DEVELOPMENT OF A FRAMEWORK FOR IMPLEMENTING DESIGN FOR ASSEMBLY (DFA) IN SMALL AND MEDIUM SIZED INDUSTRIES (SMIS)

(PEMBANGUNAN SEBUAH RANGKA KERJA PERLAKSANAAN REKABENTUK UNTUK PEMASANGAN DALAM INDUSTRI KECIL DAN SEDERHANA (IKS)

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2003

Lampiran 20

UTM/RMC/F/0024 (1998)

UNIVERSITI TEKNOLOGI MALAYSIA

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TAJUK PROJEK : THE DEVELOPMENT OF A FRAMEWORK OF DESIGN FOR ASSEMBLY (DFA) IN SMALL AND MEDIUM SIZED INDUSTRIES (SMIs)

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ACKNOWLEDGEMENT

First and foremost, gratitude to the research team members- Prof. Dr. Awaluddin Bin Mohamed Shaharoun and Dr Masine Bte Md Tap for their constructive idea and full commitment. Their participations have contributed to the success of the project.

The gratitude is also to the company under project for giving us the privilege to conduct the case studies. Appreciation is extended to its top-level management, especially Tn Hj. Salleh Yahaya, Mr. Pakarudin Musa and Mr Zawawi Ibrahim, for their co-operation and hospitality during the course of conducting the case studies.

Last, but not least, the acknowledgement goes to our family for their support and encouragement. Without their support, inspiration and sacrifice, the project work would never have been completed.

ABSTRACT

DEVELOPMENT OF A FRAMEWORK FOR IMPLEMENTING DESIGN FOR ASSEMBLY (DFA) IN SMALL AND MEDIUM SIZED INDUSTRIES (SMIs)

(Keywords: DFA, Product development stages, IDEF-0, TeamSET software)

Design For Assembly (DFA) is a well-known technique, but little published work exists for its detailed implementation. This research has developed a DFA framework suitable for implementation in Small and Medium Sized Industries (SMI). A survey of design practices in Malaysia revealed that there were about five different types of practices involved in product development in Malaysia. Some problems in implementing DFA were also reported by users or potential users in the survey. For the purpose of research, a case study on an SMI company making automotive parts was used. A proposed framework was developed in which the product development cycle was outlined in detail and various stages were identified in which DFA could be implemented. To assist in the implementation, IDEF0 modeling methodology was used to model the functions and information flows of the DFA activities and its relation to other functions of the product development cycle. Project phases for DFA implementation were also proposed to help managers plan and execute the DFA implementation program. A DFA software was also used to evaluate a typical automotive part in order to demonstrate the feasibility of further product design improvement. The research concludes that the framework is generic, flexible and offers a significant improvement to managers and engineers who wish to implement DFA within their product development operations successfully.

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ABSTRAK

Design For Assembly (DFA) merupakan satu teknik yang telah dikenali untuk mengurangkan kos dan masa pemasangan tetapi tidak banyak terbitan penyelidikan yang memperincikan perlaksanaan tersebut. Penyelidikan ini membina satu rangka kerja yang sesuai untuk perlaksanaan DFA dalam Industri Kecil Dan Sederhana (IKS). Satu tinjauan dibuat menunjukkan terdapat lima jenis amalan yang terlibat dalam pembangunan produk di Malaysia. Maklum balas terhadap masalah perlaksanaan DFA dinyatakan dalam tinjauan tersebut. Untuk tujuan penyelidikan, satu kajian kes terhadap sebuah kilang membuat bahagian automotif dijalankan. Satu rangka kerja perlaksanaan dibangunkan dengan mengambil kitaran pembangunan produk sebagai panduan asas atau garis kasar. Beberapa peringkat pembangunan produk yang sesuai untuk perlaksanaan DFA dicadangkan. Untuk membantu perlaksanaan tersebut, metodologi permodelan IDEF0 digunakan untuk memodelkan fungsi dan aliran maklumat aktiviti DFA, seterusnya menunjukkan kaitannya dengan fungsi lain dalam kitaran pembangunan produk. Satu fasa projek perlaksanaan DFA dicadangkan sebagai panduan untuk membantu pengurus merancang dan sebagai persediaan menggunakan program DFA. Perisian DFA digunakan untuk membuat penilaian terhadap kajian kes produk automotif. Ini bertujuan untuk menunjukkan bagaimana DFA dinilai dan rekabentuk semula boleh dibuat. Penyelidikan ini menyimpulkan bahawa rangka kerja yang dicadangkan adalah umum, fleksibel dan menjanjikan satu kaedah pembaikan kepada pengurus dan jurutera yang berhasrat untuk melaksanakan DFA dengan jayanya.

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GLOSSARY

Assembly analysis	-	Analysis to simplify an assembly due to rework and product failures.
Assembly planning	-	Planning that considers the selection of assembly techniques and production equipment in terms of assembly rates, model mix and critical assembly steps
Assembly system design	-	Design of parts fitting, assembly sequence problems, task assignment and system layout.
Design manual	-	A manual that consists of data sheets, fact sheets and general information sheets on design topic.
Design changes	-	Changes required in a design after some test or evaluation.
DFA report	-	A report consisting of the results of functional analysis, handling analysis, assembly analysis and assembly planning (shown as an assembly flowchart) and part list.
Final report	-	A report that includes all the technical drawings, part lists, process planning report, problems and solutions. As a guideline for the future project or if any design changes are required.
Functional analysis	-	An analysis which is done to determine which components are essential and which are not based on the product failures.
Handling analysis	-	An analysis which is done to simplify the handling and orientation required for assembly which gives the rate of he handling of the individual components from bulk to point of assembly.
Hard Prototype	-	Prototype which is produced by using hard tooling. Normally, done in the detail design stage.
Hard tooling	-	Tool which is produced by using metal - that will be used for prototype fabrication and actual production.

IDEF0 - *I*ntegrated *Def*inition, a modeling tool for modeling functions and information flow of a system and is one of the Structured Analysis Design Technique.

Master schedule - a schedule showing the activities involved in completing a product including the parties involved.

Model changes - changes made to the design of a product .

Operating manual - a manual that provides guidelines for the operation of a product.

Process planning report - a report on how to process a part and may include a process flow chart.

Product design data - a data/ report that consists of product structure, part list, assembly plan, design review report, feasibility review report, material specification and design specification. It also included the new equipments, tooling and facilities requirement .

Product development stage/ cycle - the cycle involved in the design and development of a product, including manufacture. It consists of project agreement, ideas generation, perform conceptual design and detail design, perform pre- production and finally production .

Product specification - a specification that describes a product in detail. It depends on the parameters or constraints of the product functions and requirements.

Product Standard - a standard that describes the product based on national standard or international standard, such as BS (British Standard) and MS (Malaysian Standard).

Project brief - a report on a design of a product, which includes customer requirements , policies, objectives of the project , control procedures and quality standards.

Quality assurance - a written statement that assures all the planned and systematic activities are implemented within the quality system.

Quality control	- activities that are concerned with the inspection of the operations and activities that are used to fulfill the requirement for quality.
Route sheet	- a sheet that describes the operation, machine type, tooling and supplies, set up time and operation time.
Soft prototype	- the prototype which is produced by using soft tooling. Normally, done in the conceptual design.
Soft tooling	- tool which is produced by using epoxy, wood, plastic- This will be used for small batch production and is easily damaged after a few production runs.
Styling surface data	- a digitized data of the contour or shapes of a product's surface. Usually a probe is used for this purpose.

ABBREVIATIONS

ADAM	-	Assisted Design For Assembly And Manufacture
AEX	-	Assembly Expert
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CE	-	Concurrent Engineering
CMM	-	Coordinate Measurement Machine
DBMS-	-	Database Management Information System
DE	-	Design Engineer
DFA	-	Design For Assembly
DFM	-	Design For Manufacture
IDEF0	-	Integrated Definition
ME	-	Manufacturing Engineer
PDS	-	Product Design Specification
PE	-	Production Engineer
PIC	-	Person In Charge
PM	-	Project Manager
PPCE	-	Product Planning and Control Engineer
Prototype E	-	Prototype Engineer
QE	-	Quality Engineer
SADT	-	Structured Analysis Design Technique
SMI	-	Small and Medium Sized Industry
SMIDEC	-	Small and Medium Industries Development Corporation
SOP	-	Standard Operating Procedure
TE	-	Tooling Engineer
TQM	-	Total Quality Management
UK	-	United Kingdom
US	-	United States
VE	-	Value Engineering
WIP	-	Work In Progress

CHAPTER I

INTRODUCTION

1.1 Introduction

This chapter provides a general description of the whole project. It discusses the background to the problem, problem statement, research objectives, scope of study, research methodology, importance of project and project organization.

1.2 Project Background

The design of products is one of the most important decisions in manufacturing organizations. It entails four basic decisions (Youssef, 1994):

a) What to design (the product)?

b) Who is going to design it (the team)?

c) How is it going to be designed (the design method)?

d) What technologies will be used in the design process (the tools)?

These decisions are basic and affect almost all functions of manufacturing as well as the financial performance of the firm.

In manufacturing, the product design process is traditionally viewed as a sequential process centered within each related department with little outside influence. The product cost is therefore unavoidably increased owing to insufficient communication and consultation among all departments involved (Wu et. al , 1995). The product development process is broken down into a series of activities or steps (Durand, 1995; Miles and Swift, 1998). Each step must be completed before the next one begins (Youssef, 1995). This means that the traditional approach has design engineers working in isolation in designing new products, and once the product is designed, the design is turned over to manufacturing to be produced according to the design specifications (Dean and Salstrom, 1990). Boothroyd and Dewhurst (1988) believed that this involved an attitude of 'we design it; you build it' and termed it as an "over the wall approach" (Boothroyd and Dewhurst, 1988; Carter and Baker, 1992).

Some of the problems faced in adopting this approach are:

i) The lead time from start to finish is very long and costly (Nevins and Whitney, 1989; Boothroyd and Alting, 1992).

ii) Product functionality is good but from the manufacturing point of view, there might be serious shortcomings, caused by the lack of manufacturing considerations in the product specification (Hartley, 1986; Gupta, et. al, 1994)).

iii) A delay in one of the activities will affect the next activity. For example, a delay by the designers may cause a very tight schedule for manufacturing to produce on time (Munro, 1994).

iv) Products are difficult to service, use or sell and less emphasis is put in the development of robust functionality and design for producibility (Huang and Mak, 1998a).

There are many different ways in which the companies can improve their manufacturing function in order to enhance their competitive advantage. For example, by reducing lead time and cost , reducing assembly time and cost and improving performance. Some of the tools that have been deployed are Concurrent

Engineering, Just in Time, Value Engineering, Group Technology and Design For Assembly.

In this project, Design For Assembly is chosen as a method to reduce product development time and cost. In particular, it looks at how DFA can be implemented in Small and Medium Sized Industries in order that these industries (which constitute more than three quarters of manufacturing industries) can also benefit from shortened product development time to increase their competitive advantage.

1.3 Problem Statement

Although a lot of work (Dean and Slastrom, 1990; Holbrook and Sackett, 1990; Rampersad, 1995; Genc, et. al, 1998; Miyakawa,et. al, 1990) have been done in the development and implementation of DFA framework, most of these DFA implementation frameworks are designed for large companies. There are a few frameworks which were proposed for Small and Medium Sized Industries (SMIs), but it must be noted that each framework was applied in a different culture. For example, Wu et. al (1995) implemented a framework for SMIs in Hongkong while Haynes and Frost (1994) studied DFA implementation in the United States. As yet in Malaysia, there has been no previous research conducted on the development of a DFA implementation framework for SMIs. There is a need to first of all determine the nature and type of design activities and functions being carried out by SMI companies in Malaysia. Individual companies in Malaysia may have to work together in developing a product from initial design to finished product (such as the vendor, subcontractor, technical partner and manufacturer). Each has a specific role in the product development and a good information flow between them is necessary to make this linkage work.

There are many manufacturing companies in Malaysia who do not design their own products. Usually the product design comes from Original Equipment Manufacturers (OEM) in other countries such as Japan, United States or United Kingdom. However, for manufacturing companies who do their own design, it is important for them to be able to design and then manufacture these products in the most effective manner. Thus, it is important for these companies to integrate design and manufacture. In Malaysia, companies are also not fully aware of the benefits of such integration and there are few local resource centres available for them to seek consultation. To propose a framework that integrates design and manufacture would require a study of the present practice in industries and the effectiveness of the implementation. No such field studies has been documented so far.

It is therefore timely and appropriate for a DFA approach to be formally proposed and implemented to assess its feasibility and consequently to develop a general implementation framework. The research will be useful for Small And Medium Sized Industries (SMIs) in Malaysia to become more competitive.

1.4 Project Objectives

The objective of this project is to propose a framework for the implementation of DFA for Small And Medium Sized Industries (SMIs) in Malaysia. The specific objectives are:

i) To assess the current state and extent of interaction between design and manufacturing in SMIs in Malaysia.

ii) To develop practical guidelines in implementing DFA.

1.5 Scope Of Project

- The project will only cover the development of an implementation framework of DFA in Malaysian SMIs.
- Only one company will be used as a case study example.
- An automotive company is selected for the case study .
- The study will develop the theoretical framework but will not cover the actual implementation process nor do any post-implementation evaluation.

1.6 Methodology of The Project

The project methodology is shown in Figure 1.1. It is carried out according to the following section:

Literature study is done to study the current research in DFA. The existing DFA framework is also studied to identify factors that need to be considered in developing the proposed DFA framework. A conceptual framework is developed based on the literature study. This will serve as an initial preparation for the implementation of DFA.

A survey is carried out to identify the nature of the design practice in the companies, to identify to what extent DFA is being applied in Malaysian industries and to identify the problems companies faced in using DFA method .

