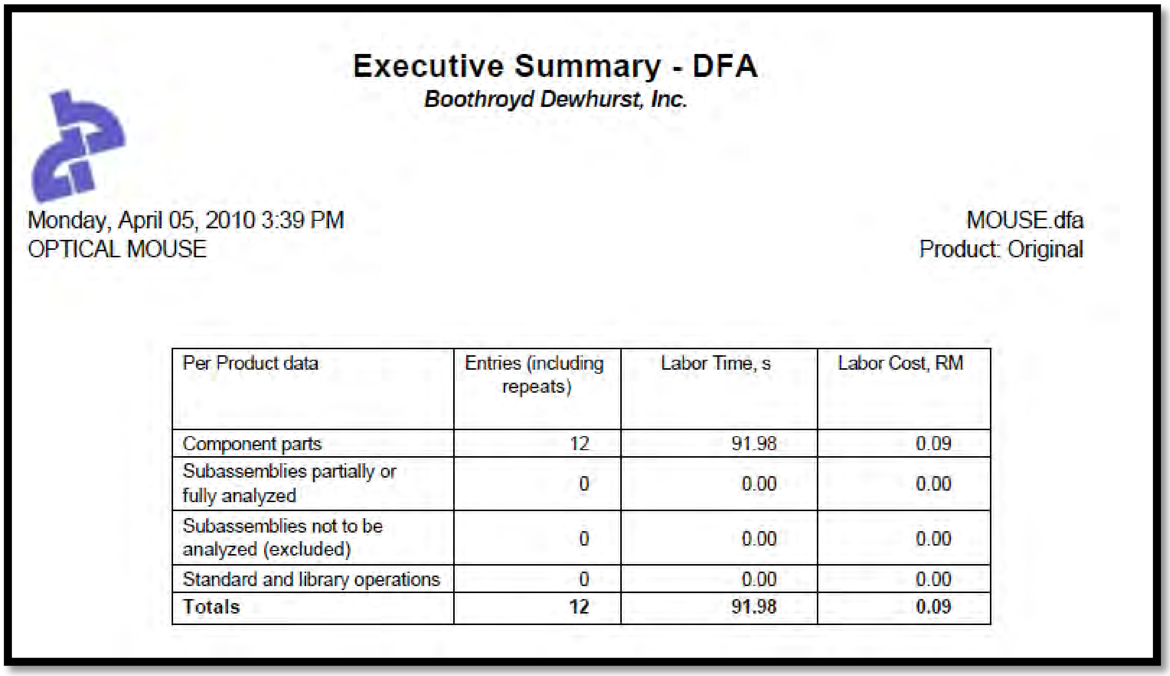
	Entry totals	Product
Count	1	12
Minimum count	1	4
Labor time, s	4.95	101.08
Labor cost, RM	0.00	0.10
Other op. cost, RM	0.00	0.00
Assy. tool/fixture, RM	0.00	0.00
Item costs, RM	2.70	20.85
Total cost, RM	2.70	20.95
DFA Index		11.6

Figure 4.19: Example DFA analysis for Part

Figure 4.19 is an example process to analyze the assembly cost for part in Optical Mouse. The figure shows the process need to be inserted for bottom cover part assembly process. At part number 1, the part name and part number is inserted in the specified columns. For part number 2, a securing method is identified. For the bottom cover, securing method has been chosen is secured later because the bottom cover is the base in optical mouse. For item in part number 3, is a minimum part criterion. For bottom cover, the base part has been selected for minimum part criterion. For part number 4, is to envelope dimension. For this item, the dimension is imported from the DFM process. Part number 5 is an item of symmetry. To complete this item, Alfa and

Beta for all parts needs to be identified. For bottom cover, the Alfa and Beta is 360 degree. From that one way has been selected in symmetry item. Part number 6 is an item of handling difficulties. For the bottom cover, not handling difficult process when assemble this part. For part number 7, the item is an insertion difficulty. For bottom cover example, align has been chosen because when assembly the part was easy to insert.

Table 4.6: Executive Summary for DFA



Executive Summary - DFA

Boothroyd Dewhurst, Inc.

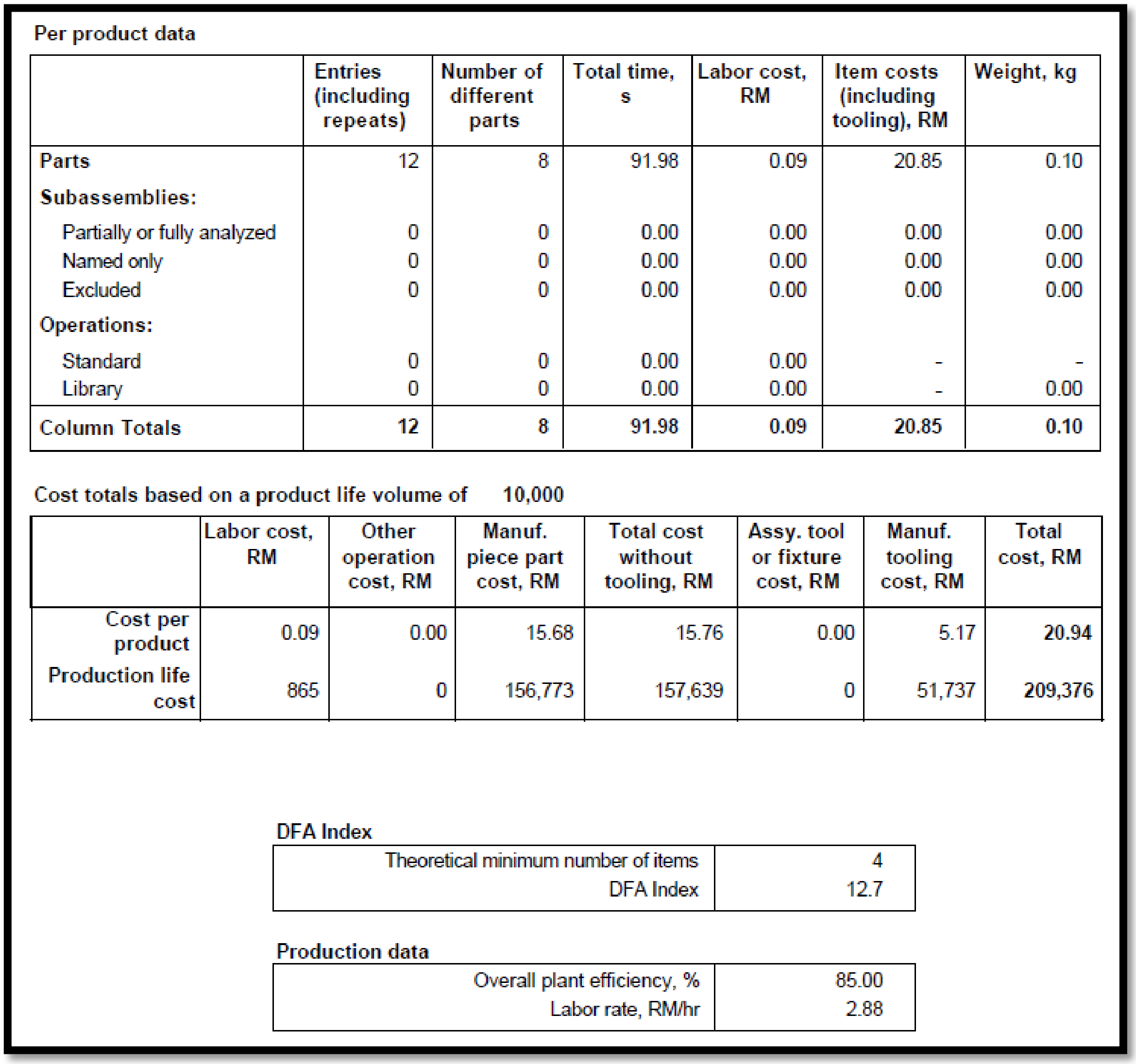
Monday, April 05, 2010 3:39 PM
OPTICAL MOUSE

MOUSE.dfa
Product: Original

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, RM
Component parts	12	91.98	0.09
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	0	0.00	0.00
Totals	**12**	**91.98**	**0.09**

Table 4.6 shows the result of labor times per second and labor cost per cent in RM. Intended for DFA analysis, the result for labor time is 91.98s and the labor cost is RM0.09.

Table: 4.7: Total Analysis for DFMA



Per product data

	Entries (including repeats)	Number of different parts	Total time, s	Labor cost, RM	Item costs (including tooling), RM	Weight, kg
Parts	12	8	91.98	0.09	20.85	0.10
Subassemblies:						
Partially or fully analyzed	0	0	0.00	0.00	0.00	0.00
Named only	0	0	0.00	0.00	0.00	0.00
Excluded	0	0	0.00	0.00	0.00	0.00
Operations:						
Standard	0	0	0.00	0.00	-	-
Library	0	0	0.00	0.00	-	0.00
Column Totals	**12**	**8**	**91.98**	**0.09**	**20.85**	**0.10**

Cost totals based on a product life volume of 10,000

	Labor cost, RM	Other operation cost, RM	Manuf. piece part cost, RM	Total cost without tooling, RM	Assy. tool or fixture cost, RM	Manuf. tooling cost, RM	Total cost, RM
Cost per product	0.09	0.00	15.68	15.76	0.00	5.17	**20.94**
Production life cost	865	0	156,773	157,639	0	51,737	**209,376**

DFA Index

Theoretical minimum number of items	4
DFA Index	12.7

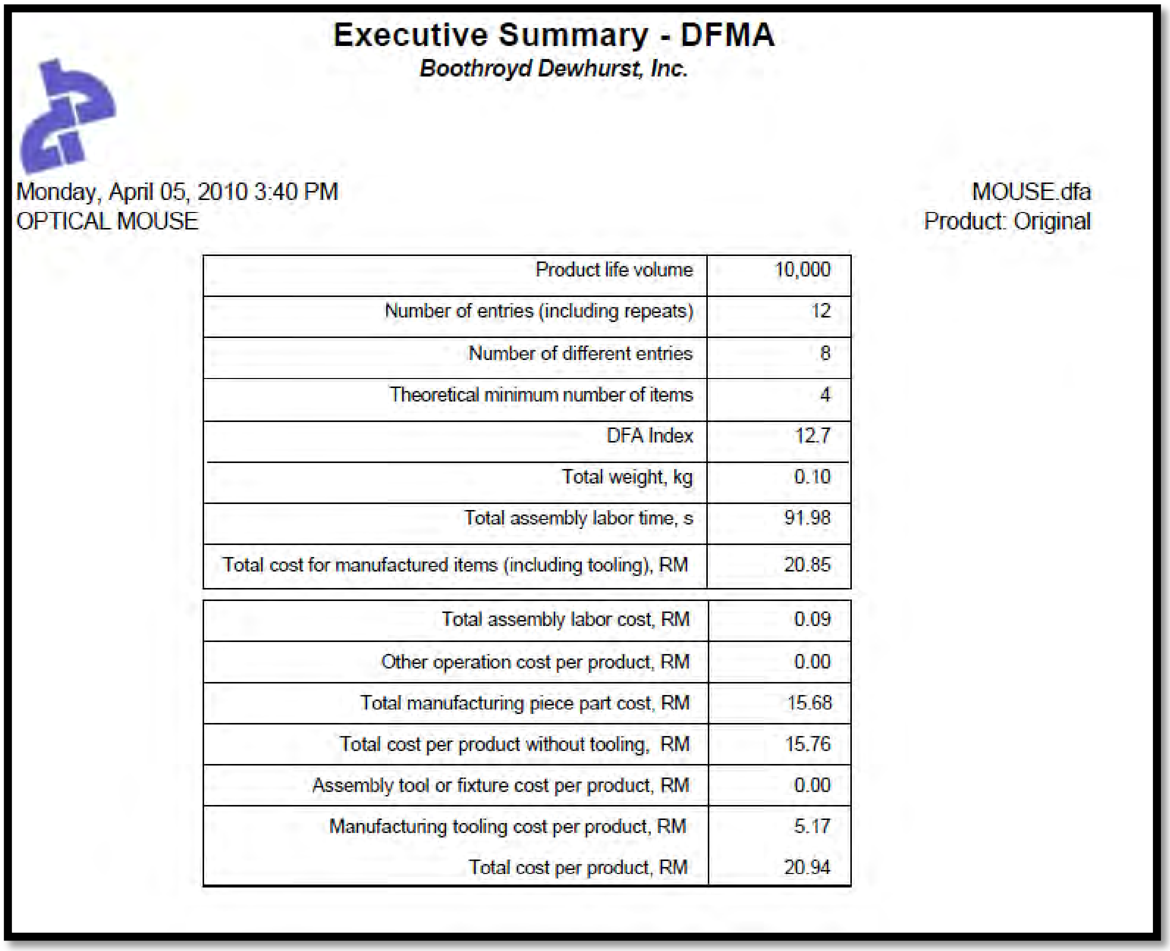
Production data

Overall plant efficiency, %	85.00
Labor rate, RM/hr	2.88

From the **Table 4.7**, the overall plant efficiency is 85 percent. The labor cost for analysis is equal to labor cost in manual analysis. The rate labor cost per hour is RM2.88.

From the DFM and DFA software analysis, the total result of DFMA had been contained. **Table 4.8** shows the DFMA result.

Table 4.8: DFMA summary result



Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:40 PM
OPTICAL MOUSE

MOUSE.dfa
Product: Original

Product life volume	10,000
Number of entries (including repeats)	12
Number of different entries	8
Theoretical minimum number of items	4
DFA Index	12.7
Total weight, kg	0.10
Total assembly labor time, s	91.98
Total cost for manufactured items (including tooling), RM	20.85

Total assembly labor cost, RM	0.09
Other operation cost per product, RM	0.00
Total manufacturing piece part cost, RM	15.68
Total cost per product without tooling, RM	15.76
Assembly tool or fixture cost per product, RM	0.00
Manufacturing tooling cost per product, RM	5.17
Total cost per product, RM	20.94

The result found by using DFMA is the total cost for manufacturing items and the total cost per product. The total manufacturing items result is RM 20.85 and total cost per product is RM 20.94.

Design Efficiency = 3 x NM / TM x 100%

Design efficiency = $\frac{3 \text{ x } 4}{91.98} = 13.05\%$

CHAPTER 5

CONCEPTUAL DESIGN

5.1 Introduction

The concept design is based on the improvement of the existing design. The existing design will go through disassemble and assemble operation for several times. For each part, an evaluation is made to determine the current design efficiency. Then from the process, two or three proposed designs of the conceptual design are obtained. The concept design developed in order to achieve the objective, which are for ease of assembly and manufacturing. The idea to generate a design can be from brain storming, research from journals, internet and books references. This concept is explained through sketching.

5.1.1 Proposed Design

Concept 1

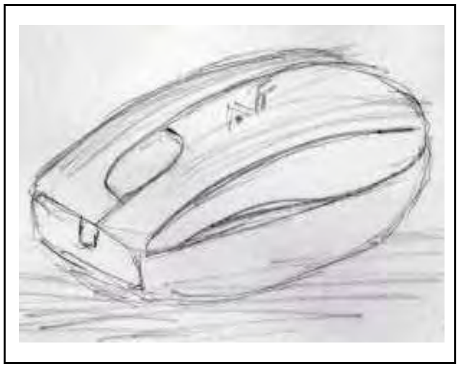


Figure 5.1: Concept 1 Isometric view

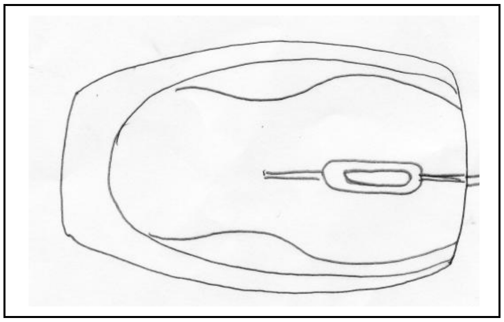


Figure 5.2: Concept 1 Plan View

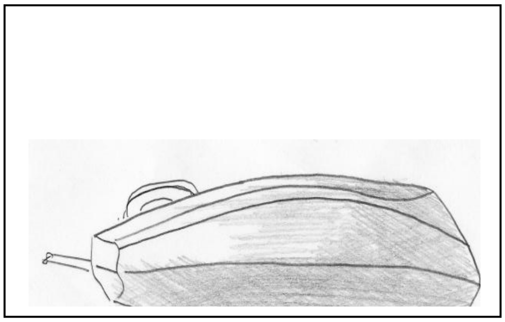


Figure 5.3: Concept 1 Side View

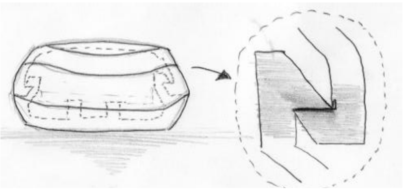


Figure 5.4: Snap Fit Mechanism

For the first concept, the cover design of optical mouse remains as existing design. The improvement of the concept of screw usage is not included in the design. The screw was replaced with the new mechanism in **Figure 5.4** as shown. The mechanism uses a snap fit system.

Concept 2

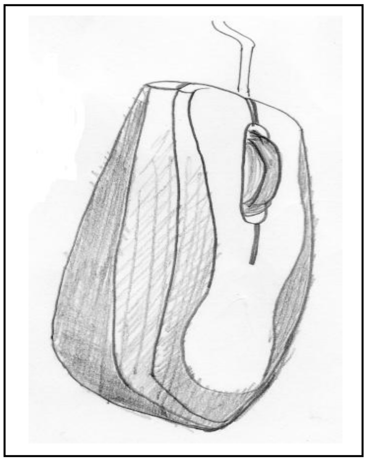


Figure 5.5: Concept 2 Isometric View

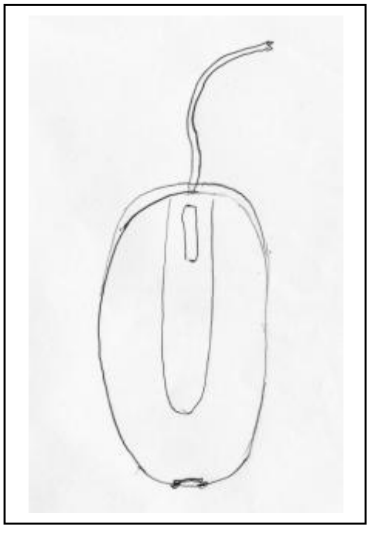


Figure 5.6: Concept 2 Plan View

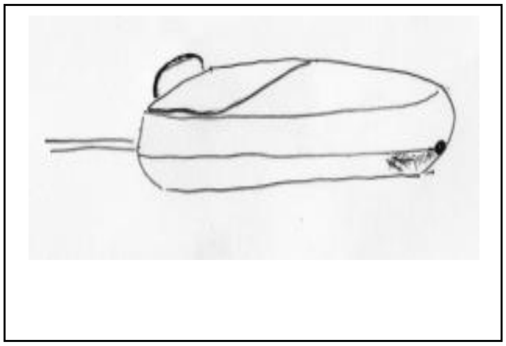


Figure 5.7: Concept 2 Side View

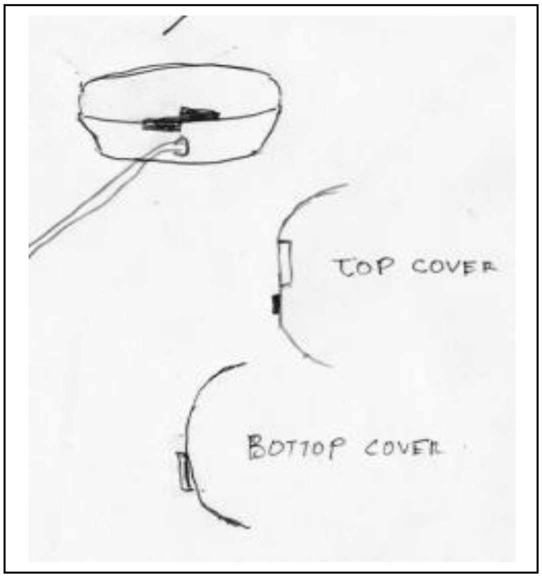


Figure 5.8: Lock mechanism

For the second concept, the design is similar to the first concept; the screw is not included in this concept. The mechanism used in this second concept is a clip system. The mechanism is similarly use in the geometric set BOFA box.