A company was selected as a case study . By examining the activities involved in the case study company and the relationship with the parties involved, a general framework was developed. For a value added, an analysis was done to a

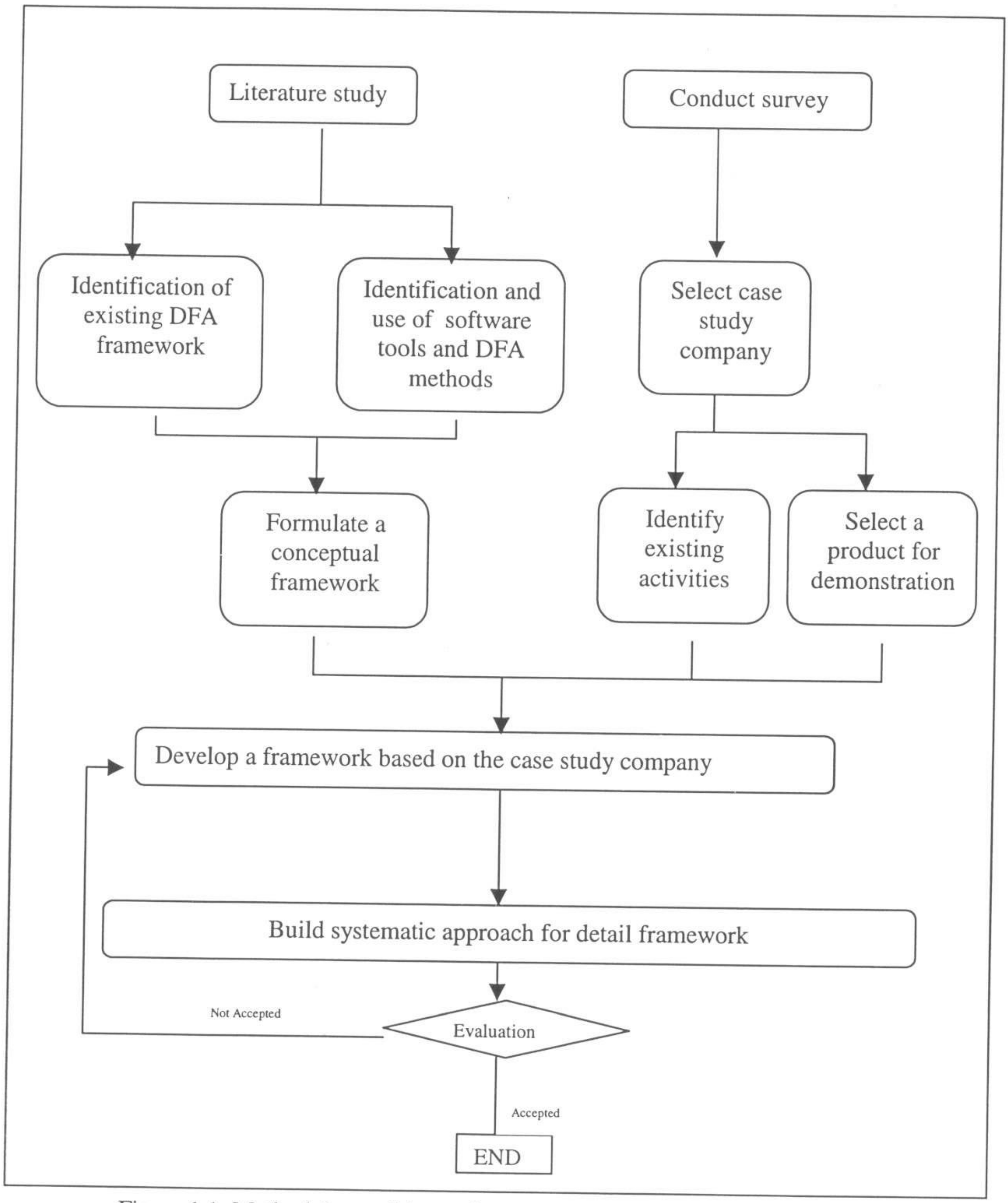


Figure 1.1: Methodology of the project.

selected product from the company. For that purpose, a DFA software was selected and used to evaluate an existing product design in the company. The aim is to demonstrate its potential for improvement.

Based on the results of the steps above, a proposed framework was built. The framework must be detailed enough for the company to use. It will be as a guideline or useful teaching and instructional tool to the company staff in understanding how the implementation can be carried out. A Structured Analysis Design Technique (SADT) software tools was identified as the systematic approach used for this research.

Finally, validation was done through discussions with DFA expert and the persons responsible in the case study company.

1.7 Significance Of The Project

DFA is a method that reduces time and cost by reducing the number of parts and ease of assembly. However, available guidelines for the implementation of DFA are mostly designed for large companies. Guidelines for SMIs are rare and not detail enough to ease implementation.

This research will develop the framework for DFA implementation. A suitable DFA framework is important as a guideline to shorten the product development time and increase competitive advantages. The design practice is an important factor to be considered in developing an appropriate framework because it involves a complex flow of design information and requirements. However, existing frameworks do not considering this factor.

A survey will be conducted to identify the current design practice in Malaysia and to identify the problem faced by companies wishing to implement it. The survey also aims to identify the level of DFA awareness and DFA tools employed by companies.

CHAPTER II

SURVEY ON DFA

2.1 Introduction

This chapter reports on the survey conducted to assess the implementation of DFA in Malaysia. This forms an initial study for the research.

2.2 Survey Background

The aim of this survey is to identify the extent of DFA application in Malaysian industries and the nature of problems that companies faced in using DFA. For companies who do not use DFA, the survey tries to identify the reasons why this is so. It is also desirable to establish the different types of design practice currently used in industries with the intention of relating it with DFA implementation. The questionnaires was mainly targeted at industries that are involved in product assembly.

The questionnaire was sent to 200 companies in Malaysia. However, only 38 responses were received (a response rate of 19%). Among them, 32 completed the questionnaires and were included in the analysis. 6 responses were either incomplete or found to be not related to the survey and were subsequently rejected.

Questionnaires were sent to and completed by senior personnel in the company such as Managing Directors, R&D Managers, General Managers, Design Engineers and Manufacturing Engineers.

2.3 The Development Of Questionnaire

The questionnaire is divided into four parts with 52 questions. (refer to Appendix A.1):

i) Part A- Company Profile
ii) Part B- Product Design and the activities
iii) Part C- for the company which implement DFA
iv) Part D- for the company which do not implement DFA

Three types of questions have been considered:

i) Objective questions
ii) Weighted questions
iii) Subjective questions

Figure 2.1 shows the flow chart of the survey.

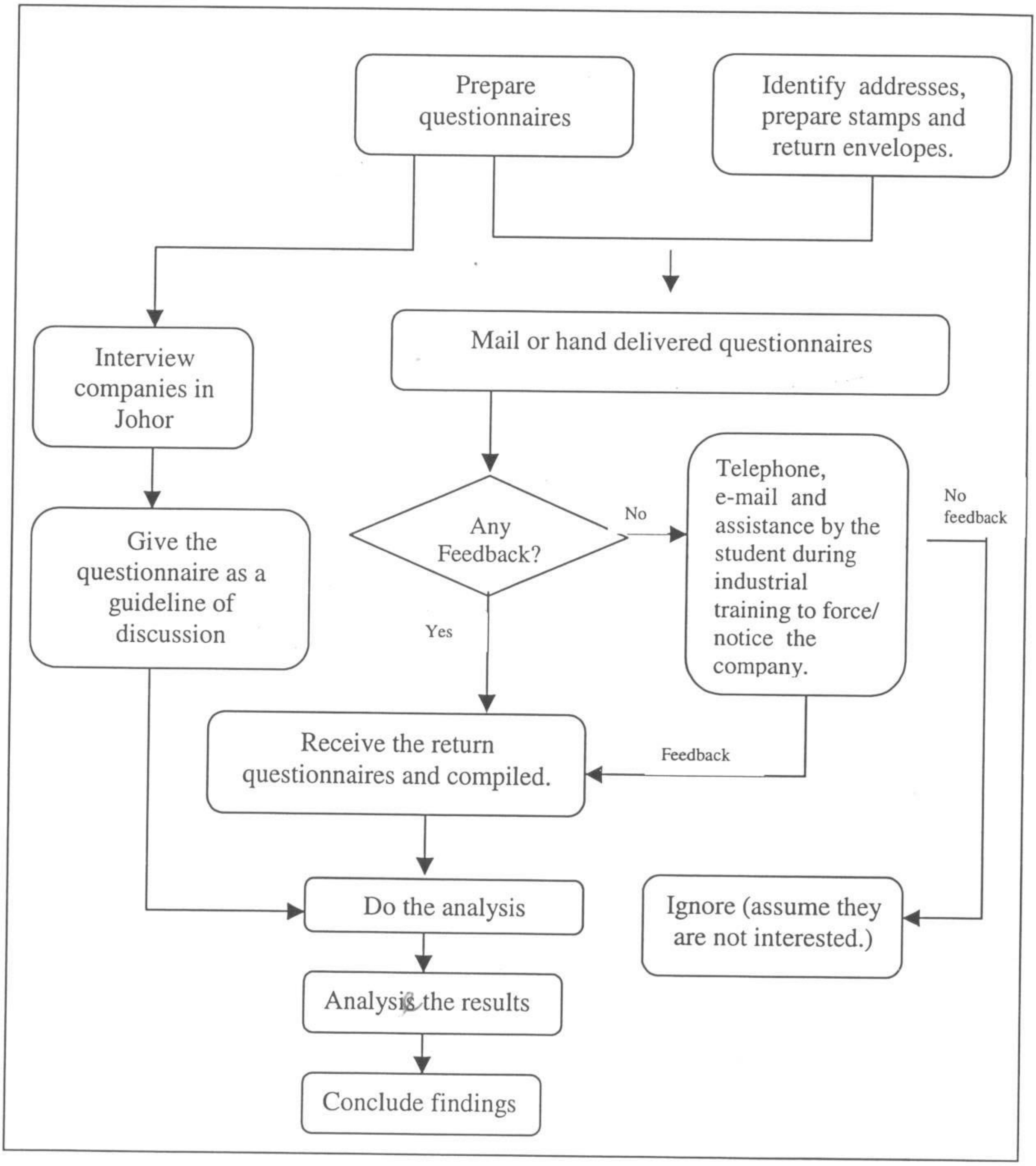


Figure 2.1: The flow chart of the survey

2.4 Findings Of The Survey

Information from questionnaires, interviews and discussions during visits to companies indicated some findings.

The survey results show that 71% of large companies in Malaysia who responded to the survey have a design department. Out of this, only 25% of them implemented DFA. Only 30% of SMIs who responded have a design department and none of them currently applied DFA. The main reasons that emerged from the study was that most companies in Malaysia do not implement DFA because they are not sure of its benefits or do not understand DFA and are concerned about its risks and costs or have never even heard of DFA. However, they are interested in DFA if the method can reduce lead-time, improve competitiveness, reduce total cost, increase sales and improve teamwork. This means that DFA has a great potential of being accepted by industries if only they can understand it and provided an appropriate implementation framework is made available.

The same survey also shows that these companies practiced at least five types of design practices. The type of design practices was determined by the technological capability of the company and its role in the product- creation process. This process may involve relationships with other companies (refer to Figure 2.2 to Figure 2.6). The five types of design practices are given as follows:

i) Client –Manufacturer/ Assembler (subcontractor)

This type involves the first party as the client who provide the product design and the second party as the manufacturer who is required to manufacture and/ or assemble the product. Refer to Figure 2. 2.

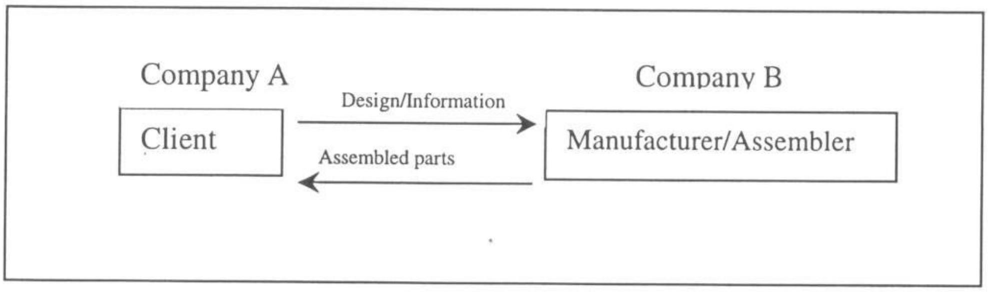


Figure 2.2: Type of company alliance: client – manufacturer/ assembler (subcontractor)

ii) Client- Manufacturer/ Assembler (vendor)

The client provides the information and the manufacturer will design it based on these information. The process of design will involve the approval from the client. After approval, assemble parts will be produced and sent to the client. Refer To Figure 2.3.

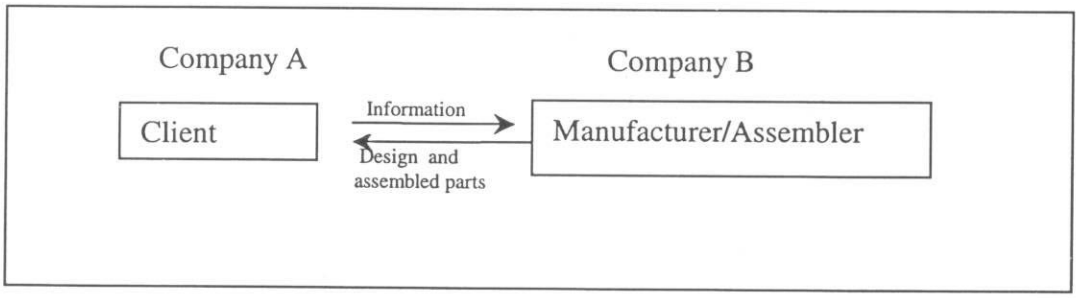


Figure 2.3: Type of company alliance: client- manufacturer/ assembler (Vendor)

iii) Consultant- Manufacturer/ Assembler

In this relationship, manufacturer will provide the information and the consultant(s) will come up with the product design. This interaction involves a two-way close loop communication with the approved product design and specification as the end result. Once this is done, the manufacturer/assembler company will produce the product and claim it as its own. Refer to Figure 2.4.

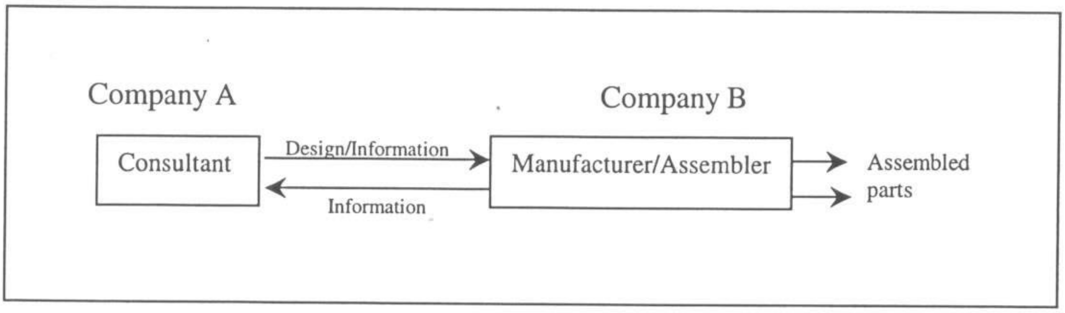


Figure 2.4: Type of company alliance: consultant – manufacturer/ assembler.

iv) Stand- alone Manufacturer/ Assembler

These companies do their product design in- house and produce the product themselves. Refer to Figure 2.5.

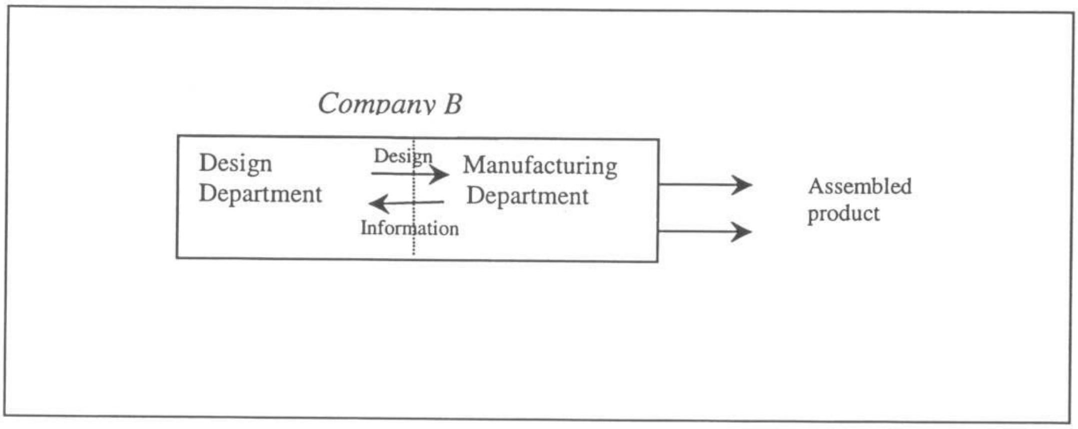


Figure 2.5: Type of company alliance: stand-alone manufacturer/ assembler

v) Hybrid alliances

The four types of companies mentioned above are the basic forms of relationships. However, it was also found that a company might practice a hybrid of these alliances. For example, referring to Figure 2.6, Company

A may do some of its design in- house and may manufacture/assemble the main product, but due to some constraints (for example, cost and process capability), the company will subcontract some of its component to another manufacturer (Company B). Company A will provide the product design and specification for that component and Company B will produce it.