Concept 3

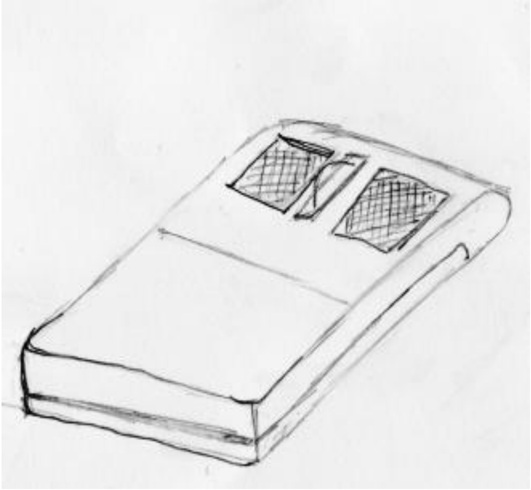


Figure 5.9: Concept 3 Isometric View

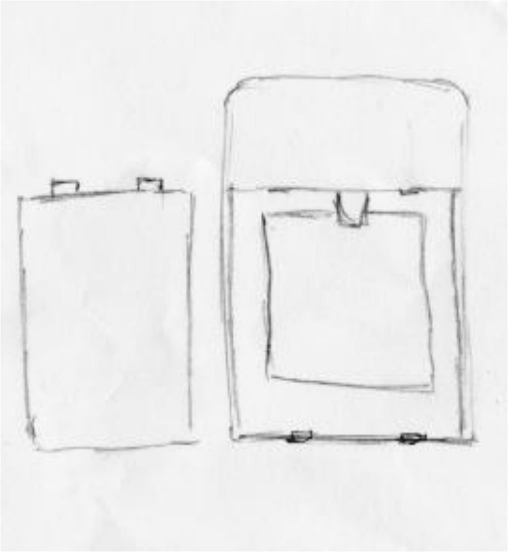


Figure 5.10: Concept 3 Plan View

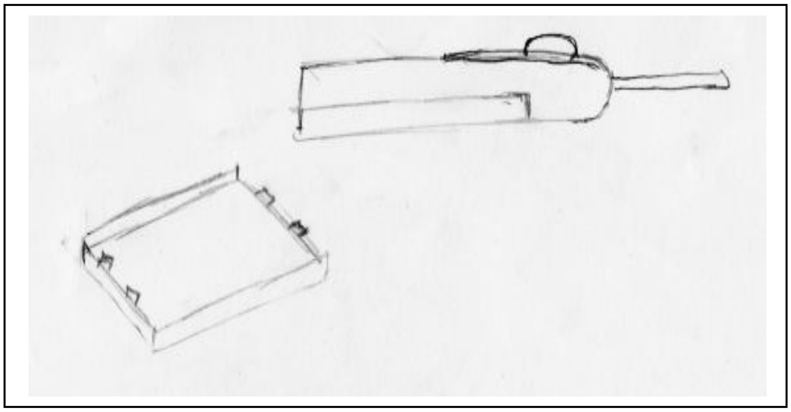


Figure 5.11: Concept 3 Side View

For the third concept, the design is similar with a mobile phone. The shape of the design is flat. For the mechanism, the design uses a sliding system. The mechanism of the design is shown in **Figure 5.11**.

5.1.2 Selection Design

Concept Selection is picking the ideas which best satisfy the Product Design Specification Stage in design process understanding customer needs, developing Product Design Specification, generating many concepts. Before detail designs, the best design was decided by concept of using Pugh's method. From the aspect that has been considered for example, there will be no need for any mouse pad, comfortable to use, attractive design, easy to assemble, sharp characterized appearance, modern and smooth shape. For a very good design, the point given is 5, good design 4 points, moderate design 3 points, poor design 2 points and very poor design 1 point.

Table 5.1: Pugh's concept selection method

Needs	Concept 1	Concept 2	Concept 3	Datum
No need for any mouse pad	4	3	3	1
Comfortable to use	3	4	4	2
Attractive design	5	3	3	2
Easy to assemble	5	2	2	1
sharp characterized appearance	2	2	2	4
Modern and smooth shape	4	3	3	4
Total Scoring / (30)	18	17	17	14

Legend:
1 – very poor 2 – poor
3 – moderate 4 – good
5 – very good

After the Pugh's concept selection method stage, the final selection of choosing the concept that achieves the highest ranking. The concept that has the highest rating will be chosen to proceed to the next stage. The first concept has the highest rating for the all criteria and the values are shown in the **Table 5.1.**

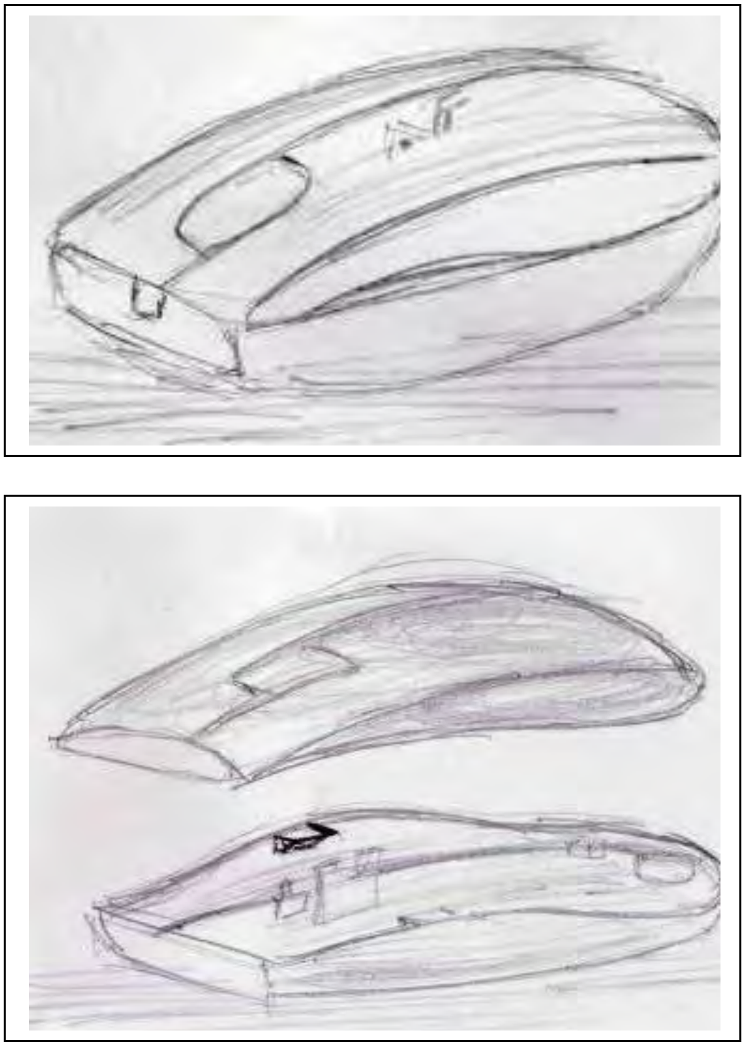
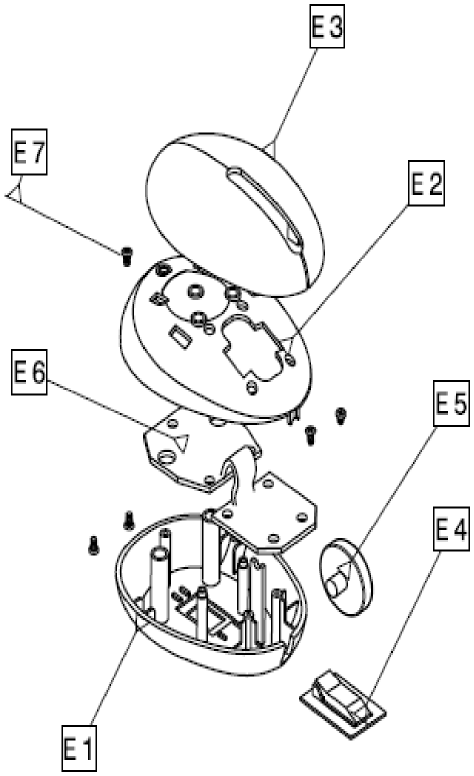
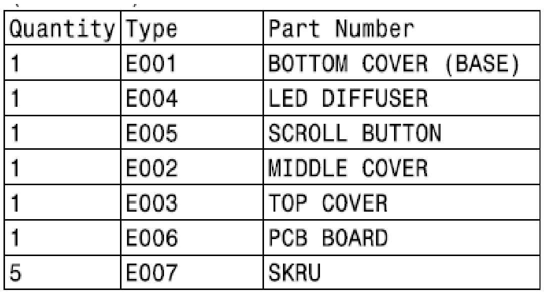


Figure 5.12: Design selected

5.2 Detail drawing

5.2.1 Drawing Design for Existing Design



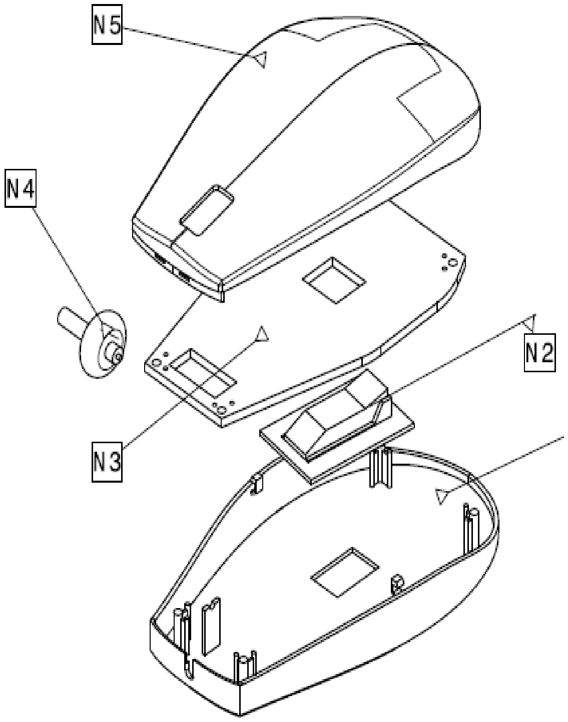


Quantity	Type	Part Number
1	E001	BOTTOM COVER (BASE)
1	E004	LED DIFFUSER
1	E005	SCROLL BUTTON
1	E002	MIDDLE COVER
1	E003	TOP COVER
1	E006	PCB BOARD
5	E007	SKRU

Figure 5.13: Bill of Material Existing Design

Figure 5.13 shows bill of material of existing design. For the detail drawing of each parts, shows in Appendix C1.

5.2.2 Drawing Design for New Design



Quantity	Type	Part Number
1	N001	BOTTOM COVER (BASE)
1	N003	PCB BOARD
1	N004	SCROLL BUTTON
1	N005	TOP COVER
1	N002	LED DIFFUSER

Figure 5.14: Bill of Material New Design

Figure 5.14 shows bill of material of new design. For the detail drawing of each parts, shows in Appendix C2.

CHAPTER 6

DFMA ANAYSIS FOR NEW DESIGN

6.1 Introduction

The product new design is carried out by applying the Boothyord-Dewhurst DFMA method. The Boothyord-Dewhurst DFMA method has developed the systematic system that is used for the ease of assembly and manufacturing. Therefore, the case study on the new design can show the applications of the method.

6.2 Analysis of the New Design (Manual)

The product has to go through the disassemble process to define the assembly process sequence carried out for the product. **Figure 6.1** shown the CAD drawing of the exploded view for the disassemble product. **Figure 6.2** show the assembly drawing in CAD drawing. For the new design, part can be reduced from eight parts to 5 parts.

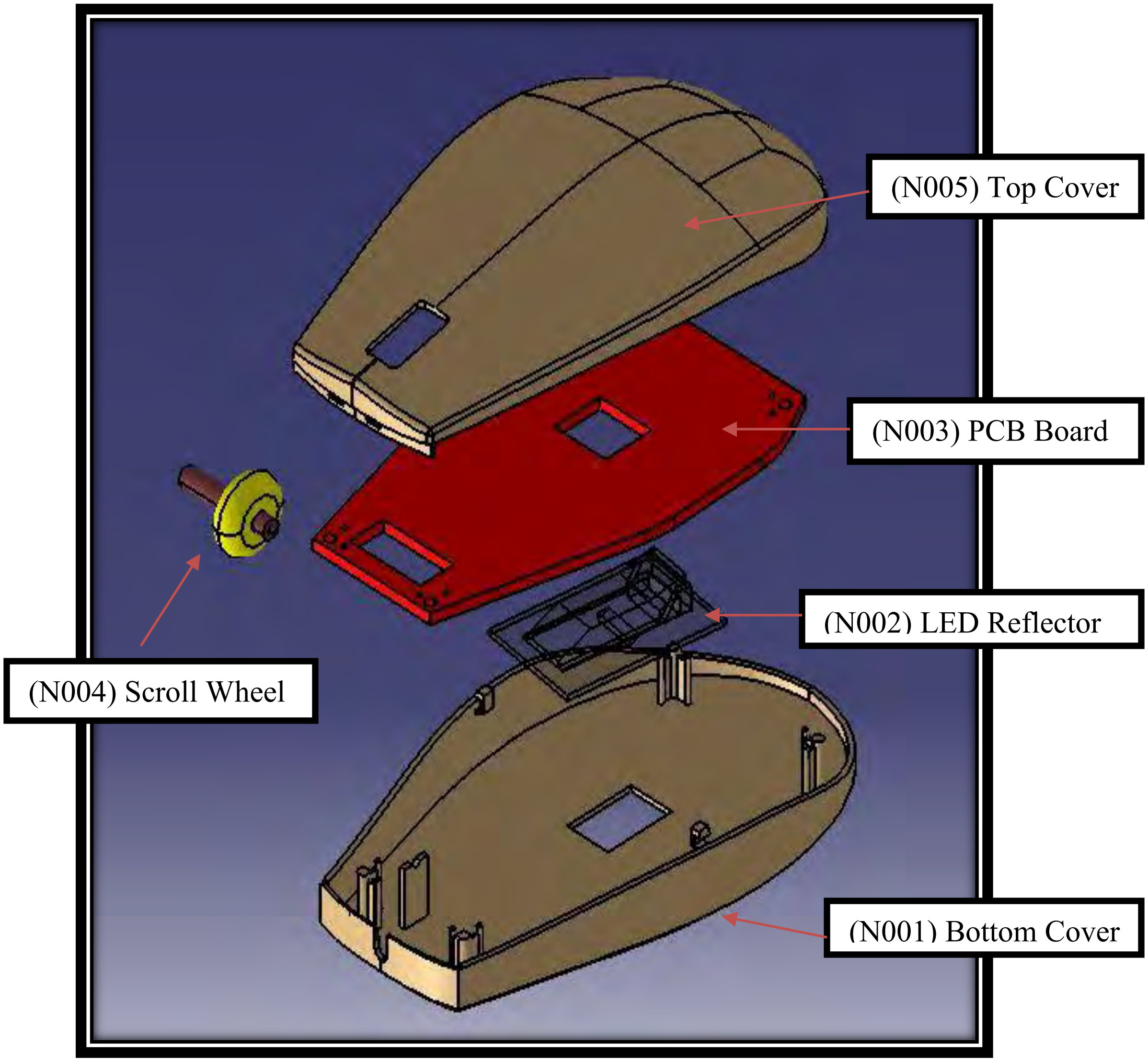


Figure 6.1: Disassembly view for New Design Optical Mouse

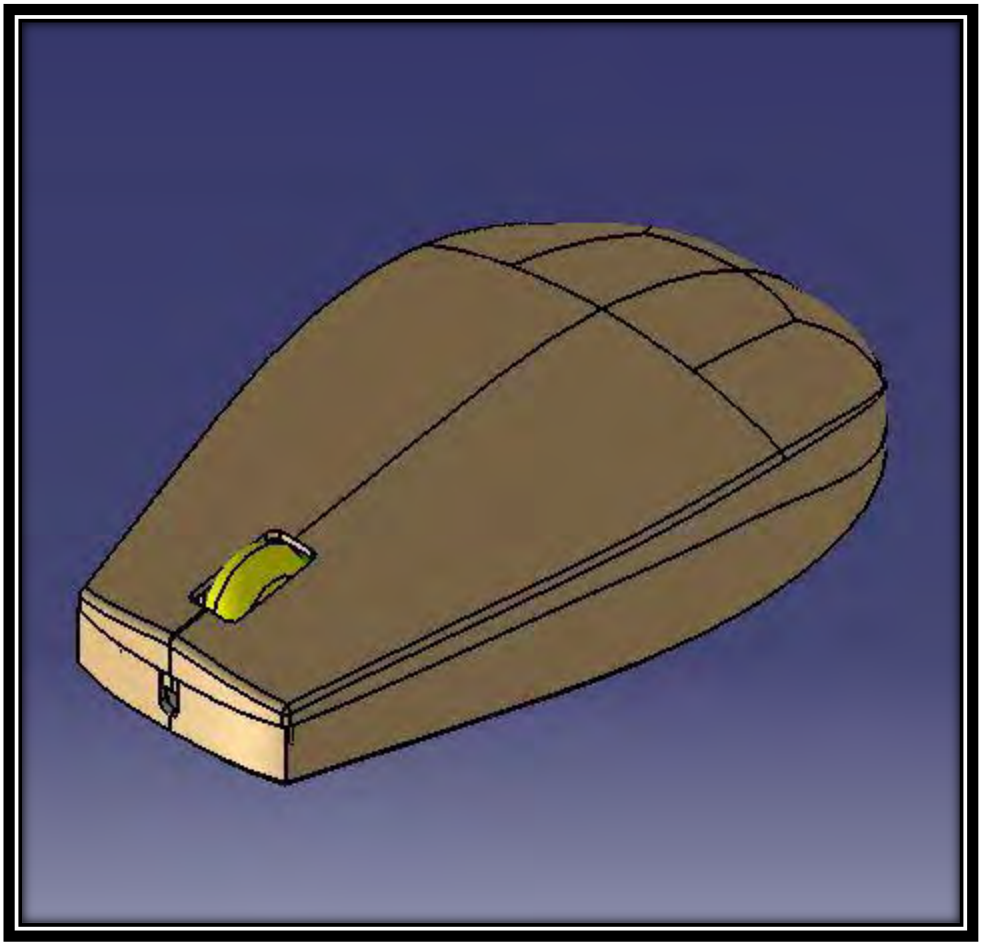


Figure 6.2: Assembly view for New Design Optical Mouse

6.2.1 Assembly Flow Chart

After the disassemble process, a flow chart for the product was constructed to identify the process assembly of the product.

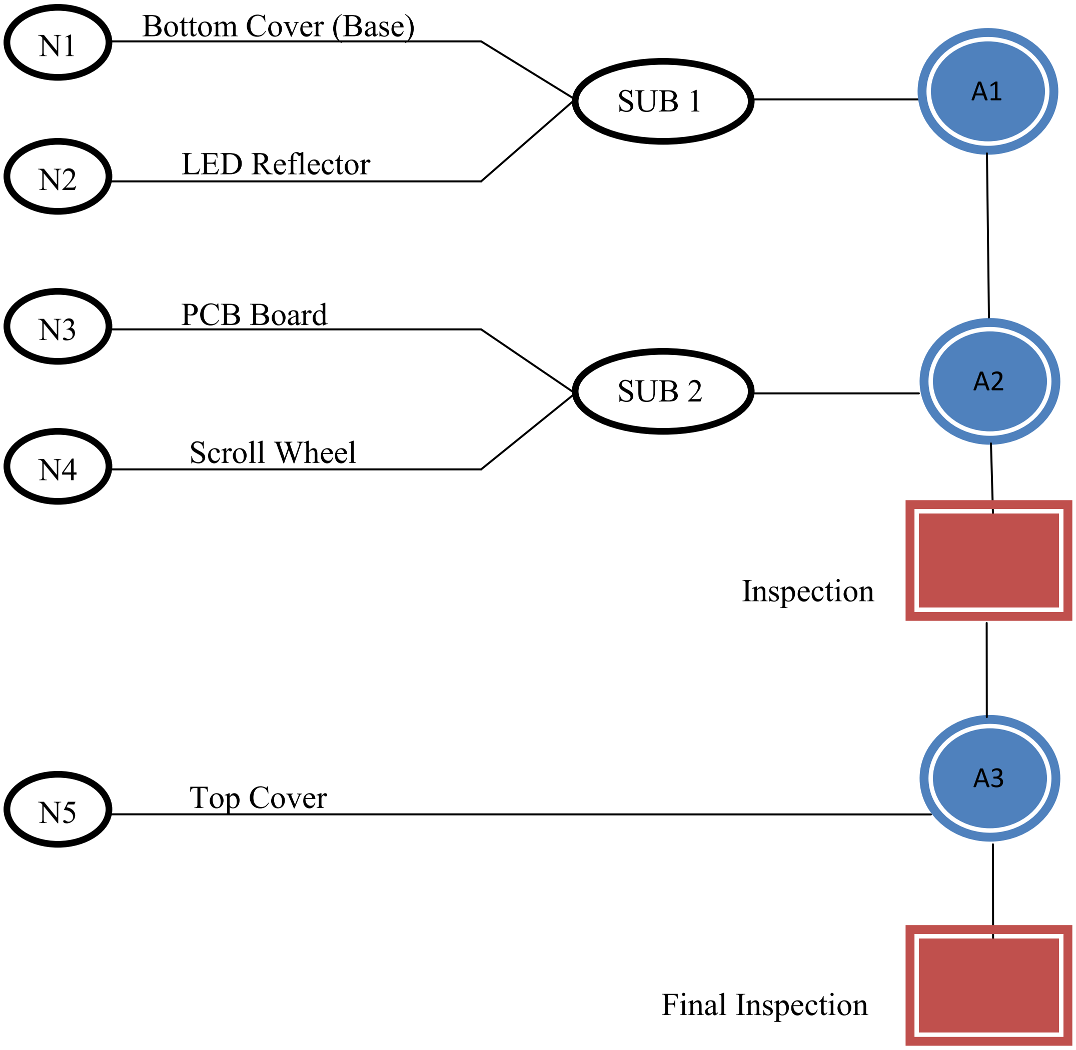


Figure 6.3: Assembly Process Flow for New Design

From the flow chart **Figure 6.3**, the process assembly of the product is:

A1 - Be full of sub-assembly 1. Assemble LED Reflector (N002) to Bottom Cover (base) (N001).

A2 - Be full of sub-assembly 2. Place in the Scroll Wheel part (N004) in slot on the PCB board (N003).

🟥 - The parts will be inspected.

A3 - After complete inspection of parts in assembly 1 and assembly 2, assemble Top Cover (E005) to continue the process assembly. The parts will be connection by using screw.

🟥 - The parts will go through final inspection.

6.2.2 The Process and Material Selection for New design

For the stage, process flow of the each part for the product must be constructing. Process flow considered the manufacture process, selection for the material, and so on. **Figure 6.4** to **Figure 6.8** is the process flow of each part.

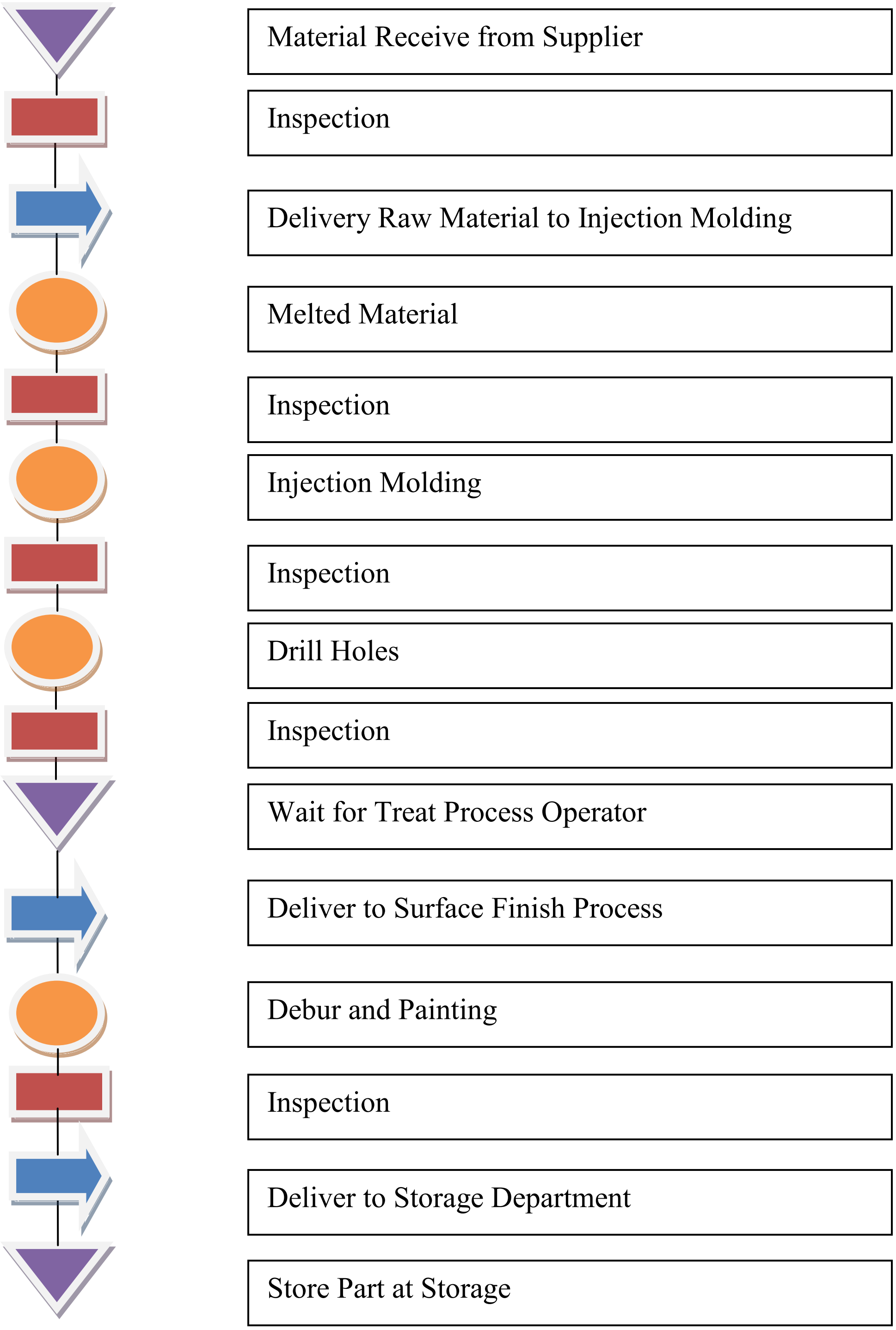


Figure 6.4: Process Flow for Bottom Cover (Base)