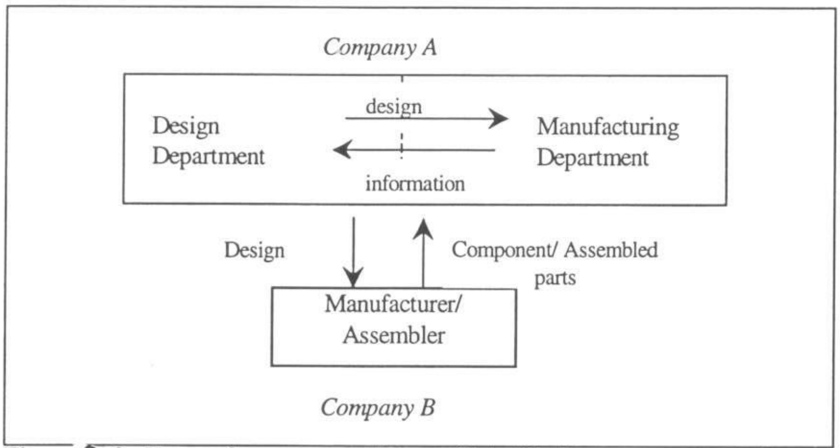


Figure 2.6: Type of company alliance: Hybrid alliance: an example

Thus, a framework must accommodate these activities in order to be widely applicable.

2.4.1 Application Of DFA

Companies are grouped into two categories;

i) large industries

ii) small and medium sized industries

This classification is done according to the number of employees, annual sales turnover and shareholders' fund. Out of 32 companies that responded, 4 did not answer the questions relating to company size. We assume that these respondents do not have the information and/ or were not sure as which category they belong to. Figure 2.7 shows the involvement of respondent companies in design activities and the application of DFA in every category.

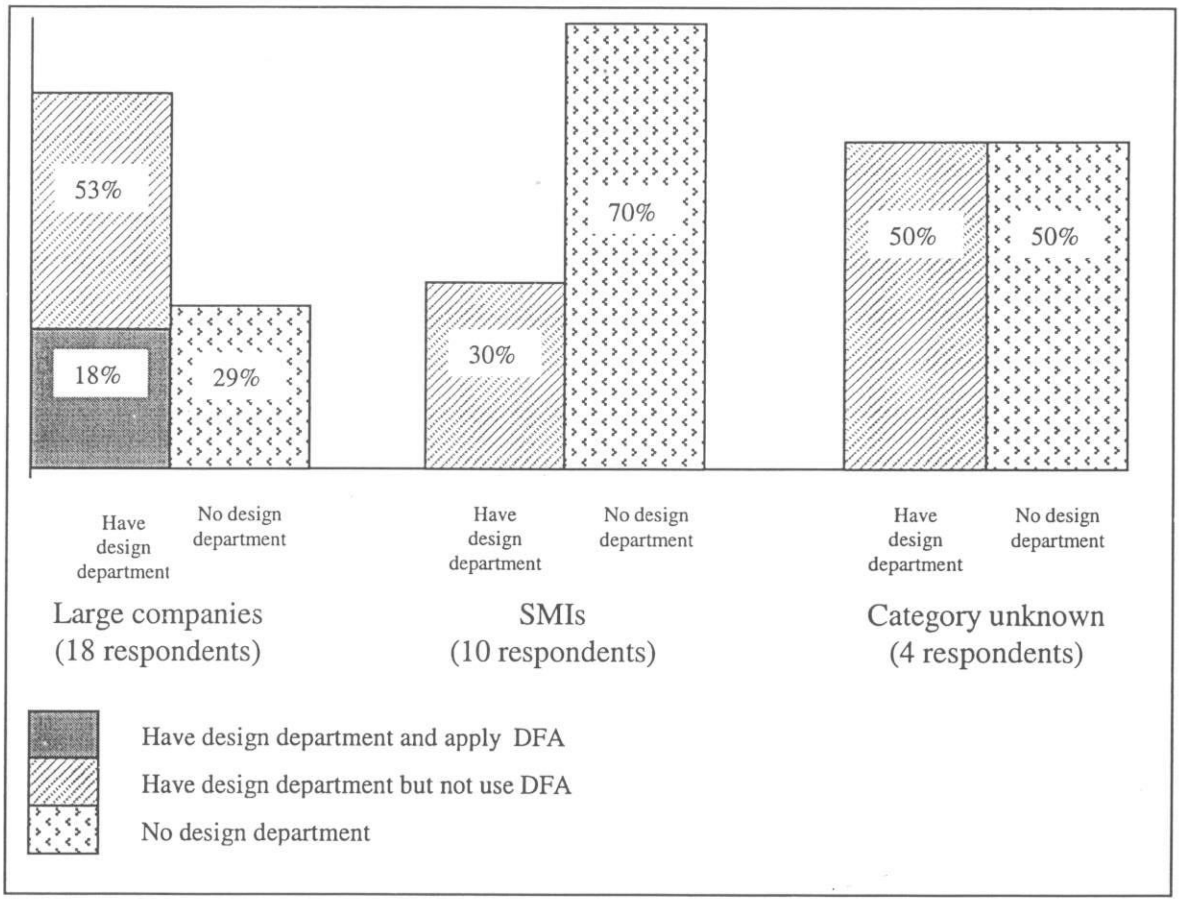


Figure 2.7: Involvement in design activities and application of DFA

There are two possible ways to categorise the companies:

i) by design practice

ii) by classification of companies (SMIs or large companies)

The survey shows that a significant number of large companies (71%) have their own design department compared to only 30% of SMIs. These large companies have the flexibility of designing and manufacturing their own range of products and that of their clients' and/ or acting as design consultants. For example, a client may provide information or partial product design specifications to these companies who will then come up with the completed product design. On approval by the\client, the product can then be manufactured or assembled. This is another form of hybrid alliances,.

Such flexibility will give an added edge of their competitiveness. These companies will benefit more if they could improve the quality of their product design through the deployment of DFA. Unfortunately, only 18% of large companies with design departments actually use DFA whereas none of the SMIs deploy it.

Companies without a design department rely on clients and consultants to provide them with the product design. For example, a client may provide a complete product design and the company needs only to manufacture or assemble the product. Another case may be where a client may give just design information or partial design specification to the company and the company will seek a consultant (which may be another manufacturing company with its own design department) to assist in producing the completed product design.

The quality of the product design used by this company is dependent on the capability of the client and/ or consultant. The quality of the product design in terms of ease of Assembler and manufacturability may affect the total product cost. Thus, the company has not total control over this factor since the design is done somewhere else. Although some communication and coordination may exist between client- manufacturer- consultant, a high level of effort, time and cost is incurred in such a project.

2.4.2 DFA Awareness

The degree of DFA awareness can be assessed through the answers given when companies, which did not implement DFA , were asked why they did not do so. The reasons are as follows:

- Not sure of its benefits (39%)
- Have never heard of DFA (26%)
- Do not understand DFA (26%)
- Concern about its risks and cost (13%)
- Felt that there was no need for DFA (8%)

(Percentages do not add up to 100% as companies were allowed to give more than one answer).

More than a quarter of respondents (26%) has never even heard of DFA. This may be because DFA is relatively new technique amidst either more popular techniques like JIT, TQM and MRP. This however seems to reflect on the need of a mechanism to disseminate knowledge and information important to the improvement of Malaysian industries.

Of those who have heard of DFA but did not implement it, the reasons given again reflect the need to inform industries on DFA and its benefits. Some are concerned about the risk and cost of implementing DFA in their product development process. A small percentage felt that they do not need DFA, perhaps an indication on the degree of ignorance.

However, when asked about the benefits of DFA that might interest them, the results are followed:

- Reduce lead time (74%)
- Improve company's competitiveness (70%)
- Reduce total cost (61%)
- Increase sales (61%)

- Improve teamwork (61%)

*(percentage do not add up to 100% as companies were allowed to give more than oine answer).

Reduction of lead times ranks the highest, followed by improvement in company's competitiveness, reduction of total cost, increase in sales and finally improve teamwork. This indicates that should these companies be given more information on DFA, its benefits and assistance in implementing it.

2.4.3 Types Of DFA Practitioners

The companies that applied DFA in this survey are involved in the assembly of the electronic devices and electric goods, electronic medical devices and communication devices.

2.4.4 DFA Tools employed

The DFA method used is either well-known or in-house methods as shown in Table 2.1.

Table 2.1: The DFA method that used in companies.

Method used	Respondents
Hitachi AEM method	1
In-house method	1
DFMA method	1

2.4.5 Benefits claimed by using DFA

These companies that responded claimed that every obtained the following benefits:

- Reduce lead time
- Reduced assembly time
- Reduced number of parts to assemble
- Help improve competitiveness
- Increased sales
- Improved teamwork

The problem that they experienced with DFA are

- Lack of DFA specialist to operate the system
- The high cost of implementing DFA

Thus, companies who did implement DFA in their product development process had confirmed the reported benefits of using DFA such as reduction in lead-time, reduction in total production / assembly time and reduction in the number of assembled parts. These benefits will lead to a reduction in total product cost. Other benefits include improvement in competitiveness, increased in sales and improved teamwork. Companies who do not implement DFA are also interested in these benefits.

2.4.6 Problems in implementing DFA

Nonetheless , companies who do not use DFA and reap its benefits report that they still face problems. These are identified as the lack of specialist to refer to and the cost incurred in the implementing DFA, for example, training cost, hardware and software cost. Perhaps a user support group could be set up among companies using DFA, so that experiences may be shared to assist others keen on using this technique. Research institutions can also play a role in solving problems related to the implementation of DFA.

2.4.7 Need For DFA Framework

Based on the findings, a guideline or framework to facilitate companies especially SMIs in implementing DFA would be a very useful in assisting companies dealing with the implementation of DFA and the teething problems that follow. Such a collaboration would not only create DFA aware ness among assembly related companies but also encourage the deployment of DFA.

The framework for implementing DFA is already viable (Dean and Salstrom, 1990; Holbrook and Sackett, 1990; Rampersad, 1995; Genc et. al, 1998) but all are designed for large companies. A framework developed for SMIs has been reported in the literature designed for the Hong Kong environment (Wu et. al, 1995) which may not be suitable for companies that have hybrid alliances such as in Malaysia. These alliances will involve a complex flow of design information and requirements not addressed by these frameworks. This for Malaysian industries, another framework should be made available to take into account these factors.

2.5 Conclusion

This chapter has described the result of the survey done in Malaysia. The objectives of the survey have been achieved. Then lack of information about DFA implementation in Malaysian industries and the barriers facing the industries in adopting DFA has been highlighted. Hence, this indicates the importance of conducting research into DFA in Malaysia which will enable the industries to realize the benefits to maintain their competitive advantage.

CHAPTER III

LITERATURE REVIEW OF DFA FRAMEWORK

3.1 Introduction

This chapter begins by defining the concept of a framework. It identifies three factors needed in developing a framework. It also reviews current models of DFA framework.

3.2 Definition Of Framework

A framework is defined as a set of basic assumptions or fundamental principles (Popper, 1994) or a clear picture of the leadership goal for organizations (Aalbregtse et al, 1991). Readers Digest Universal Dictionary (1987) explained that a framework is 'a structure for supporting, defining, or enclosing something; especially skeletal erections and supports as a basis for something to be constructed' and also as ' a basic arrangement, form or system'. Yusof and Aspinwall (2000) explained that a framework represents the *modus operandi* and the activities to be carried out.

Although the term framework has been used in various fields of research, they have the common objective of providing proper and suitable guidelines that are easy to follow. A framework must be effective for a company to benefit from its implementation. It may also be used to illustrate an overview of a particular method or to communicate a new vision of the organization and to highlight a substantial list of key issues which otherwise might not be addressed. It can also give an insight into the organization's strength and weaknesses (Aalbregtse et al, 1991).

In this project, the term DFA implementation framework means a set of basic and general guidelines, which provide structure upon which it is then possible to implement the technique completely and effectively. Such guidelines must retain certain generic characteristics so as to be widely applicable yet flexible enough to be customized for specific user requirements and constraints.

3.3 Success Factors In Framework Development

Three factors need to be considered in developing the DFA framework, that are:

i) The approaches used in framework development.

ii) The capability of principal developers of the framework.

iii) Very well structured product development stages.

3.3.1 The Approaches Used In Framework Development

This factor is essentially a viewpoint which considers what the general form of the framework should look like. Yusof and Aspinwall (2000) identified two approaches used in developing a framework. They categorized them as:

i) Step approach

ii) System approach

The step approach in framework development views the framework as a series of sequential steps that need to be carried out in order to implement the framework, whereas the system approach considers the framework from a holistic or overall viewpoint when it views the implementation process (Yusof and Aspinwall, 2000). Most of the authors in DFA tends to develop a framework using the step approach such as Holbrook and Sackett (1990), Fabricius (1994), Wu et al (1995), Rampersad (1995b), Genc et al (1998) and Bralla (1996); whereas the system approach has been applied for Total Quality Management (TQM) by Yusof and Aspinwall (2000) and Concurrent Engineering by Paashuis and Boer (1997) and Evans et al (1995).

3.3.2 The Capability Of Principal Developers Of The Framework.

This success factor considers the main person(s) responsible for developing the framework. Basically, three types of framework exist (Yusof and Aspinwall, 2000) and they are:

a) Consultant / Expert-Based.

b) Academic-Based.

c) Award-Based.

Consultant- based frameworks are derived from personal opinions, judgment and through experience in providing consultancy services to organizations. Haynes and Frost (1994) reported several cases of such a framework and Bralla (1996) reported on a practical guideline for a Consultant-Based Framework.

Academic-Based Frameworks are those developed by academics and authors mainly through their own research and experience in the field (Yusof and Aspinwall, 2000). Some examples of these types of framework are those developed by Yusof and Aspinwall (2000), Peters et al. (1999), Fang and Rogerson (1999), Genc et al (1998), Fabricius (1994), Rampersad (1995b), Wu et al (1995), Holbrook and Sackett (1990) and Pugh (1990).

Award-based frameworks are developed for organizations seeking to be recognized as leaders in the quality management field, for example, in acquiring ISO 9000 recognition. Very little has been published on this type of framework. For this reason further discussion will be made on the consultant based and academic based framework only. Table 3.1 shows the contribution of various authors in the field of framework development in manufacturing.