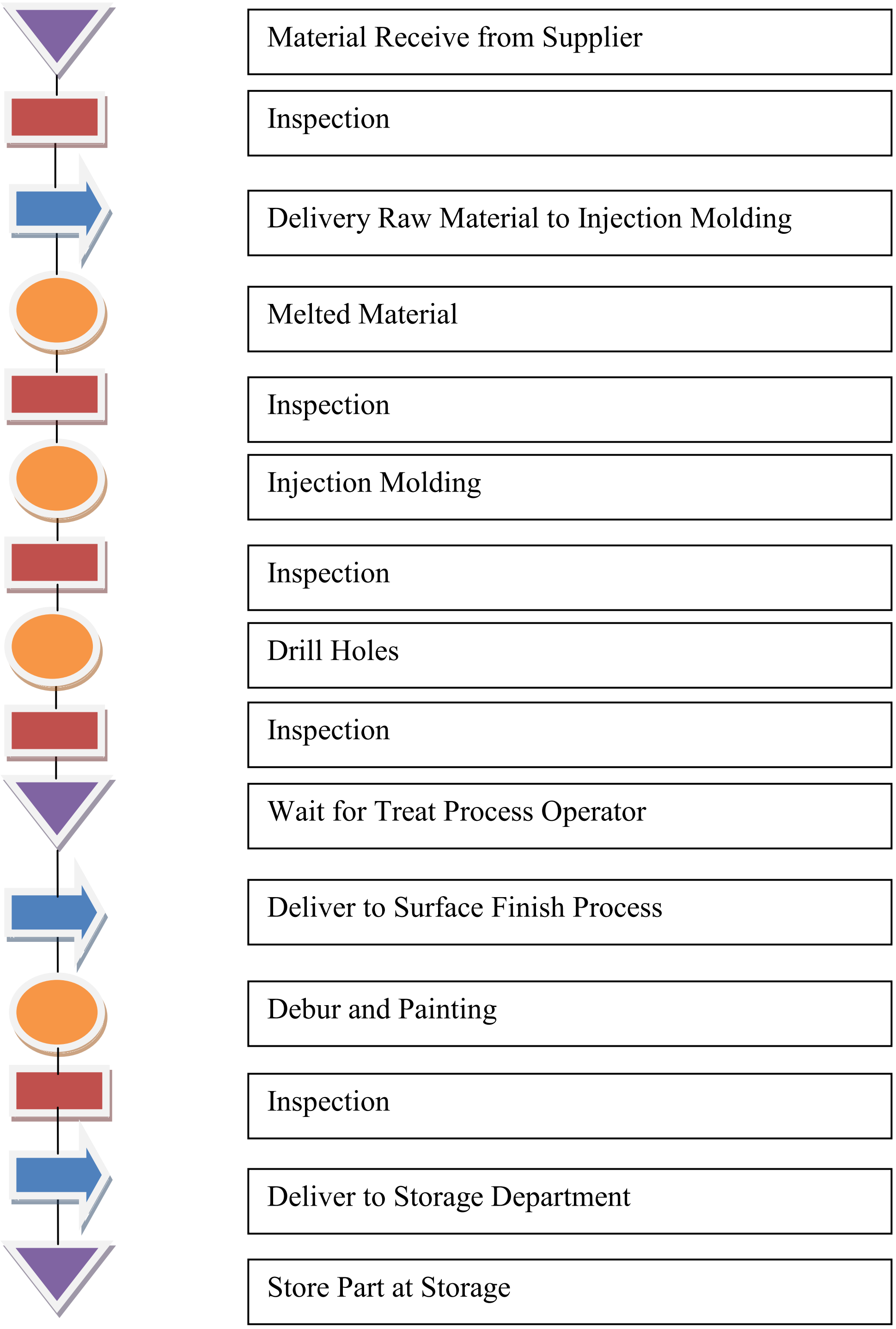


Figure 6.5: Process Flow for Led Reflector

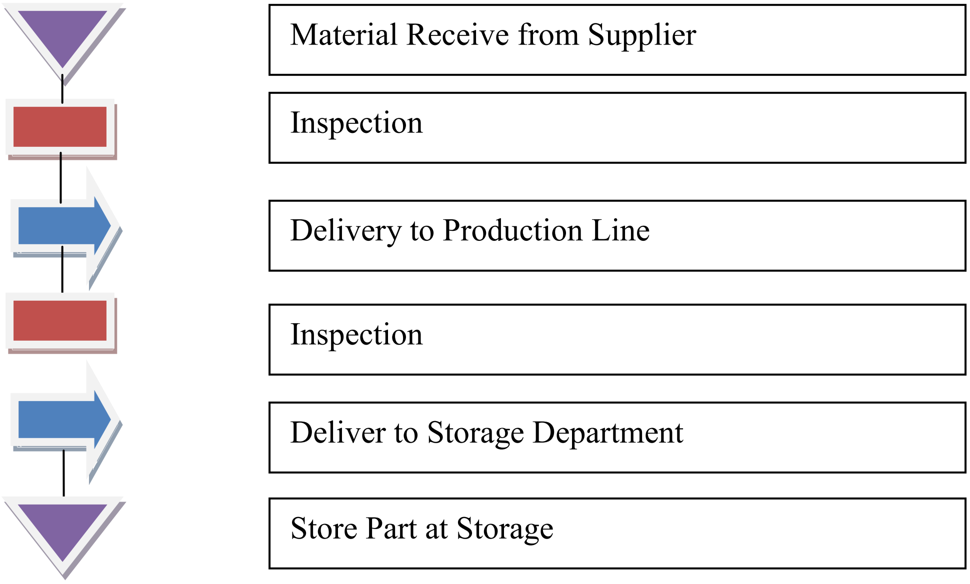


Figure 6.6: Process Flow for PCB Board

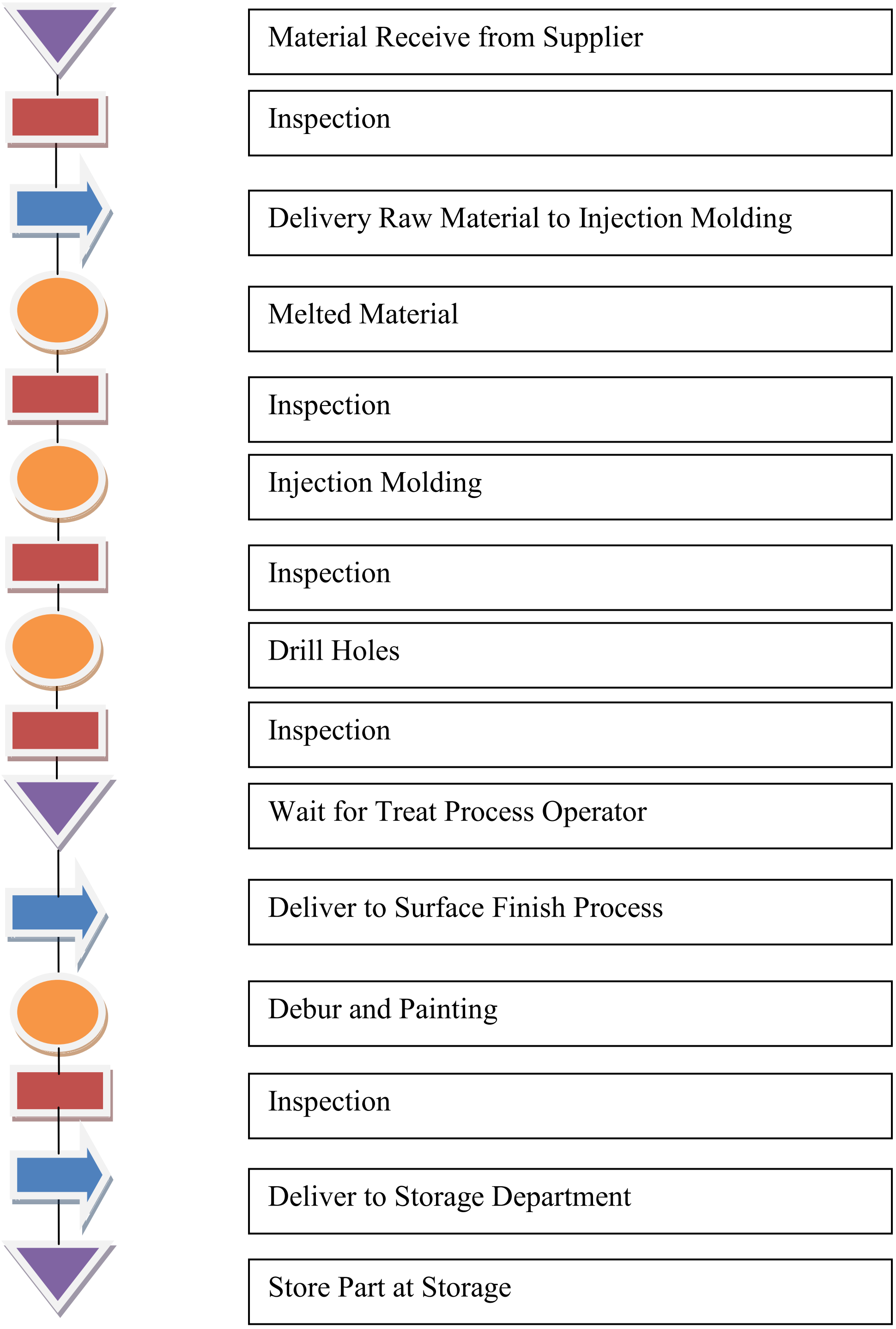


Figure 6.7: Process Flow for Scroll Wheel

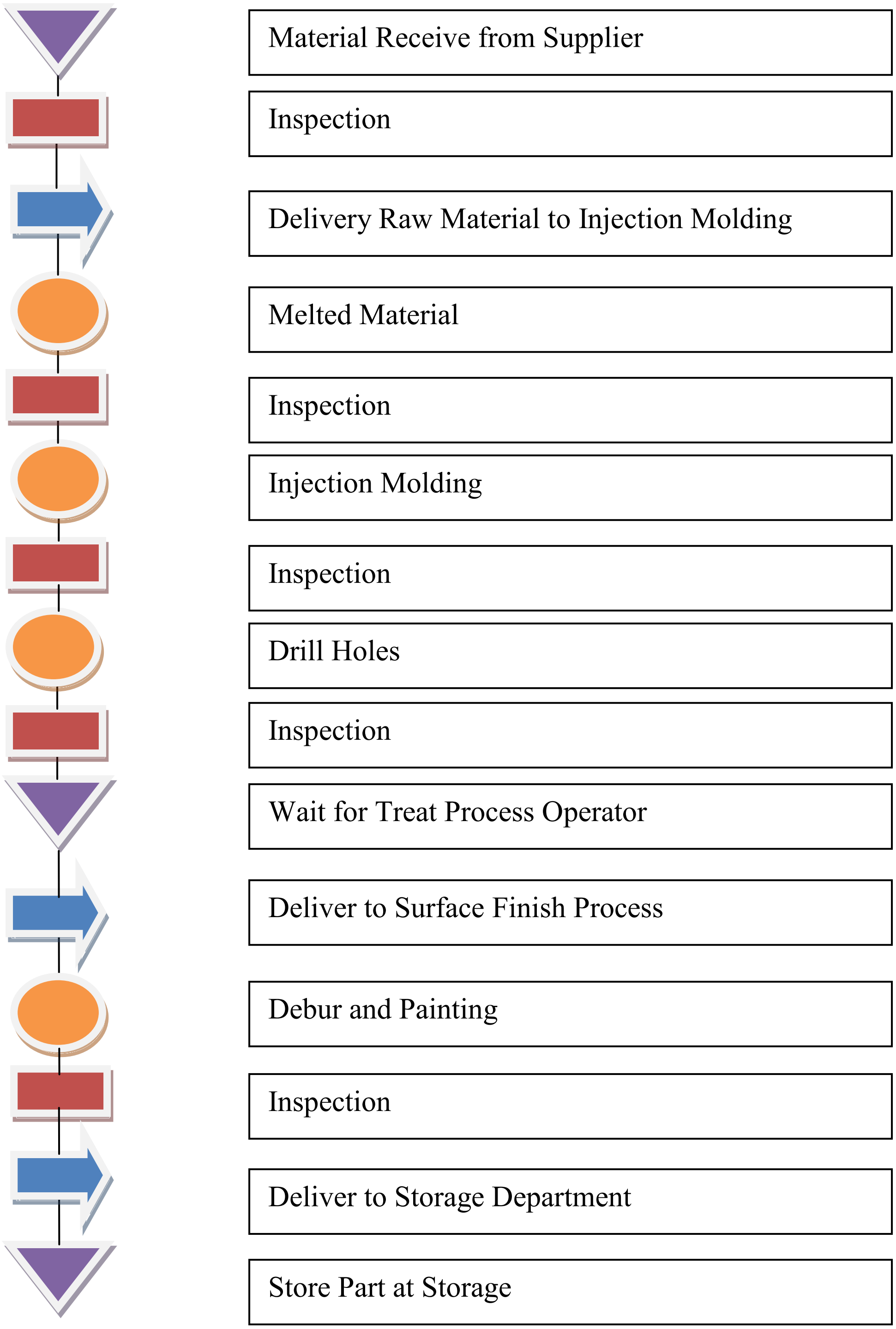


Figure 6.8: Process Flow for Top Cover

6.2.3 Theoretical Part

After a new design is obtained, all the parts in new design needed to be analyzed to find the new theoretical part. The analyzed guideline for the new design is similar to the guideline for existing product analyze.

Table 6.1: Theoretical Part for New Design

Part No.	Part Name	Material	Movement	Separation	Theoretical Part Count
N001	Bottom Cover (Base)	No	No	Yes	✓
N002	LED reflector	Yes	No	Yes	✓
N003	PCB Board	Yes	Yes	Yes	✓
N004	Scroll Wheel	Yes	Yes	Yes	✓
N005	Top Cover	No	No	Yes	✓

From the theoretical part analyzed, **Table 6.1** shows the result for theoretical part for new design. For the new design, all of the parts are a theoretical part because the parts in the new design are improvements of the existing design.

6.2.4 Alpha and Beta symmetric

Alpha and Beta symmetric is one of the principal geometrical design features that affects the times required to grasp and orient a part is its symmetry. For new Alpha and Beta, the parts need to be analyzed with the same guideline as of in the existing product.

Table 6.2: Alpha & Beta of Optical Mouse part

Part No.	Name Part	Alpha	Justification	Beta	Justification
N001	Bottom Cover (Base)	360	Consider LED Reflector attach on the body.	360	Consider LED Reflector attach on the body.
N002	LED reflector	360	Due to the shape of LED	360	Due to the shape of LED
N003	PCB Board	360	consider the position of electronic component	360	Consider the position of electronic component
N004	Scroll Wheel	360	Consider the position of the scroll	0	Symmetric shape
N005	Top Cover	360	Due to the shape of top cover	360	Due to the shape of top cover

From the guideline in analysis of Alpha and Beta, the result for Alpha and Beta show in **Table 6.2.**

6.2.5 Handling and Insertion Time

From **Table 6.1** and **Table 6.2**, the value of total assembly time can be defined. Thus the efficiency can also be defined by 3 multiplied with the total theoretical minimum part and divided by total operation time. **Table 6.3** shows all the processes to define all the value.

Table 6.3: Analyze Handling and Insertion Time

Part ID n0.	**No. or Item**	**Manual Handling Code**	**Manual Handling Time Per Part**	**Manual Insertion Code**	**Manual Insertion Time Per Part**	**Operation Time (Second)**	**Operation Cost (Per Second)**	**Figure For Theoretical Minimum Part**	**Name Of Assembly**
N001	1	30	1.95	00	1.5	3.45	0.00276	1	Bottom Cover
N002	1	30	1.95	00	1.5	3.45	0.00276	1	LED Reflector
N003	1	83	5.6	00	1.5	7.1	0.00568	1	PCB Board
N004	1	10	1.5	03	3.5	5	0.004	1	Scroll Wheel
N005	1	83	5.6	30	2	7.6	0.00608	1	Top Cover
					Total	**26.6**	**0.02128**	**5**	
						TM	**CM**	**NM**	

From the **Table 6.3** of part analysis, the total of the parts for optical mouse is 8. There total assembly time for new optical mouse is 26.6 seconds and total assembly cost for new optical mouse is RM0.02126 per sec. The corresponding assembly cost is RM0.0008 per second, which count RM2.88 per hour, RM23.08 per day, and RM600.00 per month for 8 hours work time per day.

Design Efficiency = 3 x NM / TM x 100%

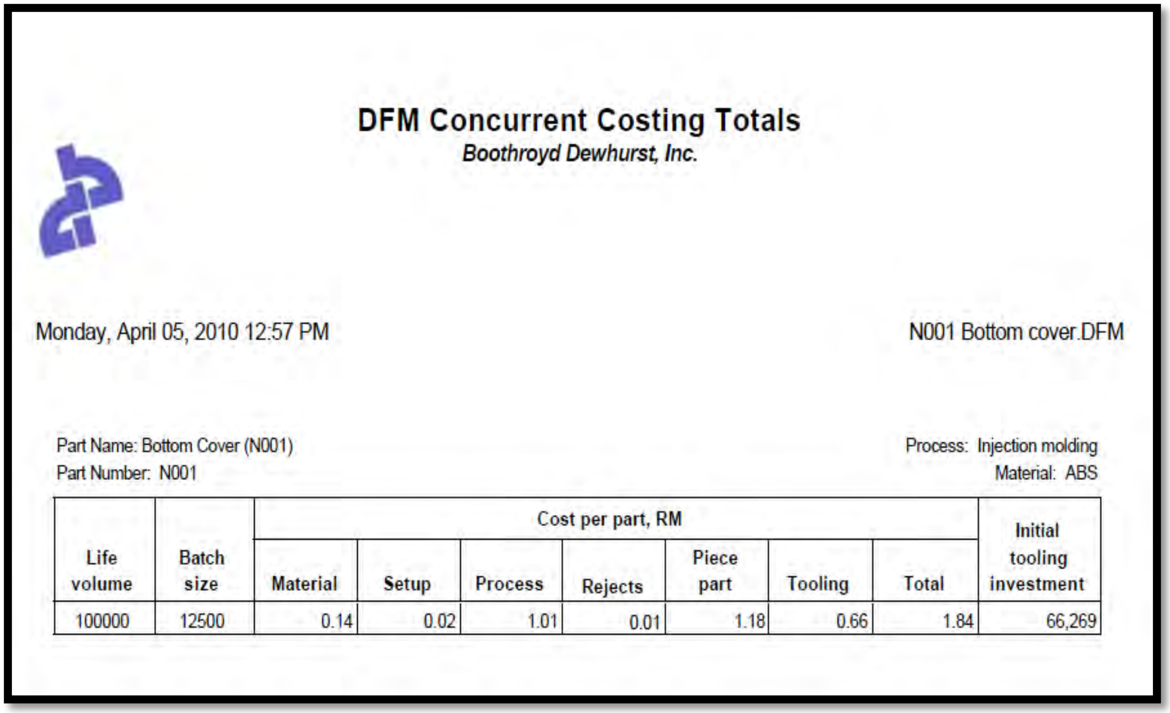
Design efficiency = $\frac{3 \text{ x } 5}{26.6} = 56.4\%$

6.3 Analysis of the New Design (DFMA Software)

6.3.1 Design for Manufacture (DFM)

For the new design part, a similar guideline for existing product analysis guideline was applied in the new design analysis. For the new design, total of part need to be analyzed is five parts. From that, the cost for each part had been obtained by using DFM analysis.

Table 6.4: DFM Software Concurrent Costing Totals



DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:57 PM

N001 Bottom cover.DFM

Part Name: Bottom Cover (N001)
Part Number: N001

Process: Injection molding
Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.14	0.02	1.01	0.01	1.18	0.66	1.84	66,269

Table 6.4 shows the example DFM concurrent costing totals for each part. From table above, the result for cost per part in RM used for bottom cover. Total cost per part was obtained from the addition of material cost, setup cost, process cost, rejected part cost, and tooling cost. The total of cost for bottom cover is RM1.84.

Table 6.5: Totals Costing per Part of each part

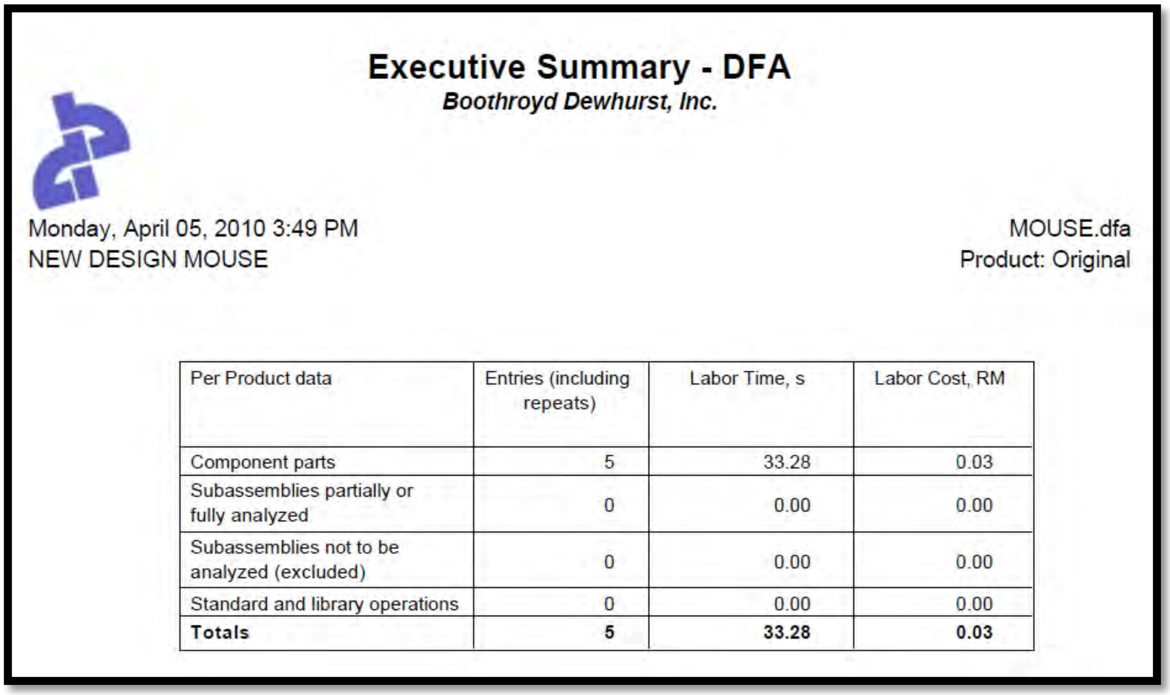
Part No.	**material cost (RM)**	**setup cost (RM)**	**process cost (RM)**	**Rejects (RM)**	**tooling cost (RM)**	**total cost (RM)**
N001	0.14	0.02	1.01	0.01	0.66	1.8
N002	0.02	0.02	1.14	0.01	0.72	1.9
N003	0.02	0.02	0.96	0.01	0.58	1.59
N004	0.05	0.02	1.30	0.01	0.60	1.98
N005	0.15	0.02	1.01	0.01	0.69	1.88
					Total	9.15

Table 6.5 shows total results of costing per part for each part of the new design. For part E001 the totals cost is RM1.80, for E002 is RM1.90, for part E003 the total cost per part is RM1.59. Mean while, for the parts E004 and E005, the result of total costing per parts are RM1.98, RM1.88 respectively. Thus, the total costing for all parts is RM9.15.

6.4 Design for Assembly (DFA)

For the new design DFA analysis, apply the same guideline in existing design of DFA analysis. For the new design, total of part which needs to be analyzed are five parts. From that, the result for assembly had been obtained by using DFA analysis.

Table 6.6: Executive Summary for DFA



Executive Summary - DFA

Boothroyd Dewhurst, Inc.

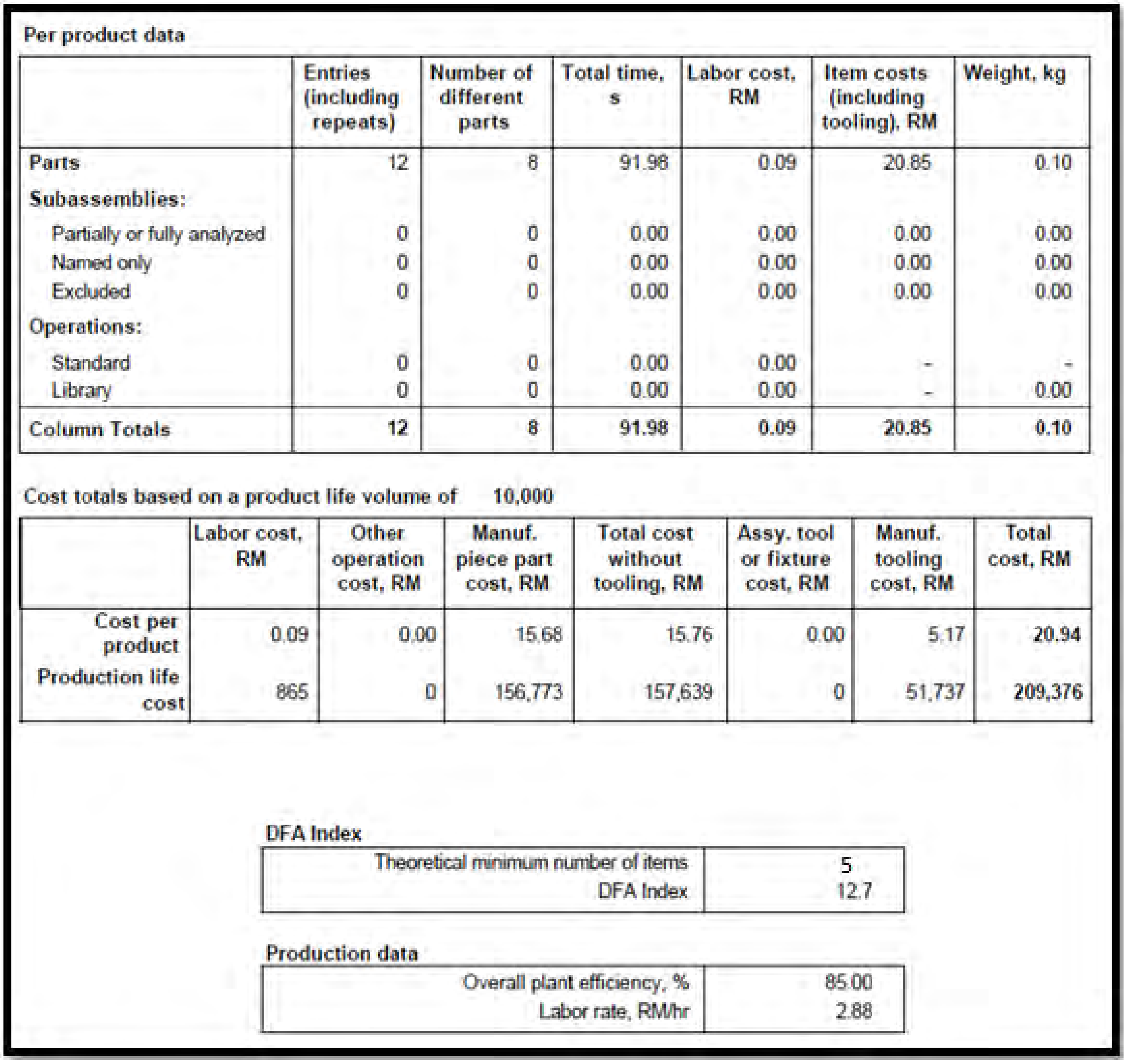
Monday, April 05, 2010 3:49 PM
NEW DESIGN MOUSE

MOUSE.dfa
Product: Original

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, RM
Component parts	5	33.28	0.03
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	0	0.00	0.00
Totals	**5**	**33.28**	**0.03**

Table 6.6 shows the result of labor times per second and labor cost per cent in RM. Intended for DFA analysis, the result for labor time is 33.28s and the labor cost is RM0.03.