Table 3.1: Framework Development According to Category

Category Of Framework	**Authors**	**Application Area**
Consultant Based Framework	Haynes and Frost (1994)	Concurrent Engineering
	Bralla (1996)	Design For X
Academic Based Framework	Yusof and Aspinwall (2000)	Total Quality Management
	Peters et al (1999)	New Product Design and Development
	Genc et al (1998)	Design For Assembly
	Fabricius (1994)	Design For Manufacture
	Rampersad (1995)	Design For Assembly
	Wu et al (1995)	Design For Assembly
	Holbrook and Sackett (1990)	Design For Assembly
	Pugh (1990)	Product Design Specification

3.3.3 Product Development Stages

The development of a framework must also take into consideration what the stages of a product development are considered to be. There are a number of different views amongst authors as to what they are and also what names are ascribed to each stage. Ulrich and Eppinger (2000) defined a product development as a set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product. Many authors have defined different phases of the product development (Andreasen and Hein ,1987; Sohlenius, 1992; Rampersad, 1995b; Riedel and Pawar ,1993; Genc et al, 1998; Peters et al, 1999; Ulrich and Eppinger , 2000). Most of these are for the technical or engineering applications. However, these phases cover stages from the initial design stage to production.

Two most recent studies are reported to highlight some of these differences. Peters et al (1999) defined the product development as consisting of the following six stages:

1) Idea generation
2) Conceptual design
3) Detail design
4) Pre-Production validation
5) Production
6) Post Company

Ulrich and Eppinger (2000) divided it into six stages. They are:

1) Planning
2) Concept Development
3) System- Level Design
4) Detail Design

5) Testing and Refinement
6) Production Ramp-Up

For each of these stages, the main activities are listed and elaborated. Table 3.2 is a summary of comparison between the two product development stages proposed by Peters et al (1999) and that by Ulrich and Eppinger (2000). The product development stages proposed by Ulrich and Eppinger only covers up to the production ramp-up stage whereas that by Peters et al is broader in that it also encompasses product disposal. However, the explanation given by Ulrich and Eppinger for each stage is quite detailed and the nature of the activities seem to imply that their definition is more suited to that of large companies. There is however very little to choose between these two proposals. Either one would be equally appropriate and the broad ideas remain the same.

In this study, the author has decided to select the product development stages proposed by Peters et al (1999) to be used for further discussion. However, when each of the stages was examined in detail, the author also referred to Ulrich and Eppingers's concept for similarities or ideas that could be incorporated within the concepts proposed by Peters et al. Accordingly, further elaboration of each of the stages are given as below.

3.3.3.1 Idea Generation

In this phase, a business opportunity is identified and evaluated with respect to the general requirements of the company (Peters et al, 1999). Responsible staff must identify and make a collation on how to bring the opportunity to light within the company so that they can be assessed for suitability. Ulrich and Eppinger (2000) started with the planning stages in which corporate strategy and assessment of

Table 3.2: Comparison In Stages Between The Product Development Cycle

PLANNING	*CONCEPT DEVELOPMENT*	*SYSTEM- LEVEL DESIGN*	*DETAIL DESIGN*	*TESTING AND REFINEMENT*	*PRODUCTION RAMP UP*
• Project approval • Corporate strategy	• Market needs • Customer specification • Product specification • Clarify problems: internal & external	• Definition of product architecture (geometry layout) • Decomposition of the product into subsystem and components	• The complete set of geometry, materials and tolerances • Standard part to be purchased from suppliers	• Construction and evaluation of multiple pre-production version of the product	• Production • Workforce training • Launch

(Ulrich and Eppinger, 2000)

PRE- DESIGN/ DEVELOPMENT	DESIGN AND DEVELOPMENT PROCESS			POST DESIGN DEVELOPMENT	
IDEA	*CONCEPTUAL DESIGN*	*DETAIL DESIGN*	*PRE- PRODUCTION/ VALIDATION*	*PRODUCTION*	*POST COMPANY*
• Business opportunity	• Detail requirements of proposed product • Feasibility study: assess all aspects of opportunity from technical capabilities, costing, budget, materials, human resources, product requirement	• Engineering design • Industrial design • Prototype • Tooling • Testing	• Ensure the smooth transition • Trial production • Testing	• Physical manufacture • Assembly • Launch • Sales • Delivery	• Complaint • Positive feedback • Disposal

(Peters et. al, 1999)

technology developments and market objectives is also considered. The output of the planning phase is the project mission statement, which specifies the target market for the product, business goals, key assumptions and constraints. Some researchers get the ideas from the discussion with other client and then sign a project agreement based on the discussion.

3.3.3.2 Conceptual Design

In conceptual design, two things need to be considered (Peters et al, 1999); generate conceptual design and evaluate conceptual design.

Ulrich and Eppinger (2000) proposed something quite similar to Peters et al (1999), that is, to identify the needs of the target market, generating and evaluating the concept and subsequently, select one or more concepts for further development and testing.

However, in generating conceptual design, some authors recommended the use of other techniques, such as Product Design Specification (PDS) (Pugh, 1990), Value Engineering (VE) (Johnson, 1998) and Design For Manufacture (DFM) (Bralla, 1996).

The Product Design Specification (PDS) defines the attributes of the required design and provides a checklist for the designers. It however requires fairly experienced designers to be able to meet the checklist completely (Pugh, 1990). Value engineering is essentially a process, which uses function cost analysis to reduce cost. Any object that is under design, development or production stage can be the subject of Value Engineering. It begins by questioning the worth of each and any feature, then attempts to use creative techniques to generate the same worth but at a lower cost (Webb, 1993). However, the judgment for this worth of a product design is quite subjective and need experts to do the evaluation (Dean and Salstrom, 1990). In addition, the use of organized knowledge based in Value Engineering has not been well refined as it is with DFM/A (Kuo and Zhang, 1995). On the other hand, DFM is not a specific tool in itself but rather it is an approach to promote simultaneous product and process design (Kengpol, 2000). Table 3.3 summarises the salient elements of each of the three techniques with respect to their role within the conceptual design stage.

Table 3.3: Salient Elements Within The PDS, VE and DFM In Generating Conceptual Design

PRODUCT DESIGN SPECIFICATION (PDS)	VALUE ENGINEERING (VE)	DESIGN FOR MANUFACTURE (DFM)
1. The model provides a better approach to designing consumer product even though there is no related product in the current market. 2. Does not give a specific guideline to create better design in the engineering design. 3. Need experience to evaluate the conceptual design. Measurement is done through experience (Abdullah and Ariffin, 1999)	1. Subjective judgment and need experts to do the evaluation. 2. Only provide partial benefits in trying to identify the critical design stage. 3. Quality is a value. Therefore, VE can be a general method to evaluate quality. 'Value' is misleading because high worth is not necessarily proportional to high value. (Dean and Salstrom, 1990) 4. The use of an organized knowledge-based has not been quite well developed as it is with DFM/A (Kuo and Zhang, 1995)	1.Considered at the conceptual design stage of a new product. Factors considered are: - Product life volume - Permissible tooling expenditure levels - Possible part shape categories and complexity levels - Service requirements or environment - Appearance factor - Accuracy factors (Boothroyd et al, 1994) Thus it will enhance the product design value.

The conceptual design needs to be evaluated and it is important to have a specific evaluation for the ideas. As can be seen in Table 3.3, in term of quantitative analysis, PDS and VE do not have a specific guideline whereas DFM has a guideline on how to generate product design and the design is then evaluated using the quantitative analysis. DFA could be used as an evaluator for the assembly cost and time and may be integrated with other methods they used to generate product design, for example, DFM, PDS and VE. Johnson (1998) and Kuo and Zhang (1995) claimed that using DFA as a tool in Value Engineering would enhance the effectiveness in designing the products.

Ulrich and Eppinger (2000) divided the conceptual design into concept development and system-level design. It includes the product architecture and the decomposition of the product into sub-systems and components. The final assembly scheme for the production system is usually defined during this phase as well. The output of this phase usually includes a geometry layout of the product, a functional specification of each of the product's sub-systems and a preliminary process flow diagram for the final assembly process. (Ulrich and Eppinger, 2000)

The conceptual design stages by Genc et al (1998) included part classification, part combination, assembly procedure, feature selection, part constraining and concept evaluation.

3.3.3.3 Detail Design

In the previous phases, a decision would have been reached on the detail requirements of the proposed product. The aim of the detail design stage is to determine the exact parameters of the product to fit these boundaries. One possible solution is to convert this to a viable set of production instructions. It includes the initial testing of any prototypes to confirm that the physical requirements are adequate and that production requirements are being met (Peters et al, 1999). It also includes the complete specification of the geometry, materials, tolerances of all the unique parts in the product and the identification of all the standard parts to be purchased from suppliers (Ulrich and Eppinger, 2000). A process plan is established and tooling is designed for each part to be fabricated within the production system.

3 .3.3.4 Pre-Production Validation

Most authors share the same view in explaining this stage (Andreasen and Hein, 1987; Nevins and Whitney, 1989; Sohlenius, 1992; Rampersad, 1995b; Riedel and Pawar,1993; Genc et al, 1998; Peters et al, 1999; Ulrich and Eppinger , 2000). This stage includes the trial production, which is to confirm the manufacturing and assembly processes required to produce the product. It ensures that the production equipment is capable of maintaining the specification required of the product and confirm that the product complies with the specification.

3.3.3.5 Production

This phase pertains to the physical manufacture of the product, as well as its subsequent release onto the market and its delivery to the market or customers. It includes the stages of manufacture, assembly, launch, sales and delivery (Peters et al, 1999).

3.3.3.6 Post Company

This stage involved mostly marketing and therefore will not be further discussed.

Peters et al (1999) clearly defined these stages but is still not detailed enough in terms of its practicality. Ulrich and Eppinger (2000) explained that their product development process is practical but is only suitable for large and stand-alone companies.

Peters et al (1999) developed a general implementation framework for a various methods with six major stages. Each stage is further broken down into smaller parts. However, it is theoretical in nature and does not have any indication as to where redesign or evaluation should occur and it is not specifically meant for DFA. Ulrich and Eppinger (2000) mentioned the use of DFA but only in the detail design stage.

Therefore further work needs to be carried out in order to spell out in detail what the DFA framework should look like.

3 .4 The Design Of The DFA Implementation Framework

Although each author have develop their own structure of framework, most agreed that a DFA framework must:

i) Be developed within a product development stages

Many authors (Andreasen and Hein ,1987; Miyakawa and Ohashi, 1990; Sohlenius, 1992; Rampersad, 1995b; Riedel and Pawar, 1993; Genc et al, 1998; Peters et al, 1999; Ulrich and Eppinger , 2000) developed their framework based on the product development stage. This will ensure that no steps are missed and that it is logical and practical. This has been previously discussed in section 4.3.3.

ii) Clearly defined DFA elements.

Some elements have been identified as an essential part for a DFA framework by Miyakawa and Ohashi, (1990), Miles and Swift (1995), Wu et al (1995), Rampersad (1995b), Genc et . al (1998). The objective of a DFA framework is to assist the user in implementing DFA. It should be able to incorporate DFA in a detailed manner as possible within the product development.

Overall, the elements must be clearly identified and it may differ from one framework to another depending on the different types of companies and their needs. Table 4.4 shows some examples of the elements of a DFA framework implemented in various types of industries.

DFA elements that should be incorporated into the framework are:

1) assemblability concepts
2) assemblability evaluation or analysis
3) decision making on whether redesign is required or otherwise

Miyakawa and Ohashi (1990) built a framework for Hitachi New Assemblability Evaluation Method (AEM) and briefly explained the steps of implementing DFA in product development stages.

Fabricius (1994) developed a framework, with a seven-step DFM procedure. The procedure starts with DFM measurement, objectives, main functions, evaluation parameters and design ideas, generation of conceptual design, verification selection and finally detailed design. The advantage of this procedure is that it focused directly on the problem and shows how to redesign quickly. However, this framework does not clearly define the person in charge for each activity. Evaluation was included but it does not mention as to how this may be done.

Wu et al (1995) have developed a DFA implementation framework and claimed that the framework is suitable for SMIs but no details were made available. Although the framework consists of simple and easy to follow steps, they did not discussed the elements in detail. Thus, a company may find some difficulties in implementing this framework.

Rampersad (1995b) described a framework for a robotic assembly. He explained it's complicated structure with integral assembly model in order to realize a controllable design process. The objective is to develop a system layout for an assembly.

Genc et al (1998) came out with a framework that stresses on its application in the conceptual design stage. Part classification, part combination, assembly procedure, feature selection, part constraining, concept evaluation are some of the elements that are considered in the conceptual design. It is suitable when DFA software is used.

A framework developed by Bralla (1996) was based on his experience in many companies and his paper merely consists of some discussions about his experience in implementing a few methods such as DFA, DFM and Design For Service in the product development stages.

Miles and Swift (1998) built a framework for DFA and a software is also provided. The steps are quite detailed and effective. Some analyses were done to assess their functionality, manufacturability, handling ratio and assemblability. This is done to find some performance measurements such as design efficiency, manufacturing index, handling ratio and assembly ratio. Evaluation and justification may be done based on these results as to whether redesign is required or not. This could be achieved by using a DFA software.

Table 3.5 shows the weaknesses of existing DFA framework.

Table 3.5: The weaknesses of existing DFA framework

Researchers	DFA	Detail about framework
Peters et. al (1999)	PDDS (DFA is a philosophy)	Not detailed enough in terms of its practicality
Ulrich and Eppinger (2000)	PDDS (DFA is a philosophy)	Suitable for large and stand-alone companies
Fabricius (1994)	Seven-step DFM	Does not clearly define the person in

	procedure	charge for each activity. Evaluation was included but it does not mention as to how this may be done
Miyakawa and Ohashi (1990)	Hitachi AEM	Some of their framework could be adapted.
Wu et. al (1995)	For SMIs	No details were made available. Although the framework consists of simple and easy to follow steps, it did not discuss the elements in detail
Rampersad, 1995b	For robotic assembly	Complicated and for large companies
Bralla (1996)	General (DFA is mentioned)	Based on his experience in many companies and it included the redesign steps. However, his paper merely consists of some discussions about the framework
Miles and Swift (1998)	Analysis of DFA	Software is provided. Do analyses to assess their functionality, manufacturability, handling ratio and assemblability
Suat and Genc (1999)	DFA application	Framework stresses on its application in the conceptual design stage . Part classification, part combination, assembly procedure, feature selection, part constraining, concept evaluation are some of the elements that are considered in the conceptual design

Although these authors (Peters et al ,1999; Ulrich and Eppinger, 2000; Fabricius (1994); Genc et al, 1999; Wu et. al,1995; Bralla,1996; Miles and Swift,1998; Rampersad, 1995, Miyakawa and Ohashi, 1990) have already proposed and developed the DFA implementation framework, it can be seen that these are not detailed enough for a successful implementation. At present , there is as yet no DFA implementation framework that can be easily and quickly implemented especially for SMIs. Thus there is a need to develop a DFA framework that is suitable for SMIs in Malaysia. This framework should:

i) Be modeled for the product development and must contain detailed elements.
ii) Have specific DFA requirements.
iii) Consider the design practices and needs of Malaysian SMIs (refer to Chapter 3 in section 3.4)

4.5 Conclusion

The term DFA framework in this thesis has been defined. Similarly various types of approaches and sources of principal developers have been identified. Various DFA framework have also been reviewed and based on this, a particular model of DFA framework has been selected for further development. Principal elements of the Product Development Lifecycle has also been elaborated.

The use of IDEF0 or SADT-based technique has also been proposed to be used to facilitate implementation of the DFA framework.

CHAPTER IV

DEVELOPMENT OF A DFA FRAMEWORK

4.1 Introduction

This chapter explains a development of conceptual model for DFA framework implementation based on an adaptation of existing models of DFA framework and the product development stages involved.

4.2 The Development of A Conceptual Framework

The general phases of product development will be considered based on Peters et al (1999), Ulrich and Eppinger (2000) and the other researchers such as Bralla (1996), Miles and Swift (1998) and Genc et al (1998) to be used in formulating the framework for Malaysian SMIs . This is due to the clear explanation given in each step and is suitable for the actual design practice of the product development in the case study company. The author will also use guidelines from Hoyle (2000) and Tricker and Lucas (2001) to ensure that the documentation ~~refers~~ ISO 9001 ~~as a~~ guideline.

Figure 4.1 shows the main phases of the product development, suitable for SMIs in Malaysia.

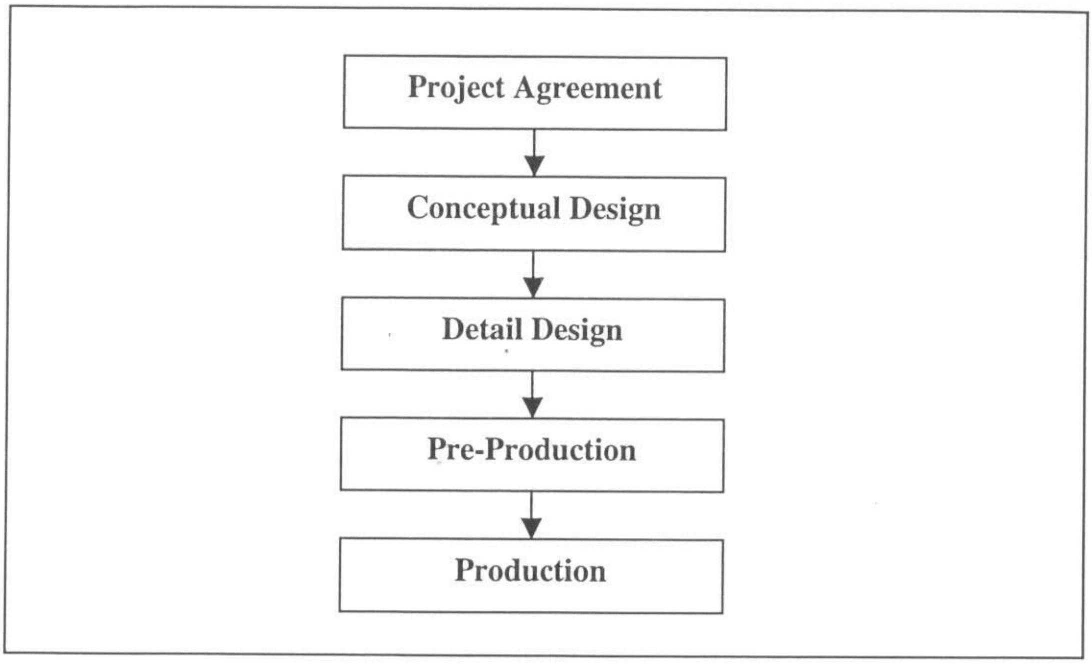


Figure 4.1: The adaptation of main phases suitable for SMIs in Malaysia

The author will then adapt the DFA framework suggested by Wu et al. (1995) and use the procedure provided by Miles and Swift (1998) from the TeamSET software for the study. This procedure will also be observed in the framework that will be developed.

4.3 The Need For Structuring The Implementation Process

When a framework has been formulated, there is no guarantee that it by itself will be successfully implemented. One of the key success factors is in the implementation process, which may be a complex process. The reason is that DFA implementation involves multiple parties who have different roles and responsibilities. These parties provide design and manufacturing information at various stages of the product development and in turn also receive similar information at various stages as well. The relationship between various parties, their responsibilities and functions, information flow and resources required need to be captured before (existing) and after the DFA implementation (proposed). The situation is further complicated by the fact that no two companies practices are ever exactly alike. Therefore, the framework to be developed must be generic so that any company can utilize it in any situation.

For this reason, the implementation of DFA may be likened to a system's redesign (or re-engineering) exercise where it is essential that any redesign or re-engineering exercise must ensure that the overall system objectives must be achieved without causing any disturbance or untoward changes within the system that may cause other problems to occur.

Hence, the provision of a general framework by itself may cause implementation problem because it is too general to allow the end-users to use it effectively. On the other hand providing too detailed a framework may be an impossible task since each company will have different requirements which may be too different to accommodate.

What is required is therefore the provision of a structured methodology as a tool to assist in the DFA implementation process. The Structured Analysis Design Techniques (SADT) is a suitable tool to help formulating the DFA framework. This technique is well proven and widely used by system analysts who are involved in systems redesign. The application ranges from design of database information systems, Business Process Re-engineering (BPR) and Computer Integrated Manufacturing (CIM). SADT involves a systematic and structured modelling of a system and its objectives and functions and involves the orderly breaking down of a complex system into its constituent parts. The method of decomposition is in a top-down manner, gradually leading from the general to the specific details at the various levels of representation. The method of analysis is top- down, modular, hierarchic and structured (Design/ IDEF User's Manual, 1995).

The philosophy of using SADT is that information is selectively displayed at various levels or viewpoints of the hierarchy which greatly assist people who are involved in the implementation process since different people in different positions holding different functions and responsibilities need only see the information or changes relevant to them and yet the whole information needs to be completely captured by the system.

It becomes very easy to capture the system intent or functions completely and yet be able to selectively display for example, information at the levels that is relevant for the viewer.

IDEF (**I**ntegrated **DEF**inition) is a well- known SADT methodology. It was first introduced in 1980's by the US Airforce in the ICAM program (The CSC Manufacturing Industry Handbook, 1996). IDEF is a family or suite of modeling techniques consisting of IDEF0 and $IDEF_{1x}$, which may be used to model the dynamic relationships between entities of the system (Design/ IDEF User's Manual, 1995).

Using IDEF0, it becomes possible to model a system to capture its behavior (in terms of functions, information and mechanisms) before initiating a system redesign exercise (or as-is state). All the relevant characteristics need to be maintained. Once the system redesign exercise is conducted, the system designer must ensure that these characteristics are maintained within the whole system as well as integrating these with the new characteristics of the new system. Hence, for example, consistency, achievement of objectives and lack of duplication can be obtained.

Since implementation of DFA framework can be viewed as a redesign process that affects everyone and every process within an organization, it is felt that the use of IDEF0 tool may potentially offer significant benefits if it can used to represent the DFA framework. Other advantages of using IDEF-0 are as follows:

i) It becomes easier to represent functional operation in a hierarchical and structured manner and to clearly define the nature of their relationship in graphical form.

ii) It proved to be a useful teaching and instructional tool to the manufacturing company's staff in understanding how the implementation can be carried out.

iii) The model captures knowledge of activities, resources, information and mechanisms in a structured manner, which can be referred upon later on when new products, systems or changes have to be accommodated.

iv) Consistency checks can be carried out with respect to information flow and functional responsibilities.

IDEF0 has a series of viewpoints that are decomposed at various levels starting from the top most level of the systems level (The CSC Manufacturing Industry Handbook, 1996, Menon and Regan, 2000). At the top most level, the viewer is shown with the system level point which consists of the purpose (or functions), global objectives of the exercise, the information flow in and out of the system, the controls and mechanisms for processing the functions. A conceptual illustration of the top level system view is given in Figure 4.2. (The CSC Manufacturing Industry Handbook, 1996).

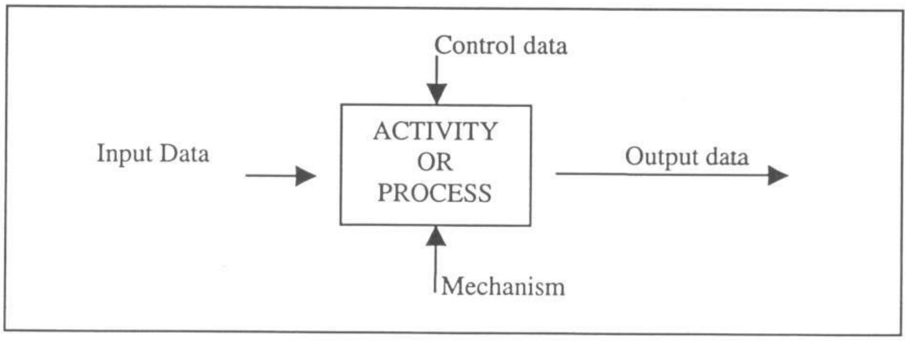


Figure 4.2: The IDEF0 Methodology (adapted from The CSC Manufacturing Industry Handbook, 1996)

At subsequent levels, this system view is decomposed into various individual viewpoints (not more than six per level) which themselves perform different mechanisms and controls, inputs and outputs but all of which contribute to the function and operation of the proceeding layer as depicted by Figure 4.3.

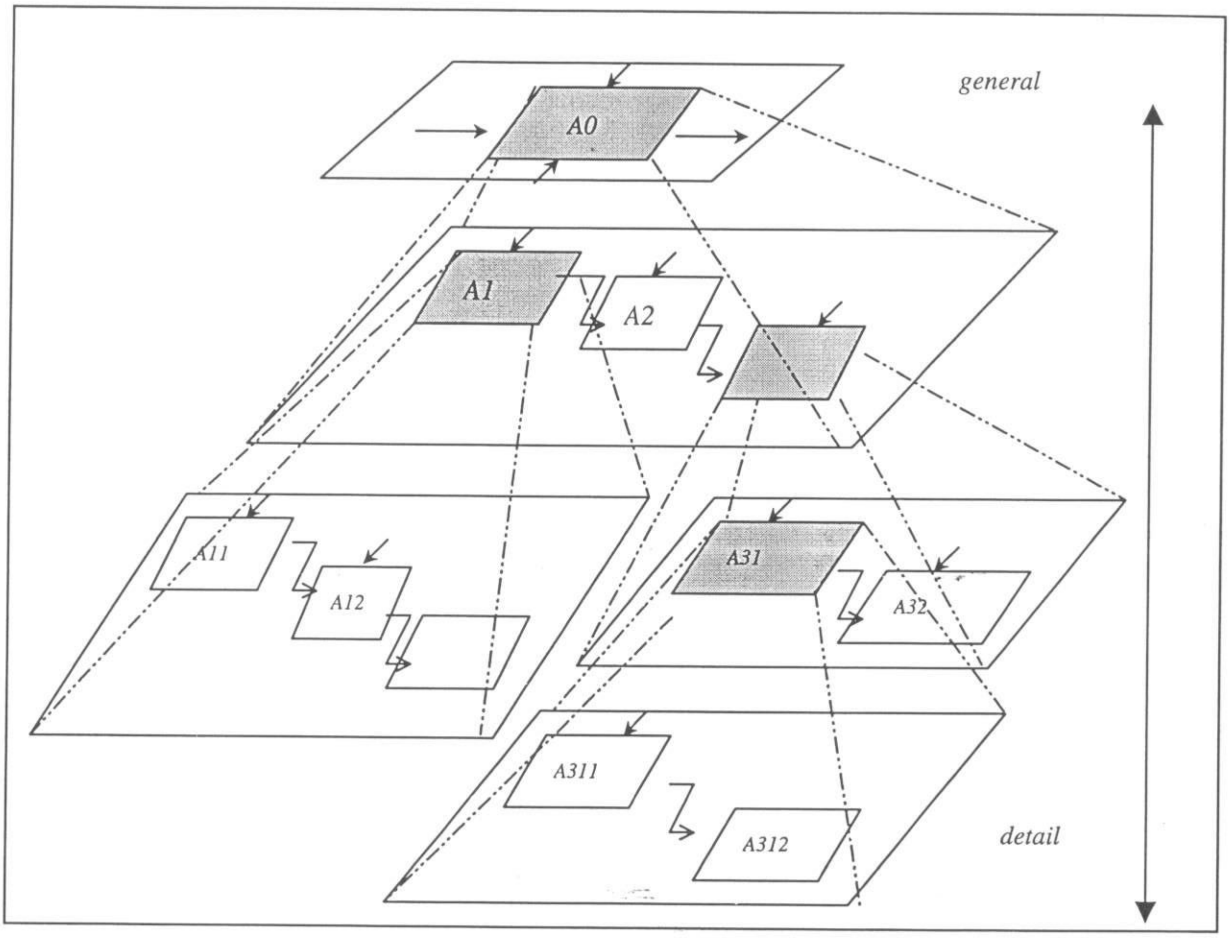


Figure 4.3: An Example Of Decomposition By IDEF0 (Adapted from Jambak, 2000)

4.4 The Proposed DFA Implementation Preparation

The project planning for the implementation process must cover all phases from start to finish. The four general phases are:

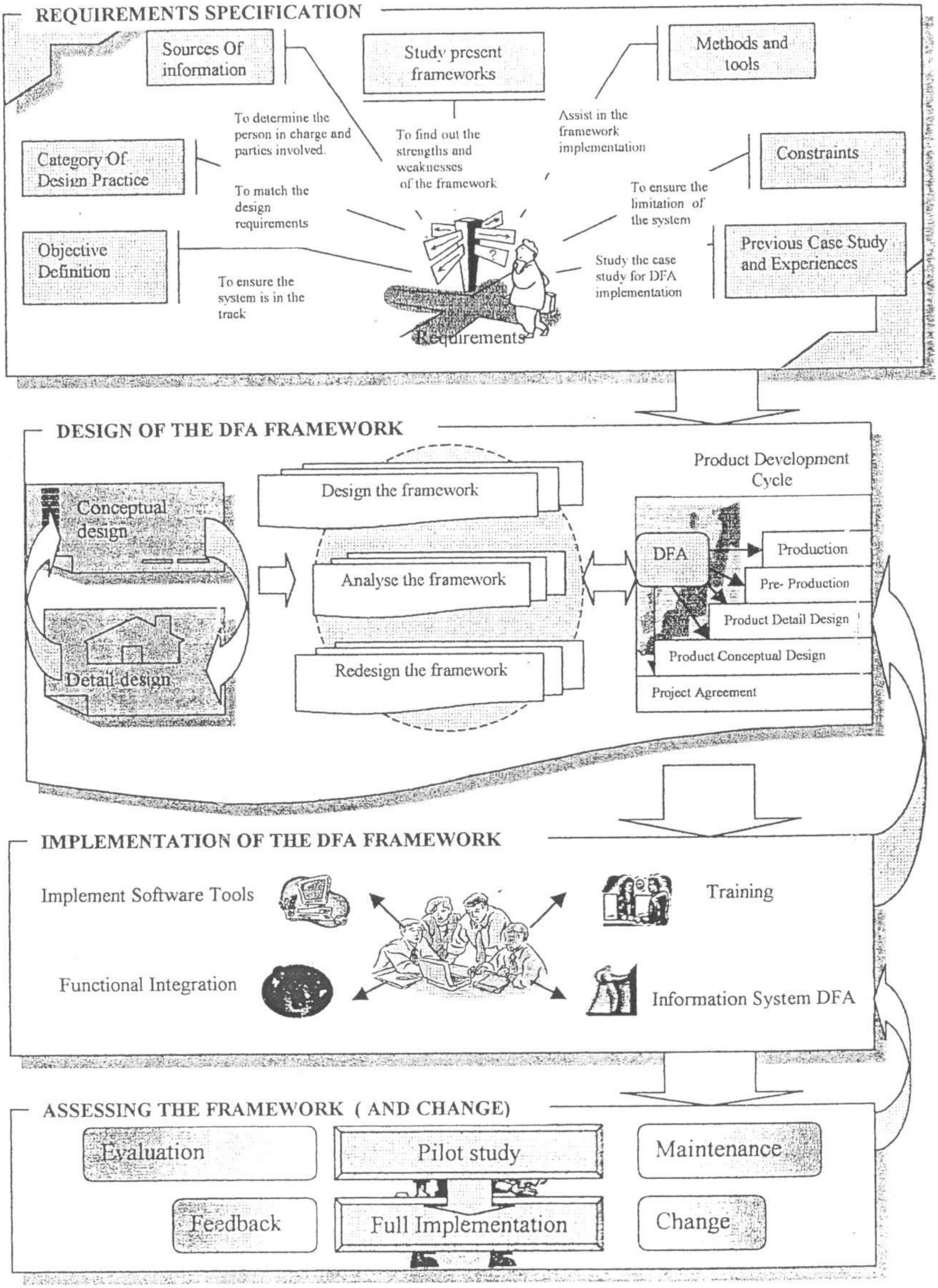


Figure 4.4: Proposed DFA Implementation Preparation .