Table: 6.7: Total Analysis for DFMA



Per product data

	Entries (including repeats)	Number of different parts	Total time, s	Labor cost, RM	Item costs (including tooling), RM	Weight, kg
Parts	12	8	91.98	0.09	20.85	0.10
Subassemblies:						
Partially or fully analyzed	0	0	0.00	0.00	0.00	0.00
Named only	0	0	0.00	0.00	0.00	0.00
Excluded	0	0	0.00	0.00	0.00	0.00
Operations:						
Standard	0	0	0.00	0.00	-	-
Library	0	0	0.00	0.00	-	0.00
Column Totals	**12**	**8**	**91.98**	**0.09**	**20.85**	**0.10**

Cost totals based on a product life volume of 10,000

	Labor cost, RM	Other operation cost, RM	Manuf. piece part cost, RM	Total cost without tooling, RM	Assy. tool or fixture cost, RM	Manuf. tooling cost, RM	Total cost, RM
Cost per product	0.09	0.00	15.68	15.76	0.00	5.17	**20.94**
Production life cost	865	0	156,773	157,639	0	51,737	**209,376**

DFA Index

Theoretical minimum number of items	5
DFA Index	12.7

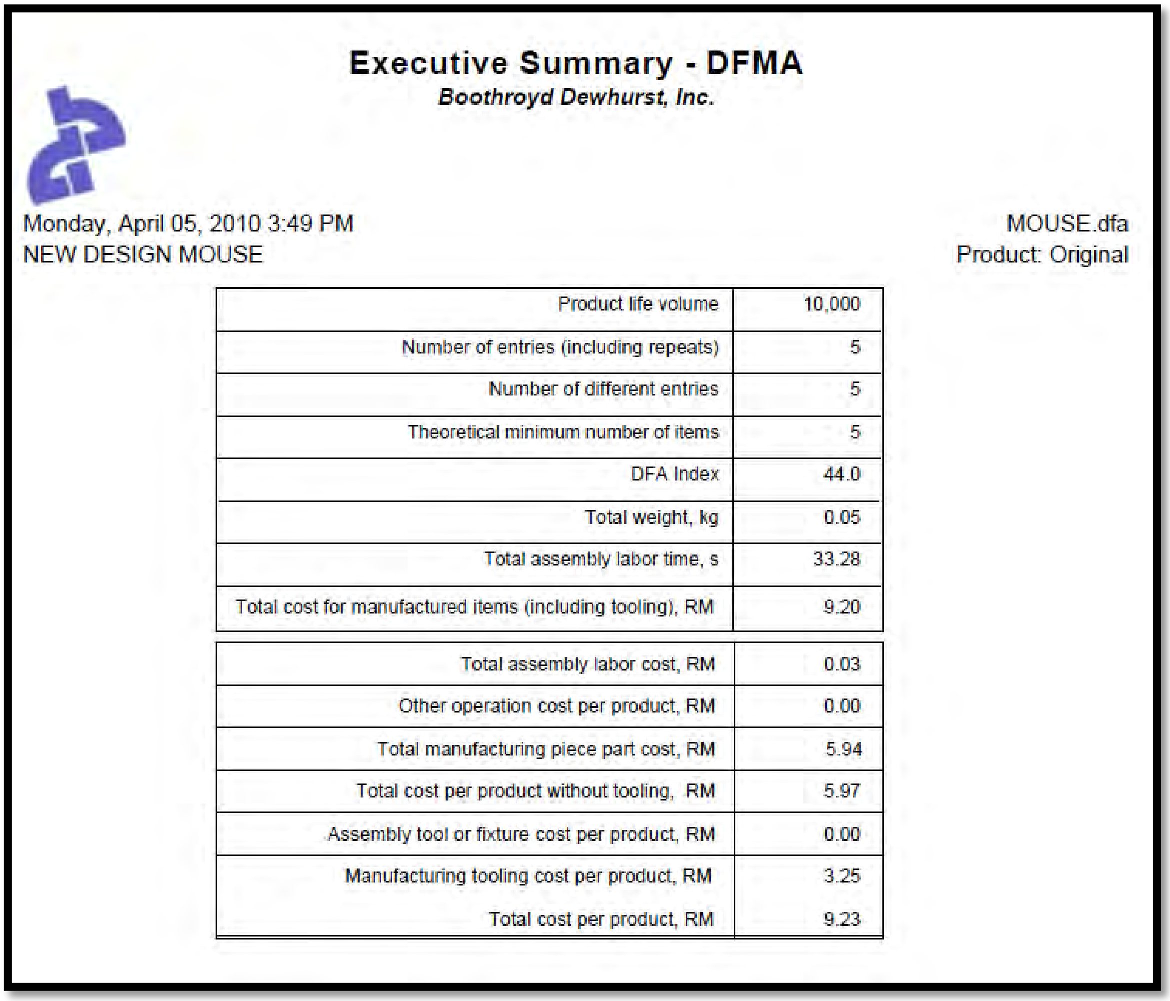
Production data

Overall plant efficiency, %	85.00
Labor rate, RM/hr	2.88

From **Table 6.7**, the overall plant efficiency is 85 percent. The labor cost for analysis is equal to labor cost in manual analysis. The rate labor cost per hour is RM2.88.

From the DFM and DFA software analysis, the total results of DFMA are shown. **Table 6.8** shows the DFMA result.

Table 6.8: DFMA summary result



Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:49 PM
NEW DESIGN MOUSE

MOUSE.dfa
Product: Original

Product life volume	10,000
Number of entries (including repeats)	5
Number of different entries	5
Theoretical minimum number of items	5
DFA Index	44.0
Total weight, kg	0.05
Total assembly labor time, s	33.28
Total cost for manufactured items (including tooling), RM	9.20

Total assembly labor cost, RM	0.03
Other operation cost per product, RM	0.00
Total manufacturing piece part cost, RM	5.94
Total cost per product without tooling, RM	5.97
Assembly tool or fixture cost per product, RM	0.00
Manufacturing tooling cost per product, RM	3.25
Total cost per product, RM	9.23

The result has been defined in DFMA is the overall result of DFM and DFA. From **Table 6.8,** the total cost for manufacturing items is RM 20.85 and total cost per product is RM 20.94. From the result, the design efficiency of can be calculated.

Design Efficiency = 3 x NM / TM x 100%

$$\text{Design efficiency} = \frac{3 \text{ x } 5}{33.28} = 45.07\%$$

CHAPTER 7

DISCUSSION

7.1 Introduction

This chapter will discuss about the product evaluation and comparison between the existing design and the new design by two items; first item is in manual analysis and second in software analysis.

7.2 Comparison of Manual and Software analysis

The analysis is compare using Boothyord Dewhurst DFMA method. The manual analysis is compared with software analysis in terms of aspect as design efficiency, part quantity, assembly time and assembly cost. The percentages are different between the designs reflect the improvement of product.

Manual DFMA Analysis

Existing design: Design Efficiency = 0.134
Part Quantity = 8
Assembly Time = 89.45 second
Assembly Cost = RM 0.07156 per second

New design: Design Efficiency = 0.564
Part Quantity = 5
Assembly Time = 26.6 second
Assembly Cost = RM 0.02128 per second

Software DFMA Analysis

Existing design: Design Efficiency = 0.1305
Part Quantity = 8
Assembly Time = 91.98 second
Assembly Cost = RM 0.09 per second

New design: Design Efficiency = 0.4507
Part Quantity = 5
Assembly Time = 33.28 second
Assembly Cost = RM 0.03 per second

Sample calculation

Percentage of Design Efficiency (manual)

$$= \frac{\text{new design efficiency} - \text{old design efficiency}}{\text{New design efficiency}} \times 100\%$$

$$= \frac{0.564 - 0.134}{0.564} \times 100\%$$

$$= \mathbf{67.2\ \%}$$

Percentage of Part quantity (software)

$$= \frac{\text{old design part} - \text{new design part}}{\text{Old design part}} \times 100\%$$

$$= \frac{8 - 5}{8} \times 100\%$$

$$= \mathbf{60\ \%}$$

Percentage of Assembly Time (manual)

$$= \frac{\text{old design assembly time} - \text{new design assembly time}}{\text{Old design assembly time}} \times 100\%$$

$$= \frac{89.45 - 26.6}{89.45} \times 100\%$$

$$= \mathbf{70.3\ \%}$$

Percentage of Assembly Time (software)

$$= \frac{\text{old design assembly time} - \text{new design assembly time}}{\text{Old design assembly time}} \times 100\%$$

$$= \frac{91.98 - 33.28}{91.98} \times 100\%$$

$$= \mathbf{63.82\ \%}$$

Percentage of Assembly Cost (software)

$$= \frac{\text{old design assembly time} - \text{new design assembly time}}{\text{Old design assembly time}} \times 100\%$$

$$= \frac{0.09 - 0.03}{0.09} \times 100\%$$

$$= \mathbf{66.67\ \%}$$

Table 7.1: Result of Manual Analysis

	Existing design	New design	Percentage
Design Efficiency	0.1305	0.564	67.20%
Part Quantity	8	5	60%
Assembly Time	89.45 second	26.6 second	70.3%
Assembly Cost	0.07156 cent/sec	0.02128 cent/sec	70.3%

Table 7.2: Result of Software Analysis

	Existing design	New design	Percentage
Design Efficiency	0.1305	0.4507	71.05%
Part Quantity	8	5	60%
Assembly Time	91.98 second	33.28 second	63.82%
Assembly Cost	0.09 cent/sec	0.03 cent/sec	66.67%

Base on calculation, the result had been containing for manual analysis, the percentage of design efficiency is 67.2 %, and for software analysis, the percentage of design efficiency is 71%. For percentage of part quantity, the result is 60% for both analyses. The result for percentage of assembly time is 70.3% for manual analysis and 63.82% for software analysis. Mean while the percentage of assembly cost is 70.3% for manual analysis and 66.7% for software analysis.

From the overall result, the result obtained in software and manual analysis was not much different. For example, in result of design efficiency, the different values in manual result and software result for existing design was not much different. For manual existing design efficiency the result is 0.134 and for software the result is 0.1305. Thus, DFMA Boothyord Dewhurst analysis is able to use either one, whichever would like to use manual or software analysis, because the result obtained was not much different.

7.3 Comparison of Existing Design and New Design

The new design is compared with the existing design in terms of the improvement in design of each part. In the comparison many parts can be reduce after analysis.

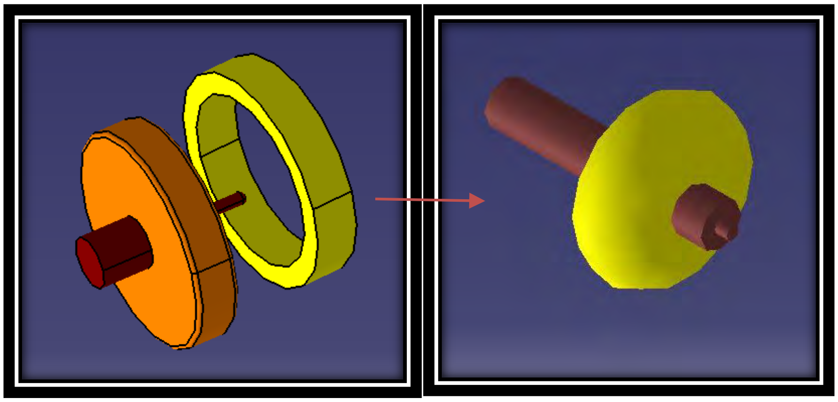


Figure 7.1: Improvement for Scroll Wheel

Figure 7.1 shows the improvement for the scroll wheel. For the new design, the part of scroll wheel comes out with one part. Compared with the existing design, the sub assembly of scroll wheel contains two parts which is scroll rubber and scroll wheel. In the new design scroll wheel, the scroll rubber was eliminated.

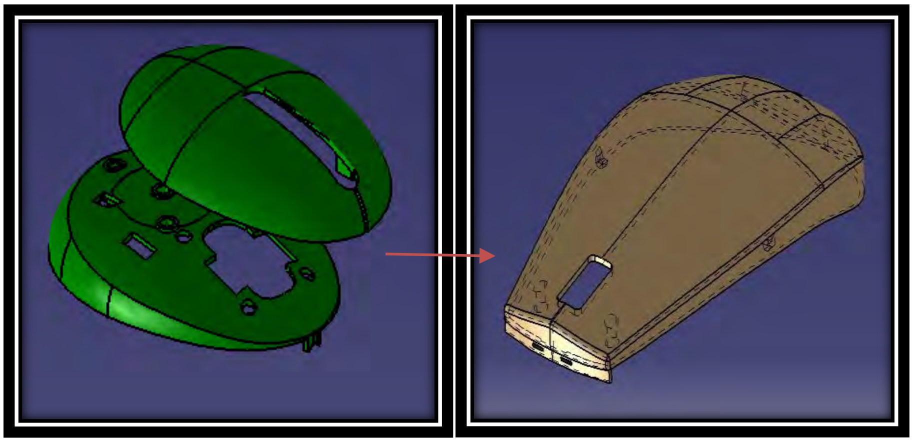


Figure 7.2: Improvement of Cover

For the cover, improvement for these parts are combined the top cover with middle cover. **Figure 7.2** shows the comparison between existing design top cover and new design top cover.

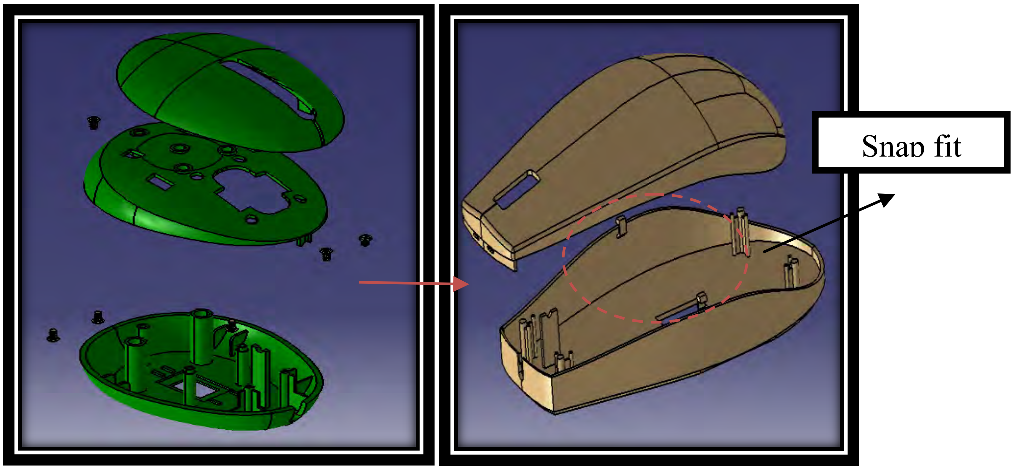


Figure 7.3: Improvement of Mechanism.

Figure 7.3 shows the improvement of the mechanism. For this improvement, the screw is eliminated and changed to a screw mechanism with a snap fit mechanism.

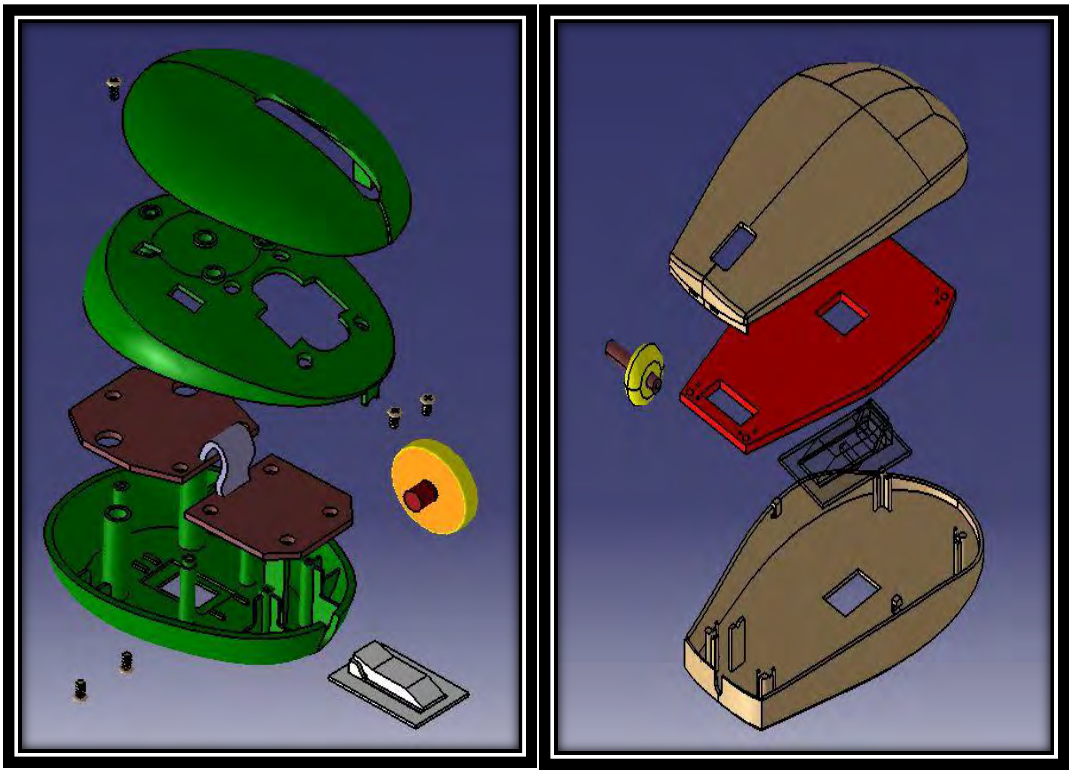


Figure 7.4: Exploded View for Compare of Number of Pars

Table 7.4 shows the comparison of the number of parts in existing design and new design. For new design, the number of parts was reduce is from 8 to 5 part.

CHAPTER 8

CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The Boothyord Dewhurst DFMA method is the systematic quantitative evaluation for design ease of assembly and manufacturing. The method applied the analytical evaluation on the each part where the product is involved. The classification of the parts characteristic well defined to generate a best redesign of product. However, the method does not have the evaluation on whole assembly sequence. Furthermore, there is no guideline on the re-design the product if the evaluation shows poor result. It is concluded that new design can be marketplace because it will give more profit to company because it has reduce time, cost and part.

In order to meet the objective of this project, many things need to be considered. The project has been divided into two parts, PSM I and PSM II. Part one is the process of preparing the project mission statement, project outline, research, dimension of optical mouse, detail design and lastly product presentation. The final design has been drawn by using CATIA V5R19 software. It provides a comprehensive overview of mechanical design that includes step-by-step instructions and helpful illustrations. The result of detailed design can be found in the Appendix. After finished with part one, part two which is PSM II was started by doing the calculation for DFMA manual method and DFMA software method. All the results from both methods are analyzed and comparisons are made. During the research, it is found that the DFMA software method is preferable to be used in industry since the design efficiency for this method is higher than DFMA manual method. The percentages for both design efficiencies are 67.20% for manual analysis and 71.05% for analysis using software. The objective of this project is achieved according to the result of the design efficiency, reducing the number of parts, and cost of production. This project has shown the correct method to design and analyze optical mouse using Boothroyd-Dewhurst DFMA methodology.

8.2 Recommendation

For the recommendation, the number of parts that needs to be analysed by computer aided DFMA analysis method should have limitation. Based on the analysis, as the part number increases, the human errors also increase because there are too many process selections need to be made in computer aided DFMA analysis method.

Besides, during the DFMA software analysis, there should be someone that specialises in material selection because the material selection in this process is one of the important things that should be considered. This is because material selection is an important element to determine the cost and the assembly time for the product.

For the future recommendation, the design can be improved by revaluating it using appropriates tools; either DFMA tools or other design tools. The method of evaluation needs consider the qualitative aspect. The methods should provide the evaluation of whole assembly sequences. The guide on redesign of the product should also be added in the future.

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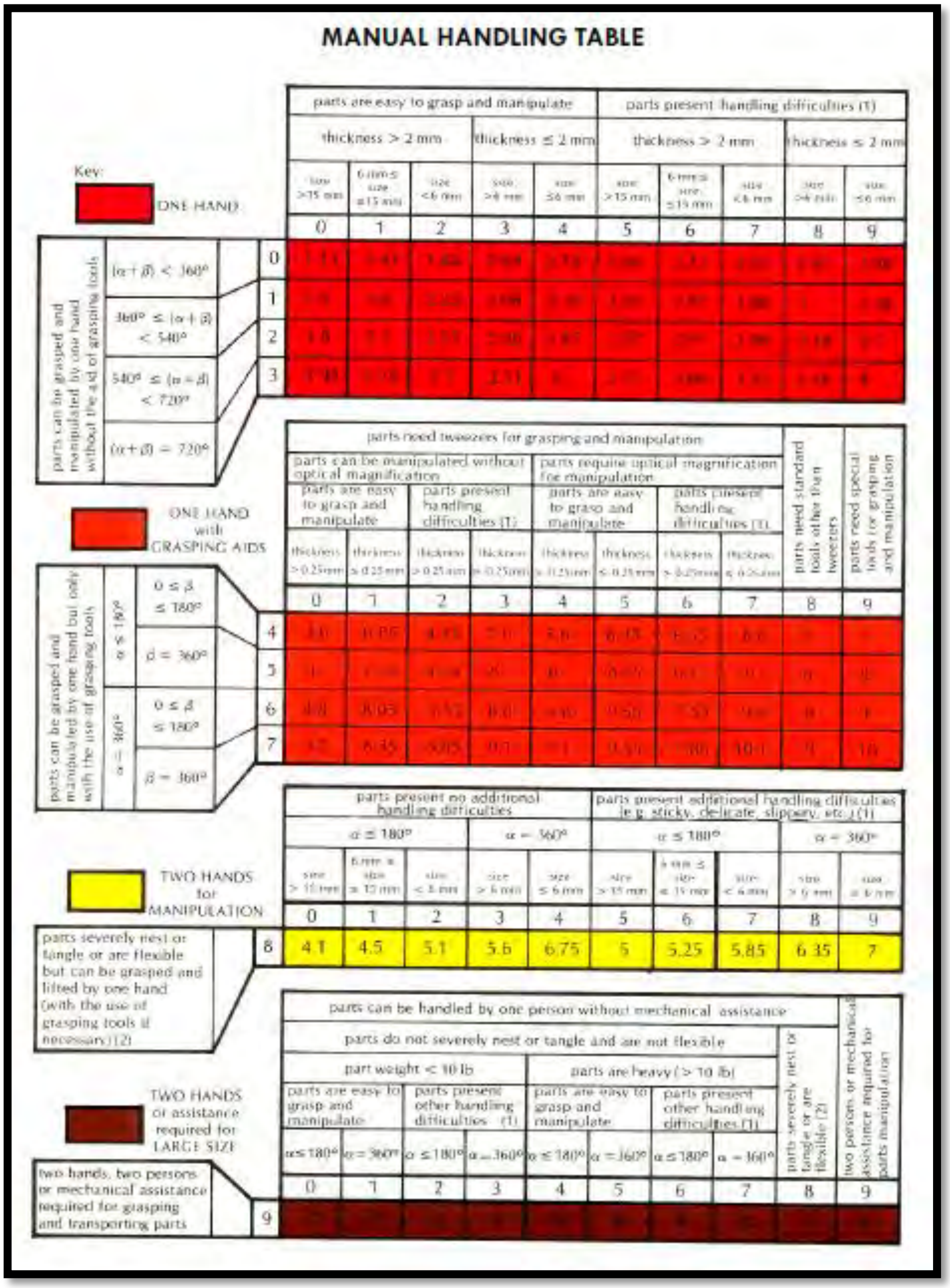
APPENDIXES

APPENDIX A1

Classification, coding, and database for feature on estimate for manual handling time



MANUAL HANDLING TABLE

Key:

🟥 ONE HAND

		parts are easy to grasp and manipulate					parts present handling difficulties (1)				
		thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
		size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
		0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of grasping tools	(α + β) < 360° 0	1.13	1.43	1.88	[illegible]	2.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	360° ≤ (α + β) < 540° 1	[illegible]	[illegible]	2.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	540° ≤ (α + β) < 720° 2	1.8	2.1	2.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	(α + β) = 720° 3	1.95	[illegible]	2.7	2.51	3	[illegible]	[illegible]	[illegible]	[illegible]	4

🟧 ONE HAND with GRASPING AIDS

			parts need tweezers for grasping and manipulation								parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
			parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
			parts are easy to grasp and manipulate		parts present handling difficulties (1)		parts are easy to grasp and manipulate		parts present handling difficulties (1)			
			thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm		
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α ≤ 180°	0 ≤ β ≤ 180° 4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	[illegible]	[illegible]
		β = 360° 5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	8
	α = 360°	0 ≤ β ≤ 180° 6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		β = 360° 7	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

🟨 TWO HANDS for MANIPULATION

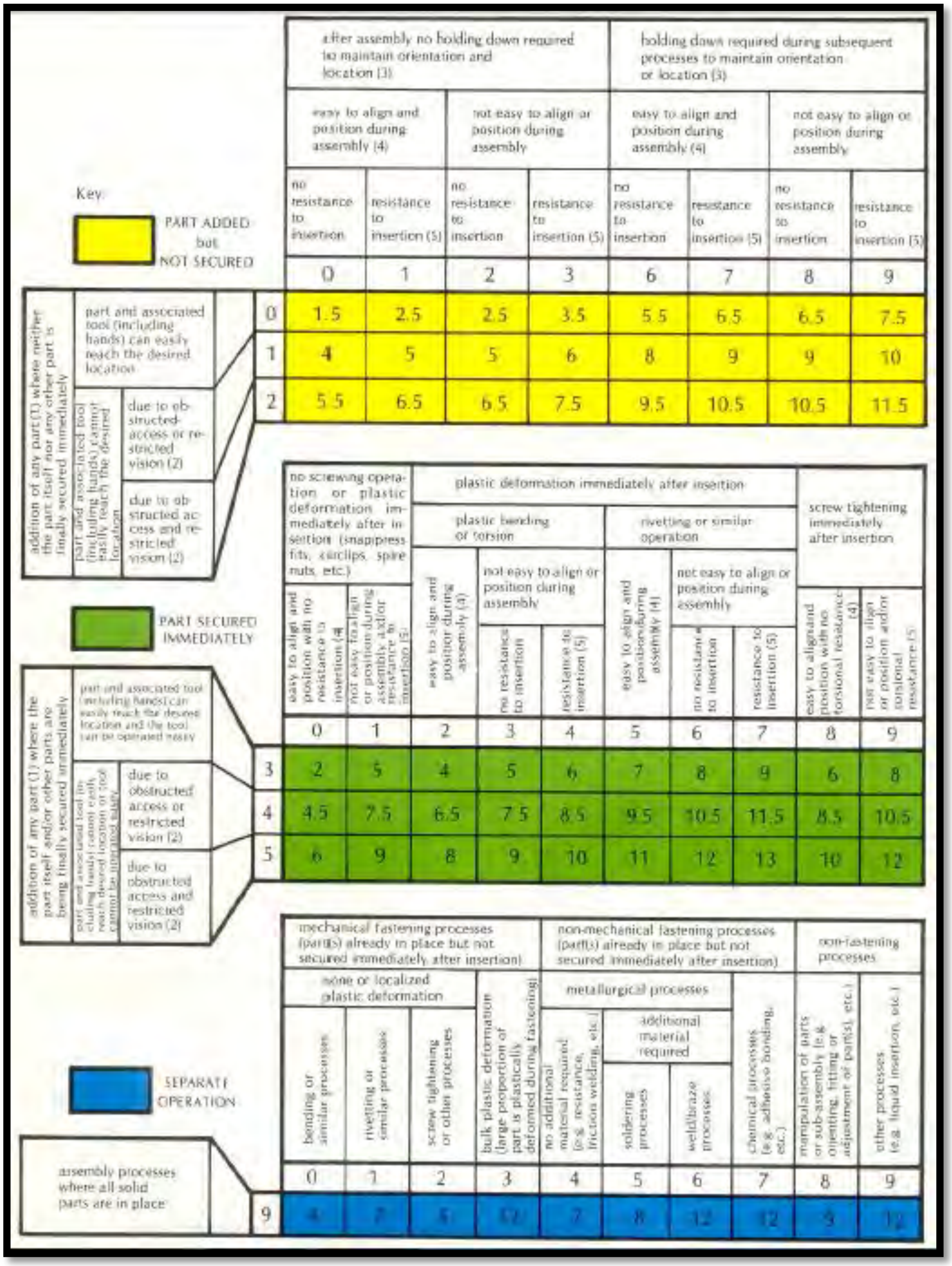
		parts present no additional handling difficulties					parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
		α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
		size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm
		0	1	2	3	4	5	6	7	8	9
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

🟫 TWO HANDS or assistance required for LARGE SIZE

		parts can be handled by one person without mechanical assistance									two persons or mechanical assistance required for parts manipulation
		parts do not severely nest or tangle and are not flexible								parts severely nest or tangle or are flexible (2)	
		part weight < 10 lb				parts are heavy (> 10 lb)					
		parts are easy to grasp and manipulate		parts present other handling difficulties (1)		parts are easy to grasp and manipulate		parts present other handling difficulties (1)			
		α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°	α ≤ 180°	α = 360°		
		0	1	2	3	4	5	6	7	8	9
two hands, two persons or mechanical assistance required for grasping and transporting parts	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX A2

Classification, coding, and database for feature on estimate for manual insertion times



Key:

🟨 PART ADDED but NOT SECURED

🟩 PART SECURED IMMEDIATELY

🟦 SEPARATE OPERATION

				after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
				easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
				no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
				0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location		0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location	due to obstructed access or restricted vision (2)	1	4	5	5	6	8	9	9	10
		due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

				no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
						plastic bending or torsion			rivetting or similar operation				
							not easy to align or position during assembly			not easy to align or position during assembly			
				easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
				0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily		3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily	due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
		due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

		mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation				metallurgical processes					
							additional material required				
		bending or similar processes	rivetting or similar processes	screw tightening or other processes	bulk plastic deformation (large proportion of part is plastically deformed during fastening)	no additional material required (e.g. resistance, friction welding, etc.)	soldering processes	weld/braze processes	chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	12	7	8	12	12	9	12

APPENDIX B1

Result for DFM analysis of existing design and new design by Software.

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 1:01 PM

N005 Top Cover.DFM

Part Name: Top cover

Part Number: N005

Process: Injection molding

Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.15	0.02	1.01	0.01	1.19	0.69	1.88	69,085

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 1:00 PM

N004 Scroll wheel.DFM

Part Name: Scroll Wheel

Part Number: N004

Process: Injection molding

Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.05	0.02	1.30	0.01	1.38	0.60	1.98	59,764

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 1:00 PM

N003 PCB Board.DFM

Part Name: PCB Board
Part Number: N003

Process: Injection molding
Material: Polypropylene

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.02	0.02	0.96	0.01	1.01	0.58	1.59	58,436

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:59 PM

N002 LED deflector.DFM

Part Name: LED Reflector

Part Number: N002

Process: Injection molding

Material: Polypropylene

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.02	0.02	1.14	0.01	1.18	0.72	1.90	71,682

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:57 PM

N001 Bottom cover.DFM

Part Name: Bottom Cover (N001)
Part Number: N001

Process: Injection molding
Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	**Setup**	**Process**	**Rejects**	**Piece part**	**Tooling**	**Total**	
100000	12500	0.14	0.02	1.01	0.01	1.18	0.66	1.84	66,269

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:12 PM

E008 Screw.DFM

Part Name: Screw
Part Number: E008

Process: Machined/cut from stock
Material: Generic high carbon steel

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.00	0.00	0.69	0.00	0.70	0.00	0.70	0

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:10 PM

E007 Top Cover.DFM

Part Name: Top Cover

Part Number: E007

Process: Injection molding

Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.23	0.02	1.43	0.01	1.70	0.73	2.42	72,682

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:10 PM

E006 Middlr Cover.DFM

Part Name: Middle Cover
Part Number: E006

Process: Injection molding
Material: ABS

Life volume	**Batch size**	**Cost per part, RM**							**Initial tooling investment**
		Material	**Setup**	**Process**	**Rejects**	**Piece part**	**Tooling**	**Total**	
100000	12500	0.30	0.02	1.83	0.02	2.16	0.53	2.70	53,421

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:08 PM

E005 Scroll Rubber.DFM

Part Name: Scroll Rubber

Part Number: E005

Process: Injection molding

Material: Polypropylene

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.02	0.02	1.49	0.01	1.53	0.82	2.35	81,877

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:07 PM

E004 Scroll Whell.DFM

Part Name: Scroll Wheel

Part Number: E004

Process: Injection molding

Material: Polyester (PBT)

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.11	0.02	1.57	0.01	1.71	1.08	2.79	107,789

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:06 PM

E003 PCB Board.DFM

Part Name: PCB Board
Part Number: E003

Process: Injection molding
Material: Polypropylene

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.04	0.02	1.67	0.01	1.75	0.77	2.51	76,503

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:59 PM N002 LED deflector.DFM

Part Name: LED Reflector
Part Number: N002

Process: Injection molding
Material: Polypropylene

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.02	0.02	1.14	0.01	1.18	0.72	1.90	71,682

DFM Concurrent Costing Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 12:57 PM

N001 Bottom cover.DFM

Part Name: Bottom Cover (N001)

Part Number: N001

Process: Injection molding

Material: ABS

Life volume	Batch size	Cost per part, RM							Initial tooling investment
		Material	Setup	Process	Rejects	Piece part	Tooling	Total	
100000	12500	0.14	0.02	1.01	0.01	1.18	0.66	1.84	66,269

APPENDIX B2

Result for DFA analysis of existing design and new design by Software.

Executive Summary - DFA

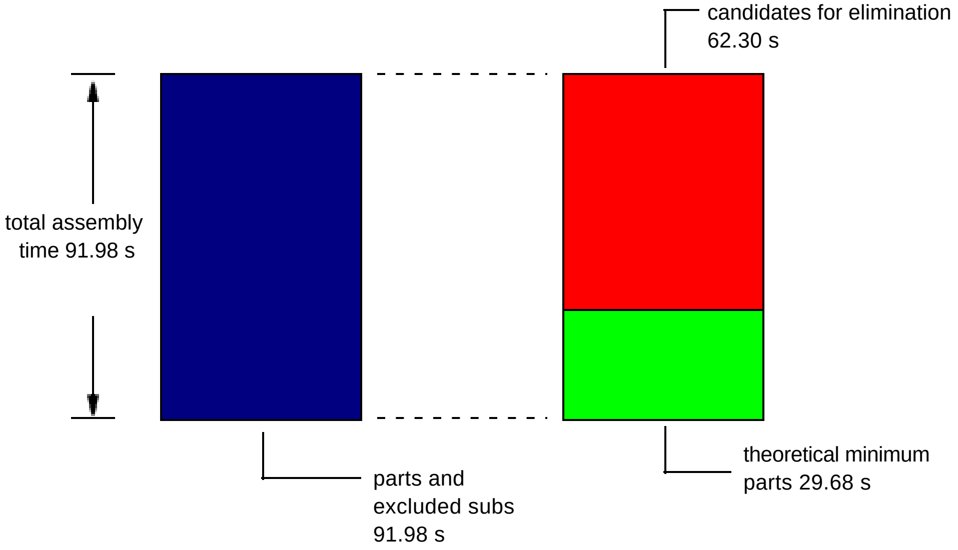
Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:39 PM
OPTICAL MOUSE

MOUSE.dfa
Product: Original

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, RM
Component parts	12	91.98	0.09
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	0	0.00	0.00
Totals	**12**	**91.98**	**0.09**

The chart shows a breakdown of time per product



Design for Assembly: Analysis Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:49 PM
NEW DESIGN MOUSE

MOUSE.dfa
Product: Original

Per product data

	Entries (including repeats)	Number of different parts	Total time, s	Labor cost, RM	Item costs (including tooling), RM	Weight, kg
Parts	5	5	33.28	0.03	9.20	0.05
Subassemblies:						
Partially or fully analyzed	0	0	0.00	0.00	0.00	0.00
Named only	0	0	0.00	0.00	0.00	0.00
Excluded	0	0	0.00	0.00	0.00	0.00
Operations:						
Standard	0	0	0.00	0.00	-	-
Library	0	0	0.00	0.00	-	0.00
Column Totals	**5**	**5**	**33.28**	**0.03**	**9.20**	**0.05**

Cost totals based on a product life volume of 10,000

	Labor cost, RM	Other operation cost, RM	Manuf. piece part cost, RM	Total cost without tooling, RM	Assy. tool or fixture cost, RM	Manuf. tooling cost, RM	Total cost, RM
Cost per product	0.03	0.00	5.94	5.97	0.00	3.25	**9.23**
Production life cost	313	0	59,431	59,744	0	32,523	**92,267**

DFA Index

Theoretical minimum number of items	5
DFA Index	44.0

Production data

Overall plant efficiency, %	85.00
Labor rate, RM/hr	2.88

Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

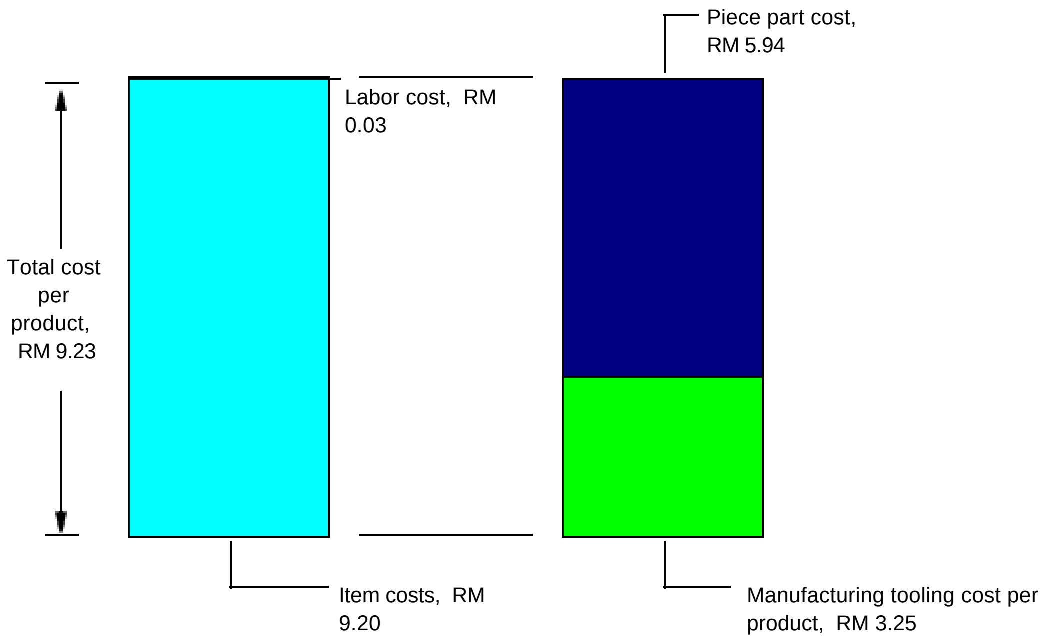
Monday, April 05, 2010 3:49 PM
NEW DESIGN MOUSE

MOUSE.dfa
Product: Original

Product life volume	10,000
Number of entries (including repeats)	5
Number of different entries	5
Theoretical minimum number of items	5
DFA Index	44.0
Total weight, kg	0.05
Total assembly labor time, s	33.28
Total cost for manufactured items (including tooling), RM	9.20

Total assembly labor cost, RM	0.03
Other operation cost per product, RM	0.00
Total manufacturing piece part cost, RM	5.94
Total cost per product without tooling, RM	5.97
Assembly tool or fixture cost per product, RM	0.00
Manufacturing tooling cost per product, RM	3.25
Total cost per product, RM	9.23

The chart shows a breakdown of cost per product



Executive Summary - DFA

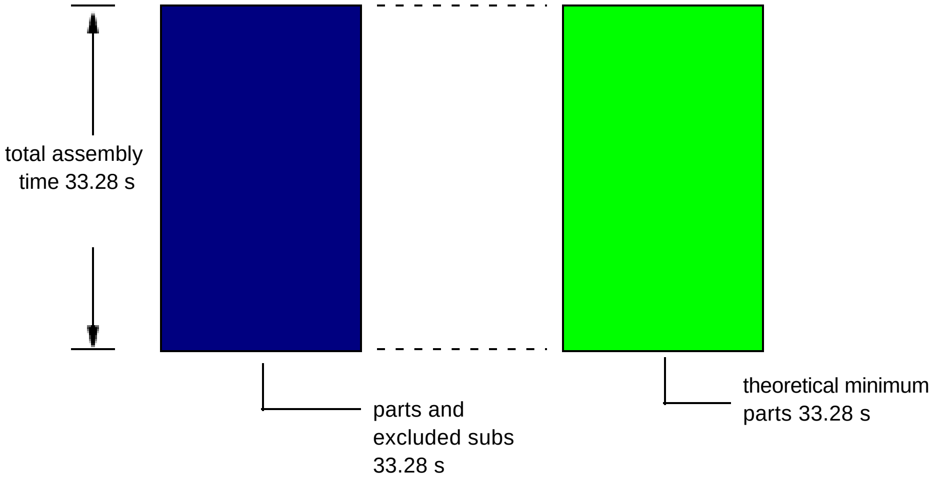
Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:49 PM
NEW DESIGN MOUSE

MOUSE.dfa
Product: Original

Per Product data	Entries (including repeats)	Labor Time, s	Labor Cost, RM
Component parts	5	33.28	0.03
Subassemblies partially or fully analyzed	0	0.00	0.00
Subassemblies not to be analyzed (excluded)	0	0.00	0.00
Standard and library operations	0	0.00	0.00
Totals	**5**	**33.28**	**0.03**

The chart shows a breakdown of time per product



Design for Assembly: Analysis Totals

Boothroyd Dewhurst, Inc.