1) Requirements Specification
1) Design Of The DFA Framework
2) Implementation of The DFA Framework
3) Assessing The Framework (and Change)

These phases act as a roadmap that can be used to plan, implement and monitor the progress of the project. The management can then set milestone at which points they can then allocate the appropriate resources in terms of human resources, materials and finance. The section below discusses the various activities involved in the different phases. Figure 4.4 illustrates the proposed project implementation phases for DFA.

4.,4.1 Requirements Specification

This level specifies the requirements in the implementation of DFA. A company who is interested in implementing DFA, needs to specify the requirements in implementing it. Firstly, the objective to implement DFA must be determined. For example, to reduce cost, reduce time and reduce labor. When these are to be achieved, they must be ready for any changes required when implementing DFA. Then, the category of the company based on its design practice must be clarified. The task of design, manufacturing and approval should be cleared to avoid any difficulty especially for approval of the product design. After that, the sources of information are determined such as the person in charge in the companies for example designers, engineers, manufacturing engineers, tooling designers and manufacturers. This requirement is to specify the person in charge, specifically responsibilities in assembly. This also includes the parties involved in producing the product, that is, whether using consultant/ technical partner or not. The study of the present frameworks and practices (if available) will determine the strengths and weaknesses of the existing framework. The methods and tools already in use in company or market and any additional tools required also need to be considered. At the same time, the DFA method and tool needs to be selected. This is important because the proposed framework will not drastically change the existing activities. The company also needs to specify suitable tools that can assist in the implementation of DFA.

Some constraints need to be added. In this research, for example, the DFA is implemented in Small And Medium Sized Industries (SMIs). Thus, the limitation of SMIs such as low specialization, low degree of standardization and division of activities are limited and unclear (Yusof and Aspinwall, 2000) needs to be incorporated within the framework. Lastly, past experience and previous case studies should be used to improve the framework so that it may be used more effectively.

4.4.2 Design Of The DFA Framework

At this stage, a suitable framework will be designed. It must be modeled by considering all its functions. After that, the framework will be analyzed based on the requirement specifications. This step is a continuous cycle of conceptual design followed by detail design and back again to conceptual and detail for several times until they achieve the objectives and fulfill the requirements. The important thing is that DFA has to be structured within the product development stages, which is through the stages of project agreement, conceptual design, detail design, pre-production and production.

4.4.3 Implementation Of The DFA Framework

When the DFA framework is completely designed, the next level is the implementation level. Some of the factors that need to be clarified are functional integration, selection and implementation of software tools, training and information system of DFA. Functional integration means that the flow of information in the company must be clarified. This is to ensure that the person responsible understands clearly their functions especially in the product design stage. Subsequently, the correct choice of DFA software tools are required if it is to be used effectively. They need to clarify which software to buy in terms of their price, performance and their affordability. Some training needs to be considered for the DFA software and the team. Lastly, a database information management system containing DFA related data would be high desirable to ensure that DFA related data would be readily accessible wherever and whenever it is required by any person within the organization.

3.4.4 Assessing The Framework (and Change)

Once the DFA framework is implemented, it is important to assess the progress of the project and measure its performance. A pilot study will be carried out and if proven to be successful, it will be followed by full implementation. Some evaluations will need to be done and feedback will be necessary. Maintenance will also need to fine tunes the way in which DFA is implemented to ensure its complete success.

4.5 Conclusion

The generic model for the implementation process for implementing DFA has been proposed. The next chapter will discuss the case study company and illustrates how IDEF0 was used to represent the current product development activities and operations.

CHAPTER V

DESCRIPTION OF COMPANY'S PRODUCT DEVELOPMENT PROCESS

5.1 Introduction

This chapter discusses Ingress's Sdn. Bhd. background and its product. Its current practices in product development will also be discussed to highlight the nature of the interactions between Ingress (manufacturer), Proton (client) and Katayama (technical partner). IDEF0 is used to represent the current state activities of the product development stages.

5.2 Case Study Company's Background

Ingress Sdn. Bhd., which has been selected for the case study, is a vendor of automotive parts (refer to Section 3.4 for the meaning of vendor), located at Nilai, Negeri Sembilan. It is categorized as a small and medium sized industry because its shareholder fund is below RM500 000 and the number of workers is below 500 (refer to Appendix B.1). It was incorporated on May 1997.

The main client of this company is Perusahaan Otomobil Nasional (Proton). It works with Katayama, a Japanese company who acts as their technical partner, consultant and tool and prototype supplier. Although Ingress has its own design department, it still needs Proton's approval from the client, that is, Proton for any design modifications.

The company produces door sash related components; small sized stamped parts, bellows and molding components.

5.3 Parties Involved In The Product Development Cycle

An example of a product development project is the door sash to be used in the Proton Wira, a car model produced by Proton. There are three parties involved in producing the door sash. Each party has its own roles and responsibilities in producing the product. Figure 5.1 shows the three parties and their relationship with one another.

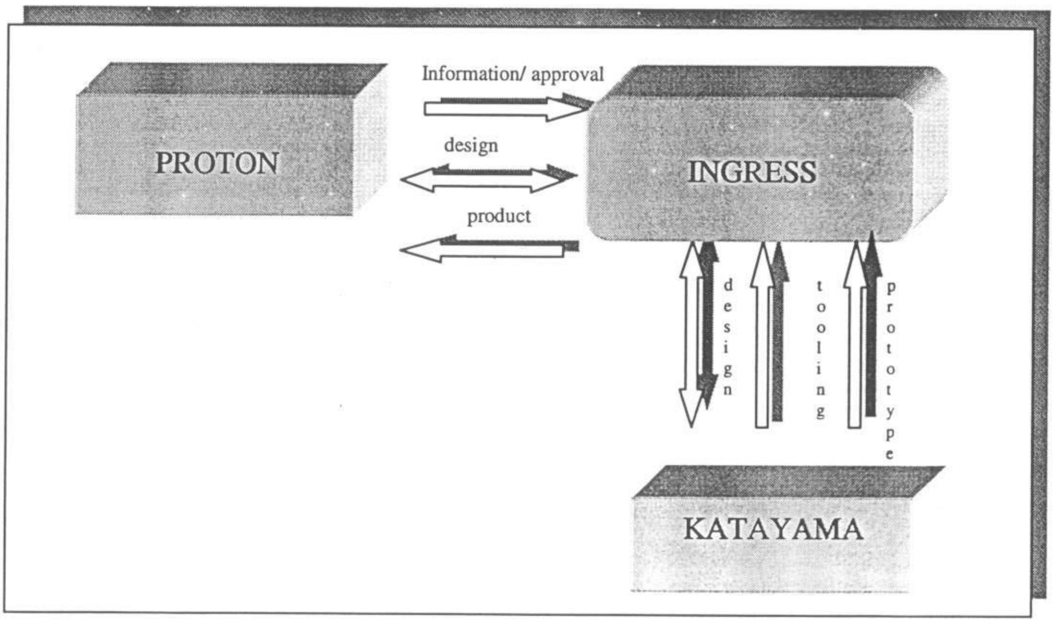


Figure 5.1: The relationship and information flow between Ingress, Proton and Katayama

i) ***Proton***

Proton is the company who needs the door sash to be used in one of its car model. Proton will send information and rough design concepts to Ingress who will refine the design. Proton must approve the design before production can proceed.

ii) ***Ingress***

The company who manufactures the door sash. However, Ingress is also involved in the design of the door sash. In fact, it assumes main responsibility in the design. Once the design is approved by Proton, Ingress may then manufacture the door sash.

iii) ***Katayama***

The company who provide necessary technical support to Ingress such as giving advice in designing the door sash and making tools and prototype that Ingress is unable to produce.

Proton and Katayama have no direct relationship with each other. From the design perspective, Ingress has two parties that can contribute to the design: -the engineers at Proton who gives the rough ideas and information which they require to produce the approved design and Katayama who gives consultation on the design and tooling. Usually, Ingress will give their ideas based on their experience while Katayama will contribute based on their technical 'know-how'.

Figure 5.2 shows the door sash's project master schedule for the product development. The three parties involved are represented to show the relationship of the activities by all parties. For this case study they took about three and a half years to complete the product design, development and manufacture. This included the two and a half years for designing the product, and a half-year for the pre-production and production.

There are two types of activities involved during the product development, they are termed formal and informal activities. The formal activities are the main events that are stated in the master schedule and the informal activities are the secondary events, which are not mentioned in the master schedule. An informal activity may not be in the master schedule but they occur many times during the product development stages.

For example, during the design, CAE modeling and the drawings must be approved by Proton before proceeding to the next activity. Referring to Figure 5.2, in the case of Ingress, between drawing concepts (1) and drawing concepts (2), Proton and Ingress need to meet frequently and discuss informally regarding changes to the design. Every time the design changes; other information will also change, for example the drawings. This means that the process of designing involves many other related activities before the final design is actually produced. This is time consuming for both parties.

The soft prototype (the prototype which is produced by using soft tooling) cannot be produced until the design concept is clear. One of the suitable times to consider assemblability (an aspect of DFA) is during the designing of the soft prototype. The prototype will allow the designer to see clearly the assemblability of the product. Thus, if the result of the analysis shows that it is difficult to assemble, or difficult to handle or orientate, the design still can be improved.

The soft prototype is usually fabricated by Katayama. Any changes in the product design at this stage will involve Ingress and Katayama and may also result in the product development process to return to the conceptual design stage. However, the sash door is only one part of the whole car, so Proton who will be assembling the main product will also need to conduct assemblability analysis. Any change in the main product may cause changes in the door sash design. This illustrates the complicated design process and information flow, which exists between the parties involved.

This complicated interaction between Ingress and Proton or Ingress and Katayama required high levels of cooperation, consensus, understanding and time.

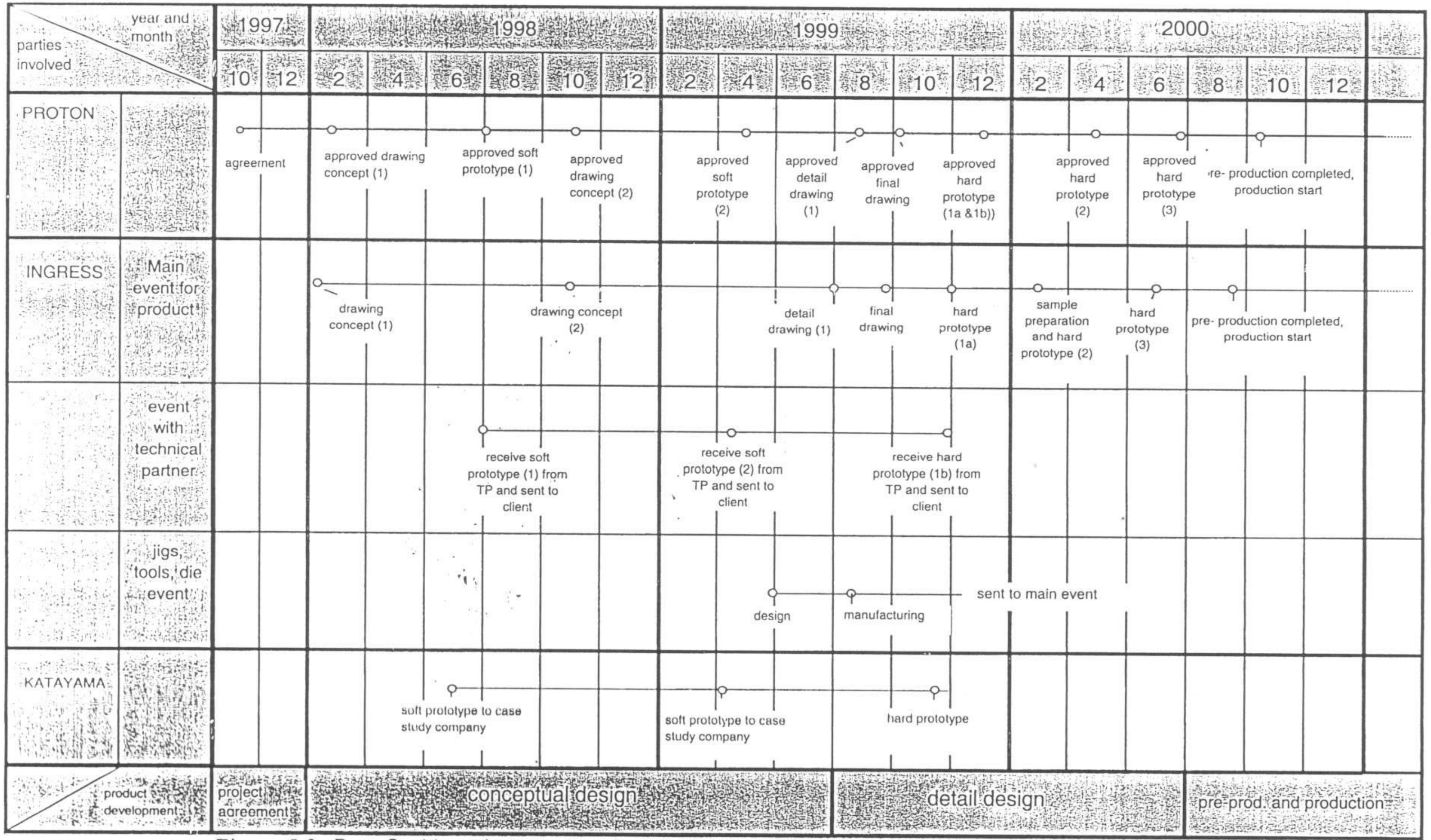


Figure 5.2 :Door Sash's project master schedule for product development
(reproduced with permission from Ingress)

5.4 Description of Activities In Product Development Stages

The existing activities in the product development stages practiced by Ingress will be discussed here. This is important because the proposed DFA implementation framework will be built based on the activities in the product development stages. The activities carried out by Ingress and Proton are shown in Table 5.1 and the activities carried out by Ingress and Katayama are shown in Table 5.2.

Table 5.1: The Activities In The Product Development Process Between Ingress And Proton.

Activities		Parties Involved
i)	Set objectives of design specification and standard	Proton
ii)	Feasibility study of product	
iii)	Mock up development	
iv)	Digitize surface of mock up using CMM	
v)	Agreement	Proton and Ingress
vi)	Generate Conceptual Design	Ingress
vii)	CAE Modeling and Drawing	
viii)	Design Analysis And Testing	
ix)	Prototype	
x)	Pre-Production	
xi)	Production	
xii)	Approval	Proton and Ingress

Table 5.2: The Activities In The Product Development Process Between Ingress And Katayama.

Activities	Parties Involved
i) Process planning and assembly system design ii) Tooling list	Ingress
iii) Tooling design iv) Tooling fabrication v) Soft tooling vi) Hard tooling vii) Prototype	Ingress and Katayama

The stages of the product development start from project agreement, followed by conceptual design, detail design, pre-production and production. Refer to Figure 5.3.

5.4.1 Project Agreement

The project agreement will be signed after Ingress agrees to Proton's conditions and requirements. Some of the considerations given in the agreement are financial budget, product standards, and project brief, which includes customer's policy and objectives.

Ingress will also receive product specification and styling surface data of the product, as well as the master schedule from Proton.

5.4.2 Conceptual Design

Information provided by Proton will be used as a rough design guideline for Ingress. Using CAE modeling, Ingress will produce the 3D data model. Proton will

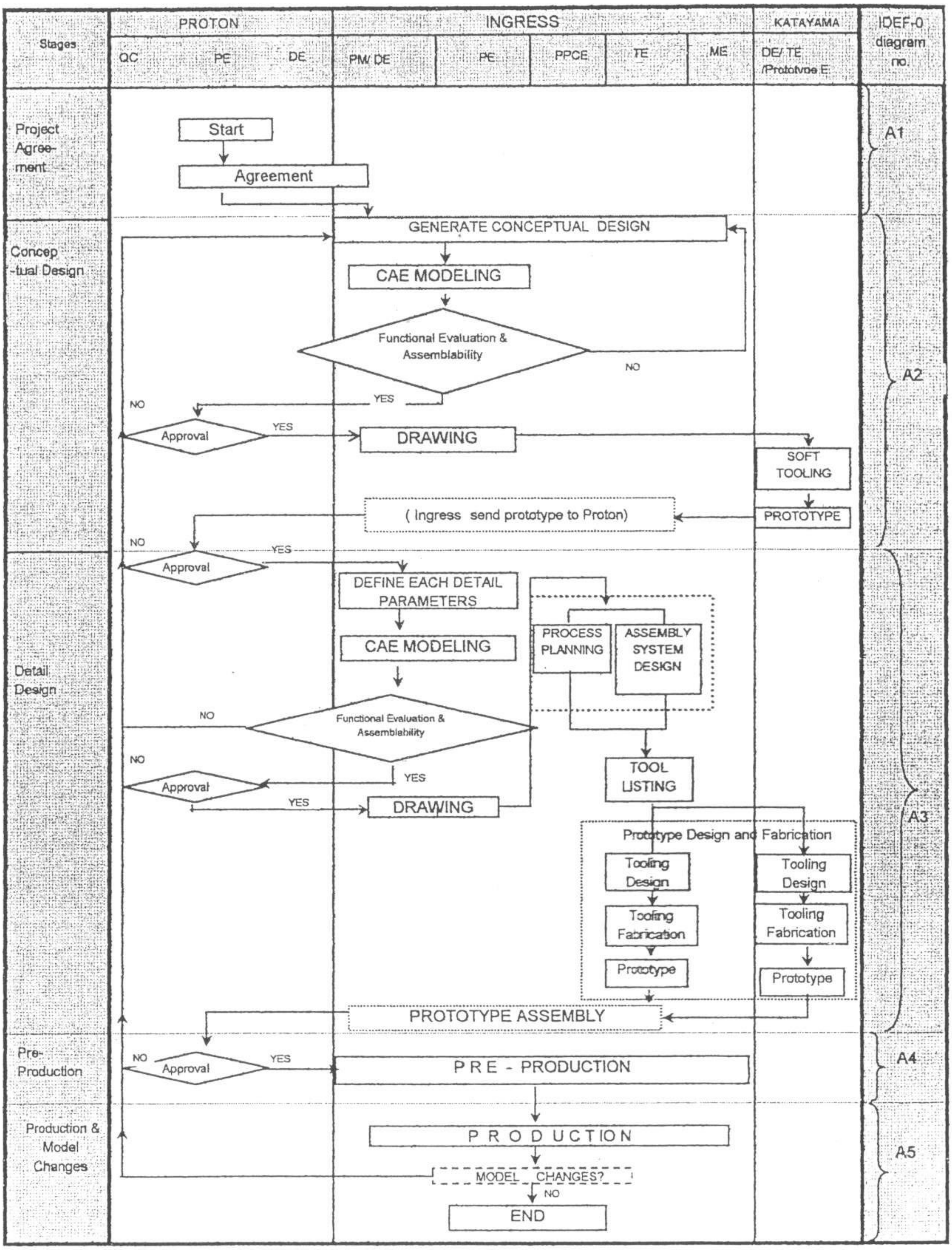


Figure 5.3: Flowchart of existing activities in producing a door sash based on product Development Cycle

check the design and Ingress will modify accordingly. This process continues until Proton approves the final design.

In concept generation, the product concept is analysed by using Value Engineering. Then, the concept is roughly evaluated based on, for example , the performance and aesthetic value. Ingress will draw up a product structure and come up with rough dimensions of the product.

CAE modeling using CATIA software will be done based on the dimensions and product structure. Here, assemblability will be evaluated in-house and a drawing will be produced as a result. Ingress will then call Proton's representative to evaluate and approve the 3D Data.

Proton will also need prototypes to be tested and approved. Ingress is responsible for supplying these prototypes. Usually, Ingress will get assistance from their technical partner, Katayama to build the prototypes. At this stage, Katayama will build the prototype using soft tooling. Soft prototype is prototype, which is done by using a soft tool. Examples of soft tools are epoxy, wood, plastic etc. This will be used just for a small batch production and will be easily damaged after a few cycles. Due to the soft and temporary nature of the tooling, the production of prototype may be time consuming as special toolings may need to be produced.

The conceptual design stage took about nine months to complete the existing product design of the door sash.

5.4.3 Detail Design

At this stage, each detail parameters such as dimension , tolerances and ergonomics factor will be determined. Every single part will be defined and the function and assemblability will be evaluated again at this stage. Some documents such as 3D models and drawings will be used for this purpose (see Figure 4.3). Then, the process planning will be done and the report will be used as the guideline to build the hard prototype. At the same time, after the detail design is sent to Katayama, tooling design and fabrication will be done by Katayama. This is also to get ready for producing a hard prototype. When Proton is satisfied with the design, the hard prototype will be made. However, Ingress does not have the capability to make all the prototypes. Thus, Katayama is employed with the responsibility of designing tools, fabricating it and producing the prototype. Hard prototype is done by using hard tooling. An example of hard tooling is metal molds and can be used for production. The process of generating a design, evaluation and modification is usually done many times before the hard tooling and prototype can be produced.

Katayama usually fabricates all soft prototypes so as to save time and cost for shipment. As for the hard prototypes, Ingress is only capable of producing 20% of it and the rest is done by Katayama.

All prototypes will be assembled at Ingress and then, Ingress will send the prototypes to Proton for approval. If it is not approved, it will go back to the design stage. This process is also a repetitive cycle that will affect the cost and time. After approval, pre-production will be done. To reach this stage, the detail design took almost one year.

5.4.4. Pre-Production

At this stage, a small production run is made to identify and solve problems that may affect mass production. Here, labor, time and other related factors will also be taken into account and checked in preparation for the actual production. After that the production will begin.

5.4.5 Production

Once production starts, any changes to the product design are not encouraged. However, some model changes do occur but usually after some time. This can either be due to model modification required by Proton or because Ingress needs some modification related to the manufacturing problems.

5.5 Ingress Project Organisation

There are four levels in the hierarchy of project organisation (refer to Table 5.3); these are:

a) Policy making and authorization
b) Project Management
c) Project Implementation
d) Technical support

Table 5.3: Hierarchical tasks from top level to bottom level (existing activities)

Functions	*Specific Task*	*Party In Charge*	*Person In Charge*
Policy making and authorization	Approval/ Authorisation	Proton	Project Manager, Design Engineer, Quality Engineer
Project Management	Review/ Analysis / Monitoring / Proposal/ Approval	Ingress	Project Manager, Design Engineer
Project Implementation	Information collection, taking	Ingress	Design Engineer, Production Engineer, Product Planning and

	action		Control Engineer, Tooling Engineer, Manufacturing Engineer.
Technical Support	Give technical advices and technical support to Ingress	Katayama	Design Engineer, Tooling Engineer

a) Policy making and authorisation:

These include initiate/ terminate/ start of the project and make policies or approve/ authorise any changes. Perform some approval based on the strategy or policy they have developed. The party involved in the policy-making and authorisation is Proton represented by its Project Manager. The Design Engineer and quality engineer (from Proton) will evaluate and approve the product design from Ingress. The representative from Ingress, that is its Project Manager needs to obtain authorisation for any activities that may affect the design and the final product.

b) Project Management

This involves review, analysis, monitoring, proposal, approval and also planning and scheduling the activities. The party in charge of project management is Ingress and the person in charge will build a team consisting of the Project Manager (PM) or Design Engineer (DE) as leader.

c) Project Implementation

Perform activities, feedback information and make changes as or when necessary. At this level, Ingress will design and manufacture the product. Any problems related to the design or manufacturing need to be addressed until Proton is satisfied with the result. Project implementation is given to the Production Engineer (PE), Product Planning And Control Engineer (PPCE), Manufacturing Engineer (ME) and Tooling Engineer (TE) at Ingress . The DE is involved in the project implementation as a leader. All of them are responsible in ensuring the smooth progression from product design to realization and this progress has to follow the master schedule.

d) Technical Support

Katayama acts as a consultant and is not involved directly in this case study. Its role is to give technical support related to the door sash to Ingress.

Ingress has a team for each project. Each team member will contribute his/ her expertise to the project. Figure 5.4 shows the organization chart for the project team. It is divided into five main tasks involving all person in charge in the product development process lifecycle. The team member includes Project Manager, Design Engineer, Production Engineer, Product Planning and Control Engineer, Tooling Engineer and Manufacturing Engineer. All the team members may not come from the same department. They may come from various departments such as Finance and Commercial Department, Localization Department, Equipment and Tooling Department; Coordination with Customer Department; Development Department and Manufacturing Department. However, the designing is done in the Development Department led by the Design Engineer. The Design Engineer also works with the design team.

The organization chart of the design team is shown in Figure 5.5. The team involves a manager (labeled as Design Engineer in Figure 5.4) , senior engineer, engineers, associate engineers and draft men. The manager and senior engineers are involved in designing the door sash, while the others are using CATIA modeling and drawing.

Normally, in a project, they do not have a specific task. They practice multi-tasking and share responsibilities for the project. Tasks are usually distributed according to the staff's experience and after discussing with the people in that team. For example, the DE is also the person who is involved in designing and fabricating the prototype. He also acts as PPCE. The post is there but the task is done by any engineer. However, in a large company, each personnel usually have a specific job.