Monday, April 05, 2010 3:40 PM
OPTICAL MOUSE

MOUSE.dfa
Product: Original

Per product data

	Entries (including repeats)	Number of different parts	Total time, s	Labor cost, RM	Item costs (including tooling), RM	Weight, kg
Parts	12	8	91.98	0.09	20.85	0.10
Subassemblies:						
Partially or fully analyzed	0	0	0.00	0.00	0.00	0.00
Named only	0	0	0.00	0.00	0.00	0.00
Excluded	0	0	0.00	0.00	0.00	0.00
Operations:						
Standard	0	0	0.00	0.00	-	-
Library	0	0	0.00	0.00	-	0.00
Column Totals	**12**	**8**	**91.98**	**0.09**	**20.85**	**0.10**

Cost totals based on a product life volume of 10,000

	Labor cost, RM	Other operation cost, RM	Manuf. piece part cost, RM	Total cost without tooling, RM	Assy. tool or fixture cost, RM	Manuf. tooling cost, RM	Total cost, RM
Cost per product	0.09	0.00	15.68	15.76	0.00	5.17	**20.94**
Production life cost	865	0	156,773	157,639	0	51,737	**209,376**

DFA Index

Theoretical minimum number of items	4
DFA Index	12.7

Production data

Overall plant efficiency, %	85.00
Labor rate, RM/hr	2.88

Executive Summary - DFMA

Boothroyd Dewhurst, Inc.

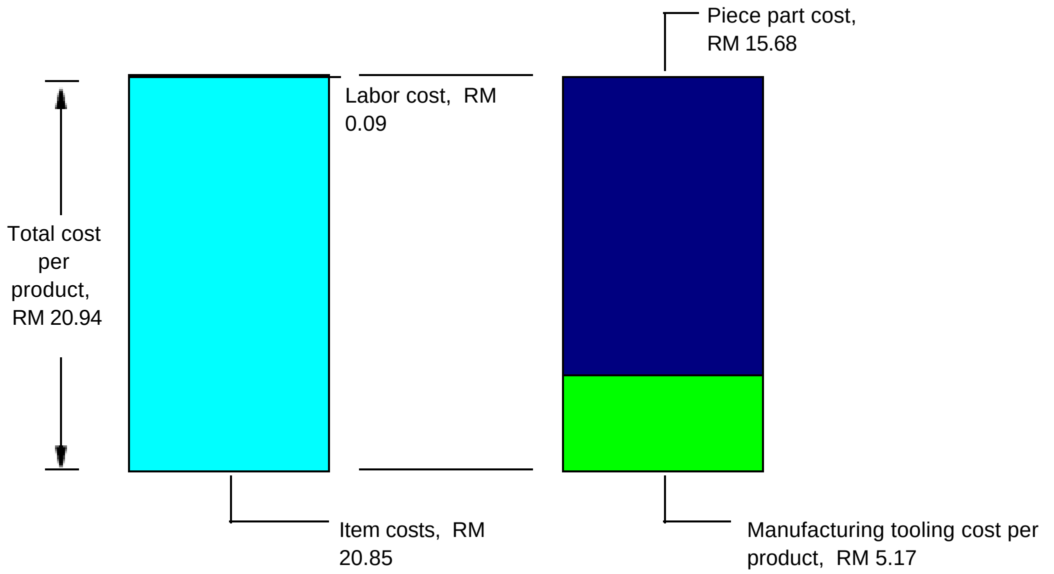
Monday, April 05, 2010 3:40 PM
OPTICAL MOUSE

MOUSE.dfa
Product: Original

Product life volume	10,000
Number of entries (including repeats)	12
Number of different entries	8
Theoretical minimum number of items	4
DFA Index	12.7
Total weight, kg	0.10
Total assembly labor time, s	91.98
Total cost for manufactured items (including tooling), RM	20.85

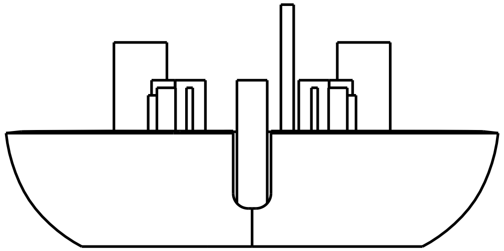
Total assembly labor cost, RM	0.09
Other operation cost per product, RM	0.00
Total manufacturing piece part cost, RM	15.68
Total cost per product without tooling, RM	15.76
Assembly tool or fixture cost per product, RM	0.00
Manufacturing tooling cost per product, RM	5.17
Total cost per product, RM	20.94

The chart shows a breakdown of cost per product

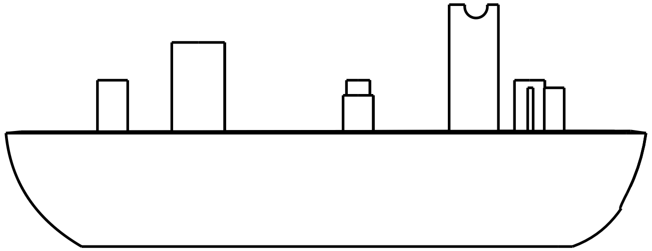


APPENDIX C1

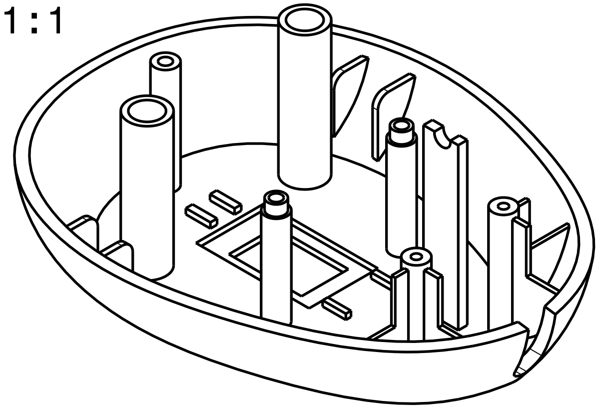
Detail drawing for existing design parts



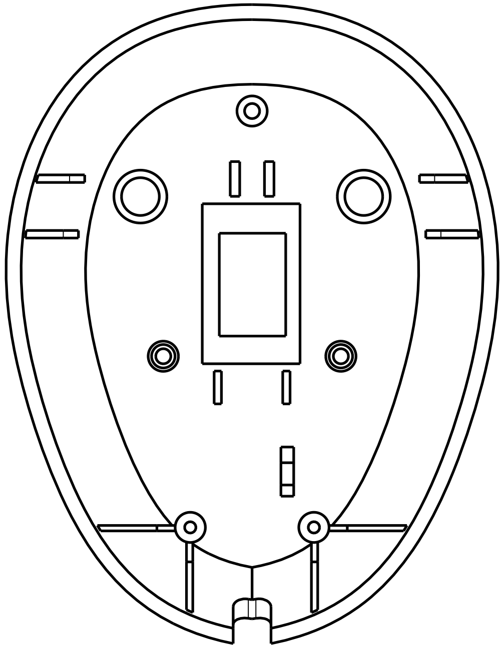
Front view
Scale: 1:1



Left view
Scale: 1:1



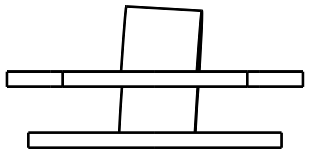
Isometric view
Scale: 1:1



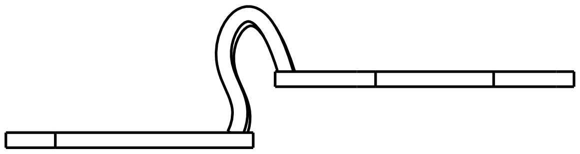
Top view
Scale: 1:1

DESIGNED BY: AIDIL DATE: 3/4/2010 CHECKED BY: EN SHAHFIZAL DATE: XXX		BOTTOM COVER (BASE)	
SIZE A4		EXISTING DESIGN	
SCALE	WEIGHT (kg) XXX	DRAWING NUMBER E001	SHEET 1/1

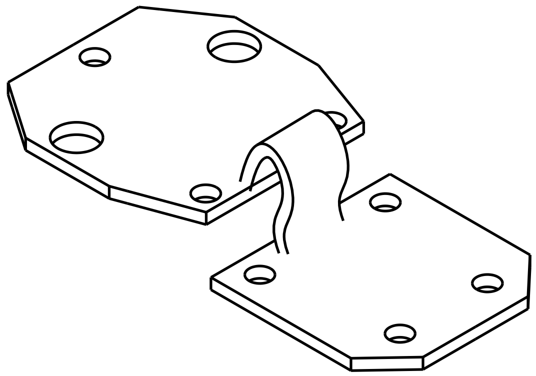
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



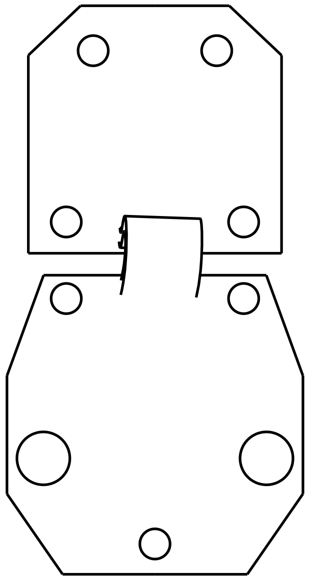
Front view
Scale: 1:1



Left view
Scale: 1:1



Isometric view
Scale: 1:1



Top view
Scale: 1:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

PCB BOARD

SIZE
A4

EXISTING DESIGN

SCALE

WEIGHT (kg)
XXX

DRAWING NUMBER
E006

SHEET
1/1

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I	_
H	_
G	_
F	_
E	_
D	_
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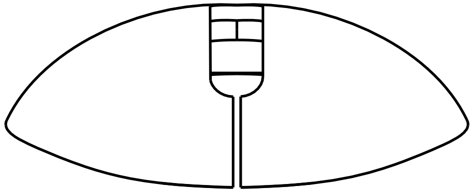
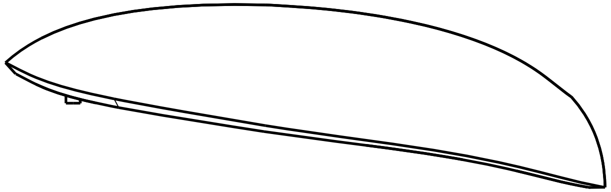
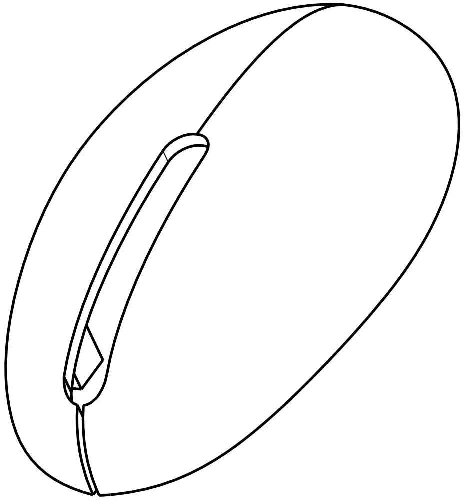
B	_
A	_



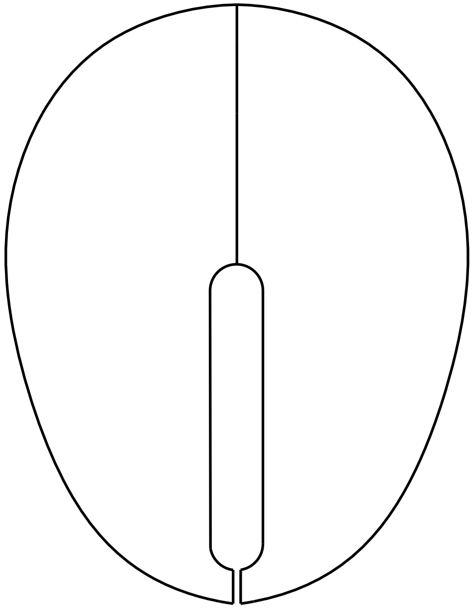
Front view
Scale: 1:1



Left view
Scale: 1:1



Isometric view
Scale: 1:1



Top view
Scale: 1:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

TOP COVER

SIZE
A4

EXISTING DESIGN

SCALE

WEIGHT (kg)
XXX

DRAWING NUMBER
E003

SHEET
1/1

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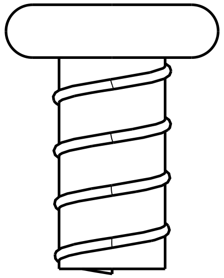
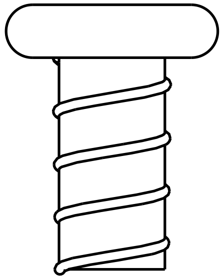
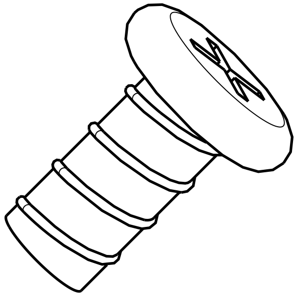
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



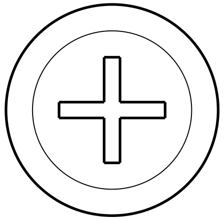
Front view
Scale: 7:1



Left view
Scale: 7:1



Isometric view
Scale: 7:1



Top view
Scale: 7:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX
SIZE
A4

SKRU

EXISTING DESIGN

SCALE
WEIGHT (kg)
XXX
DRAWING NUMBER
E007
SHEET
1/1

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

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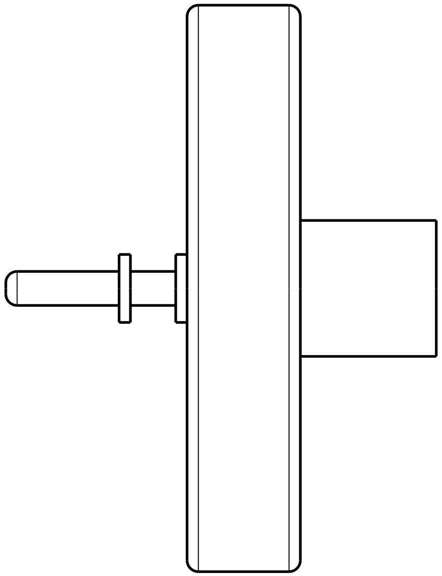
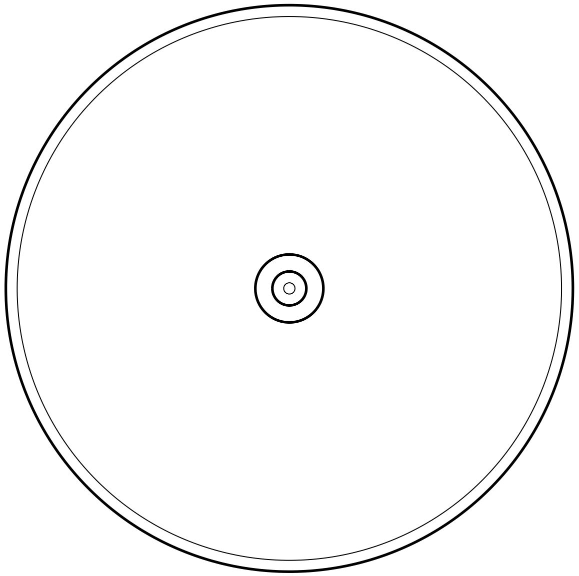
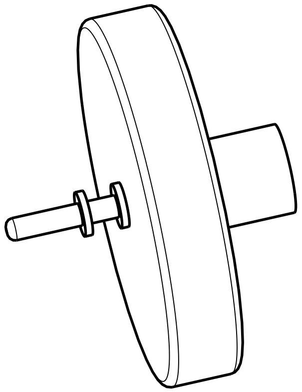


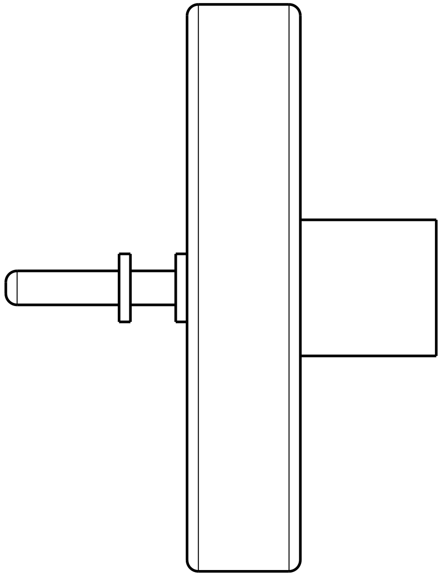
Front view
Scale: 3:1



Left view
Scale: 3:1



Isometric view
Scale: 2:1



Top view
Scale: 3:1

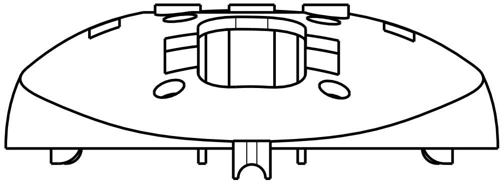
DESIGNED BY: AIDIL
DATE: 3/4/2010
CHECKED BY: EN SHAHFIZAL
DATE: XXX

SCROLL BUTTON

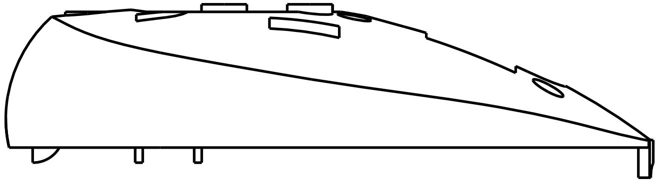
EXISTING DESIGN

SIZE: A4
SCALE:
WEIGHT (kg): XXX
DRAWING NUMBER: E005
SHEET: 1/1

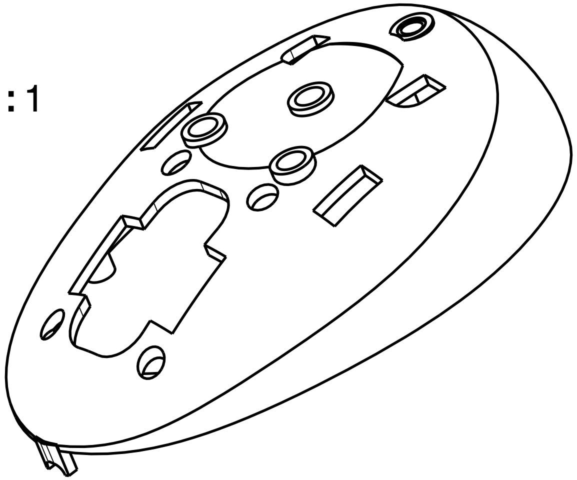
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



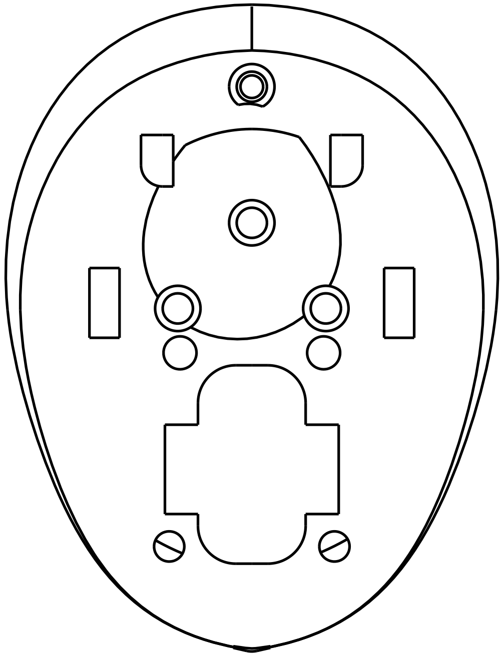
Front view
Scale: 1:1



Left view
Scale: 1:1



Isometric view
Scale: 1:1



Top view
Scale: 1:1

DESIGNED BY: AIDIL DATE: 3/4/2010 CHECKED BY: EN SHAHFIZAL DATE: XXX	MIDDLE COVER		I	_
			H	_
			G	_
			F	_
			E	_
SIZE A4	EXISTING DESIGN		D	_
SCALE	WEIGHT (kg) XXX	DRAWING NUMBER E002	SHEET 1/1	C _
			B	_
			A	_

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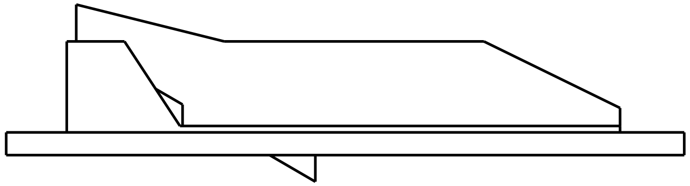
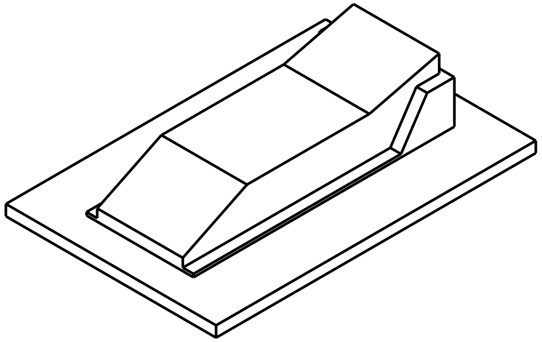
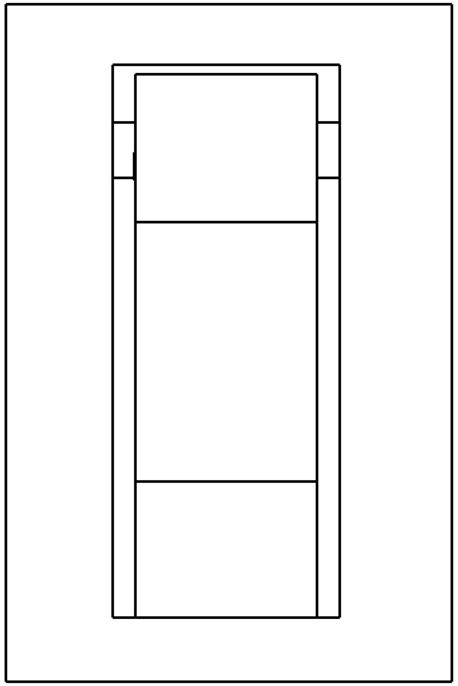
Front view
Scale: 3:1





Isometric view
Scale: 2:1

Left view
Scale: 3:1



Top view
Scale: 3:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

LED DIFFUSER

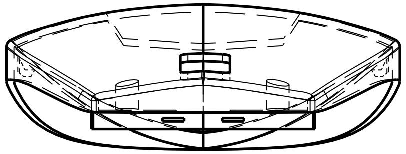
SIZE
A4

EXISTING DESIGN

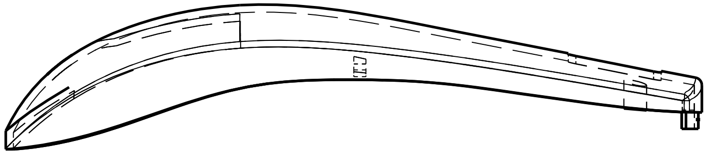
SCALE
WEIGHT (kg)
XXX
DRAWING NUMBER
E004
SHEET
1/1

APPENDIX C2

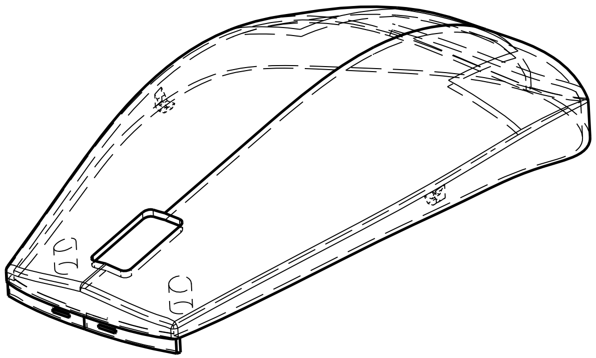
Detail drawing for new design parts



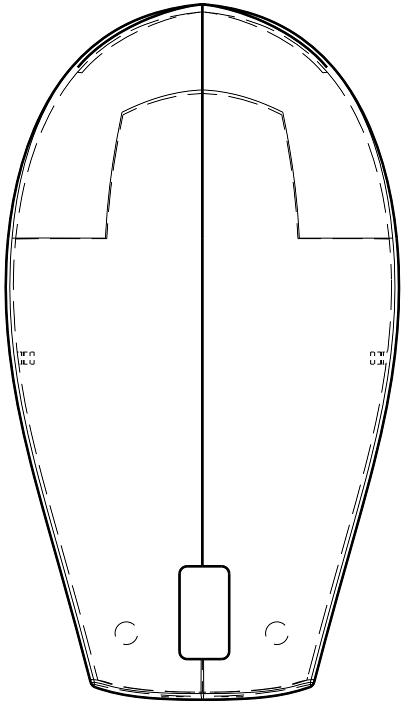
Front view
Scale: 1:1



Left view
Scale: 1:1



Isometric view
Scale: 1:1



Top view
Scale: 1:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

TOP COVER

SIZE
A4

NEW DESIGN

SCALE
WEIGHT (kg)
XXX
DRAWING NUMBER
OPTICAL MOUSE (REDESIGN)
SHEET
1/1

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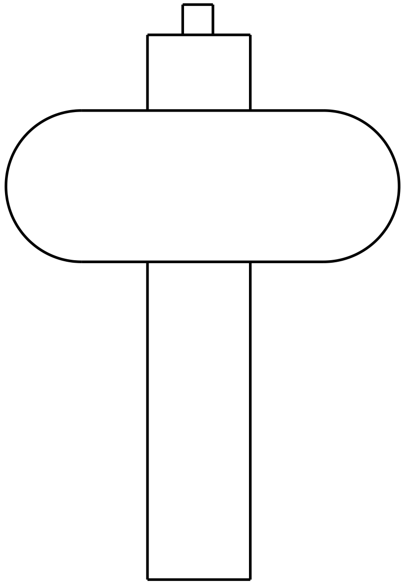
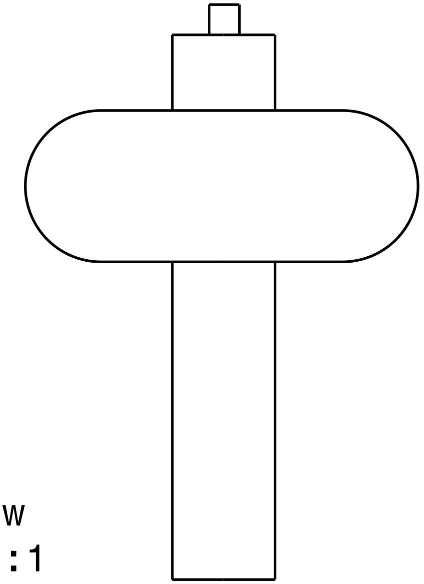
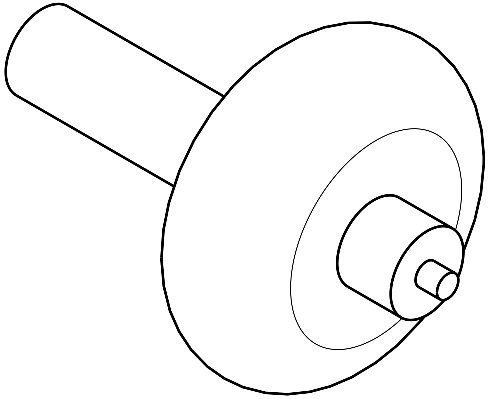
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



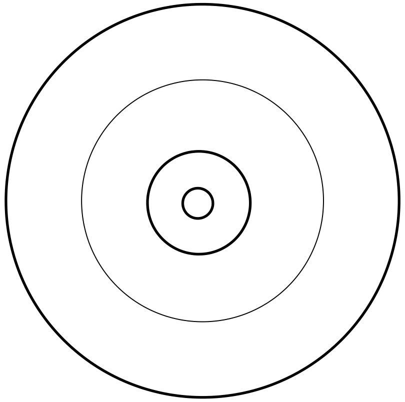
Front view
Scale: 4:1



Left view
Scale: 4:1



Isometric view
Scale: 4:1



Top view
Scale: 4:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX
SIZE
A4

SCROLL BUTTON

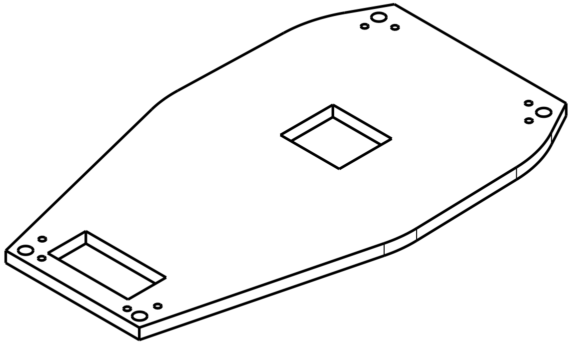
NEW DESIGN

SCALE
WEIGHT (kg)
XXX
DRAWING NUMBER
OPTICAL MOUSE (REDESIGN)
SHEET
1/1

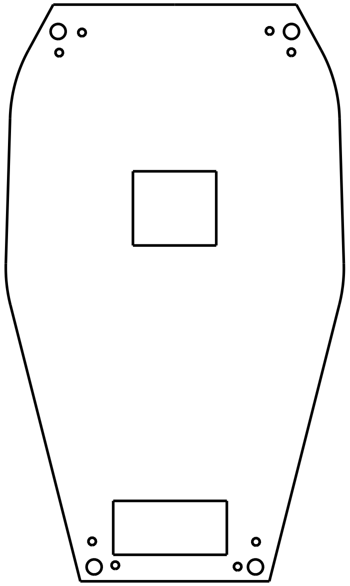
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

Front view
Scale: 1:1

Left view
Scale: 1:1



Isometric view
Scale: 1:1



Top view
Scale: 1:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

PCB BOARD

SIZE
A4

NEW DESIGN

SCALE

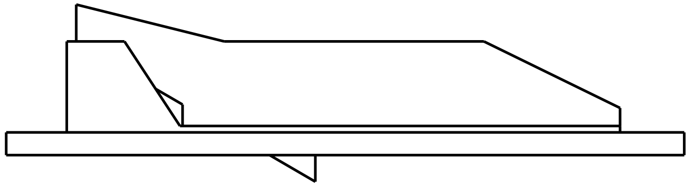
WEIGHT (kg)
XXX

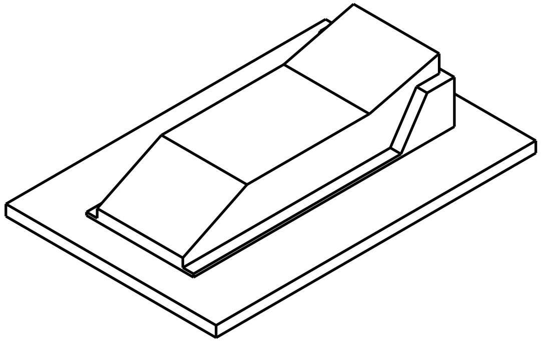
DRAWING NUMBER
OPTICAL MOUSE (REDESIGN)

SHEET
1/1

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

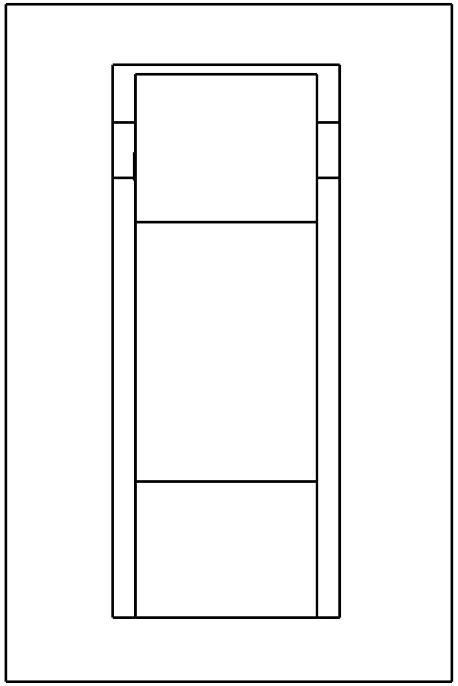
Front view
Scale: 3:1





Isometric view
Scale: 2:1

Left view
Scale: 3:1



Top view
Scale: 3:1

DESIGNED BY:
AIDIL
DATE:
3/4/2010
CHECKED BY:
EN SHAHFIZAL
DATE:
XXX

LED DIFFUSER

SIZE
A4

NEW DESIGN

SCALE

WEIGHT (kg)
XXX

DRAWING NUMBER
OPTICAL MOUSE (REDESIGN)

SHEET
1/1

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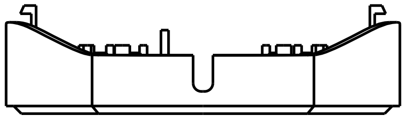
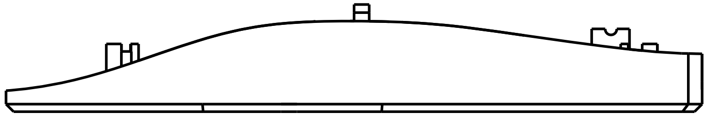
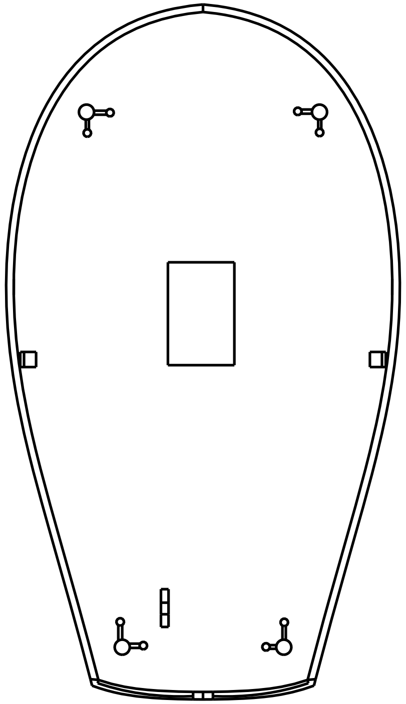
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



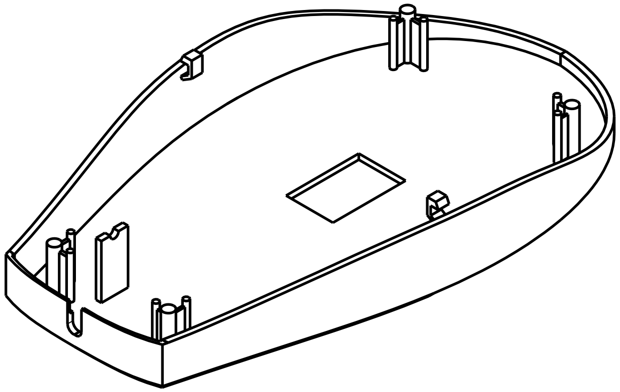
Front view
Scale: 1:1



Left view
Scale: 1:1



Top view
Scale: 1:1



Isometric view
Scale: 1:1

DESIGNED BY: AIDIL
DATE: 3/4/2010
CHECKED BY: EN SHAHFIZAL
DATE: XXX

BOTTOM COVER (BASE)

SIZE: A4
NEW DESIGN
SCALE:
WEIGHT (kg): XXX
DRAWING NUMBER: OPTICAL MOUSE (REDESIGN)
SHEET: 1/1

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

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PSM II Gantt Chart

	WEEK													
SUBJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Proceed the Project as planned	■	■	■											
Detail drawing using CATIA				■	■									
Manual analysis DFMA						■	■	■						
DFMA Software analysis									■	■				
Comparison between manual with software DFMA and existing design with new design											■	■	■	
Prepare the full report											■	■	■	■

PSM I Gantt Chart

SUBJECT	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Select title for the project	■													
Supervisor Agreement		■	■											
Understand the Scope of the Project			■	■										
Search Information					■	■	■							
Discuss with Supervisor						■	■	■	■					
Study the Concept									■	■				
Literature Review									■	■				
Methodology										■	■			
Writing Report										■	■	■		
Submit the Report												■		
Seminar														■