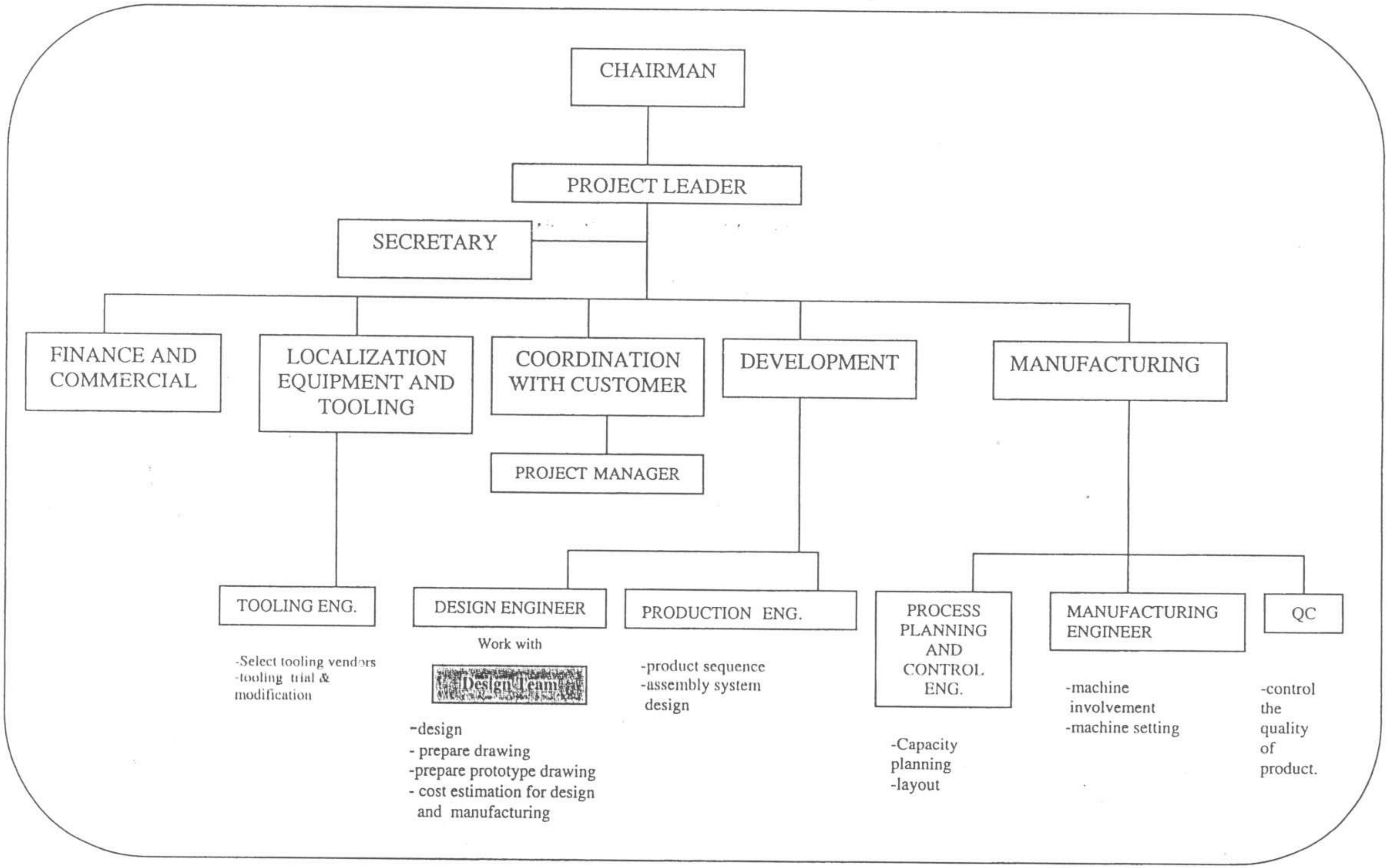


Figure 5.4: Project Organization chart for Ingress

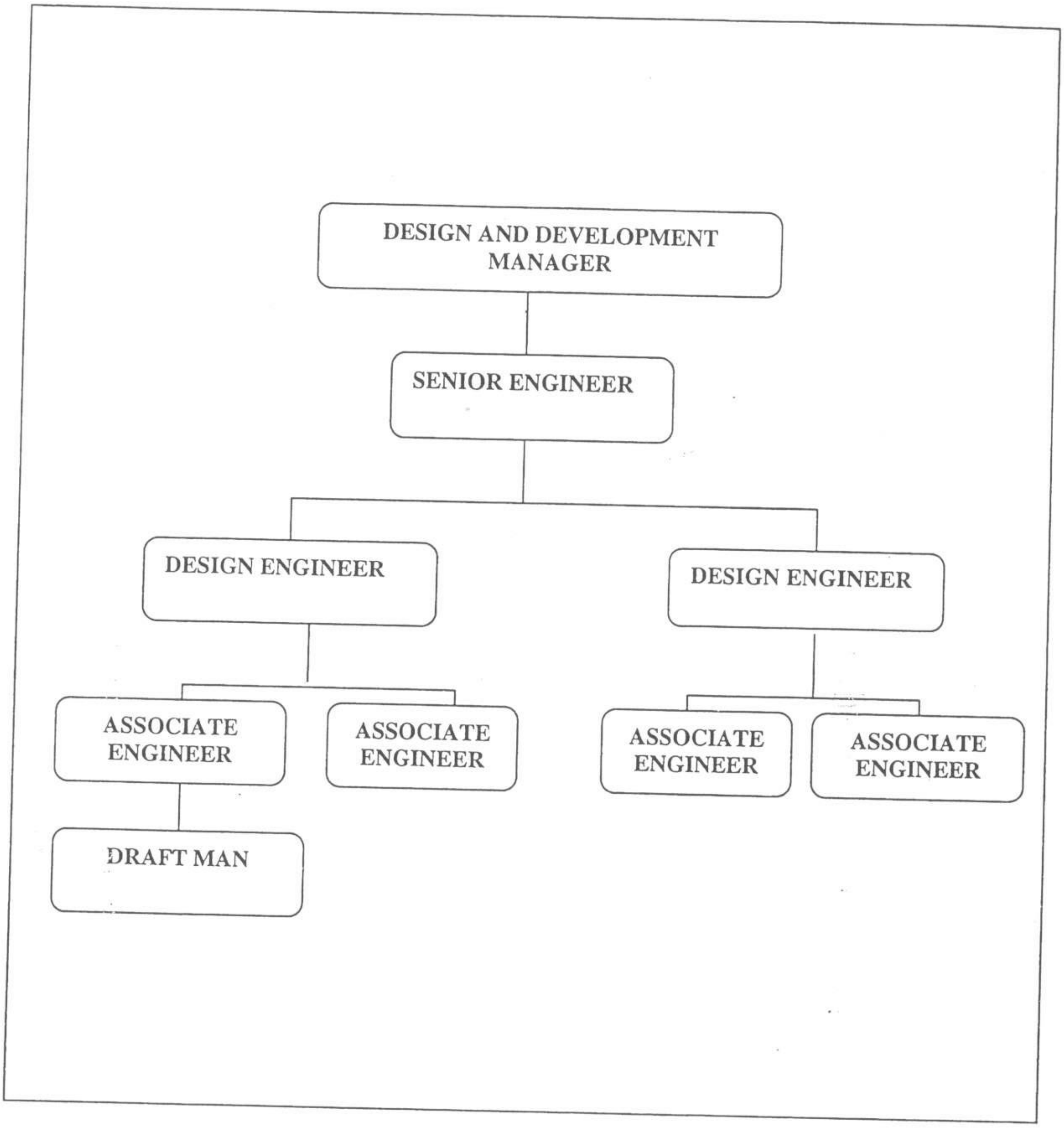


Figure 5.5: Organization chart for the design team at Ingress

Appendix C.1 to Appendix C.5 show in detail the responsibilities of the person in charge (PIC) of the product development stages.

The responsibilities in each product development stage (refer to Figure 5.3) will be discussed in detail below.

5.5.1 Responsibilities In Project Agreement Stage

Normally at this stage they will sign the project agreement, generate product designs and then evaluate the assemblability by using CAE modeling. In the existing activities, the assemblability is not a priority. All PIC are represented to contribute to what is needed in the product such as quality control, service, safety and performance. Appendix C.1 shows the responsibilities for PIC.

5.5.2 Responsibilities In Conceptual Design Stage

Here, the design will be generated and will be modified until satisfied by the team in Ingress and approved by Proton. The PIC is shown in Appendix C.2 to C.4.

5.5.3 Responsibilities In Detail Design Stage

Most of the persons in charge are involved in detailing the product specification such as parameters, quality, control, service, safety and performance. This stage also considers the assembly system design, process planning, tooling and prototype preparation and fabrication. The specific task is shown in Appendix C.3.

5.5.4 Responsibilities In Pre-production Stage

The activities for pre-production are shown in Appendix C.4.

5.5.5 Responsibilities In Production Stage

For model changes, the PIC is similar to those in the conceptual design. However, the need to have model changes will be identified by the Project Manager and Design Engineer. Refer to Appendix C.5.

5.6 Current Weaknesses and Limitations Of Existing Product Development Stages.

Discussions with the Project Manager and the analysis on the existing activities in Ingress revealed two types of weaknesses. The first is the weaknesses within Ingress itself and the second type is the weaknesses in the interactions between Ingress and its partner.

- **Weaknesses within Ingress**

The weaknesses within Ingress have been identified as follows:

i) Time consuming due to repetition of activities.

The design must be approved by Proton. Thus, several cycles of design changes usually occur before a design is finally approved. Some designs may face problems in assemblability and manufacturability. This will cause delays due to redesign and will delay the production stage until the customer is satisfied.

ii) Cost.
Many design changes occur before the final approval. This will propagate delays downstream and increase the development costs.

iii) No internal technical support and advice on assembly.
The company relies solely on the knowledge of its designers to optimize assembly.

- **Weaknesses between Ingress and the other party**

The weaknesses due to the interaction between Ingress and other party are:

i) Sometimes a product cannot be made as simple as possible because the product has been subcontracted to other companies. Although the number of parts may be reduced, this design for assembly effort will involve several companies and may involve complicated interactions and may also affect companies' policies.

ii) Time consuming because activities will involve different companies and require formal and informal discussions and meetings.

The interaction between the companies is very complicated. It is suggested that a better information flow would also help reduce the product development time.

5.7 IDEF0 Representation Of Product Development Stages

The flowchart in Figure 5.3 shows only the activities involved in the product development. However, the information flow involved is not shown due to its complexity. This will be represented using IDEF0 software, mentioned in Chapter 3 Section 3.5.

The activities in the product development process, the input, the output, the mechanism and the control activities are shown using this method in Figure 5.6. At this level, the main function is the performance of product development. Amongst the input (I), required into this process is product specifications, project brief, master schedule and external approval. The output (O) is the product design data, 3D data model and drawing, soft prototype and hard prototype. The control (C) is financial budget, product standard, quality control and time. The mechanisms (M) are the personnel, machines and equipment , and computer and software.

Figure 5.7 shows that 'Perform Product Development' can be further divided to other main activities: 'sign project agreement', 'perform conceptual design', 'perform detail design', 'perform pre-production' and 'perform production'.

Each of these activities have their own **I**nput, **C**ontrol, **O**utput and **M**echanism (ICOMs). They are different from one activity to another. The outputs from one activity can be the input of another activity or it can act as the controls. The total of information flow for this level must be equal to the total information flow from the preceding level, for example, A0.

Each of these activities/ stages can be further decomposed into more detailed activities/ stages. The number at the bottom right hand side indicates the number given to that activity number. Outside the box indicates the page number of IDEF0. For example, for activity 'perform conceptual design', it is given the activity number A2 and viewers can refer to page 3 (p.3) of the IDEF0 for the decomposition of 'perform conceptual design' that is 'perform data collection'

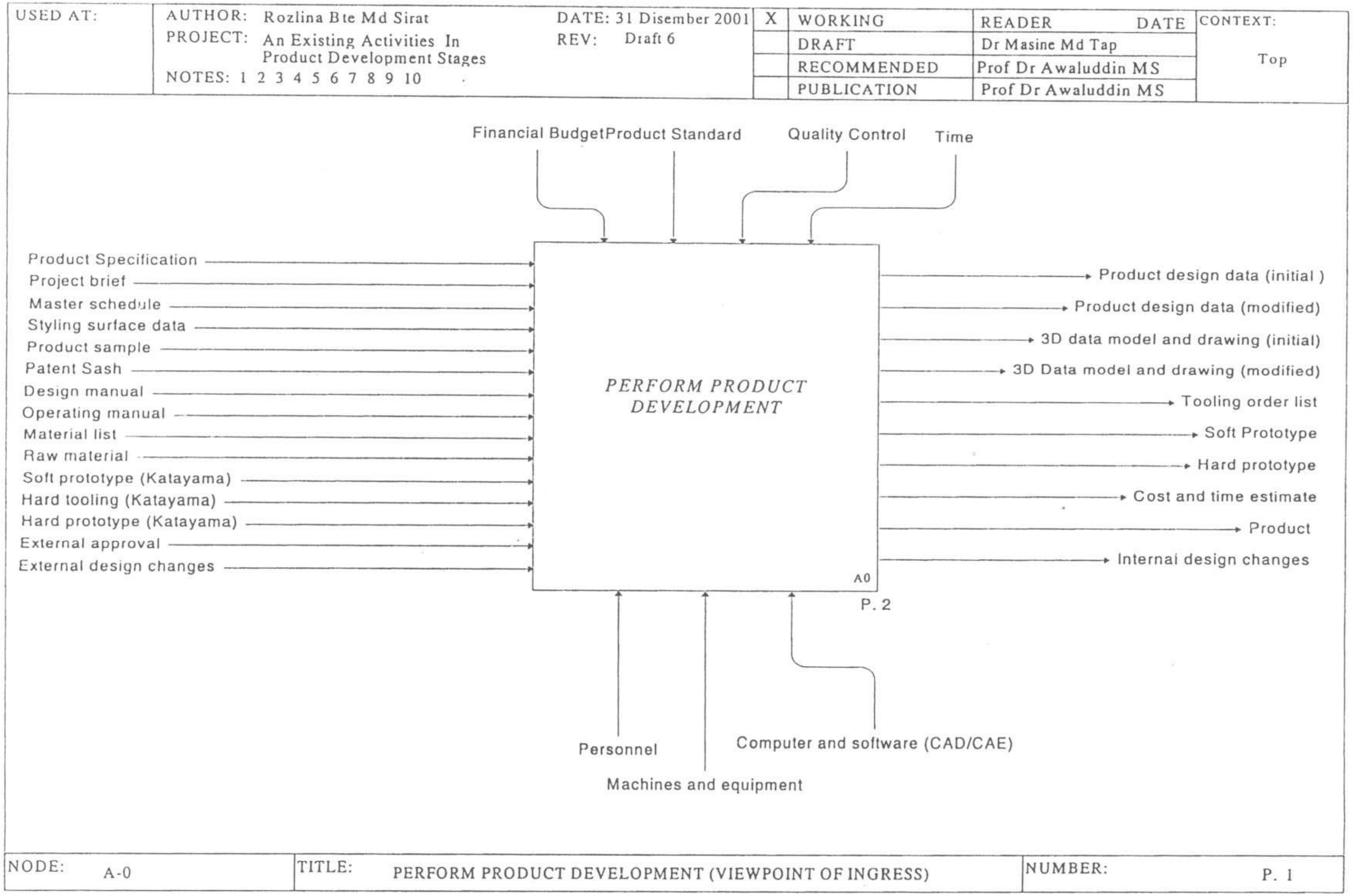


Figure 5.6: IDEF0 showing the existing product development carried out by Ingress.

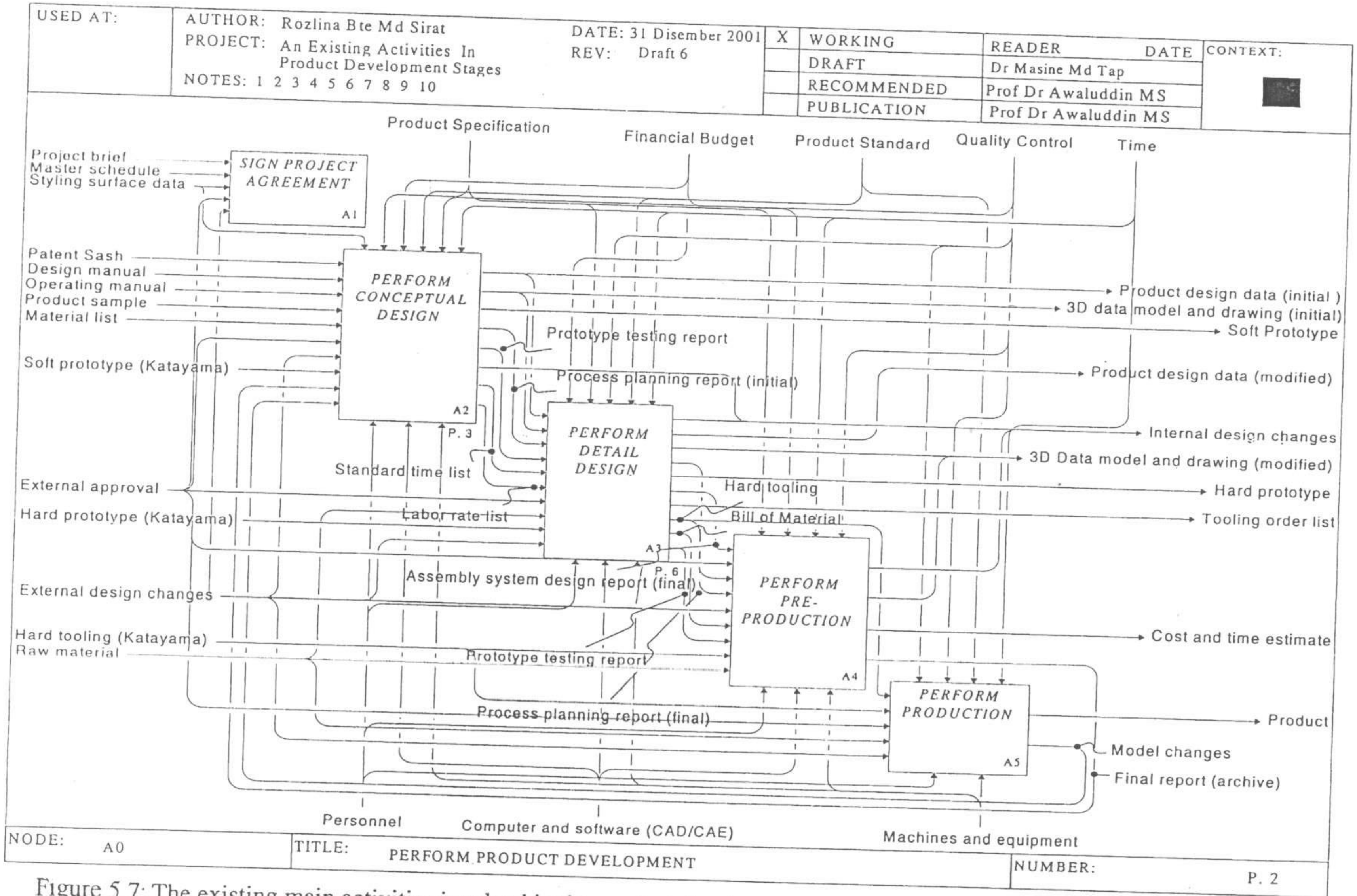


Figure 5.7: The existing main activities involved in the product development cycle.

(A21), 'generate conceptual design' (A22), 'perform CAE modeling and drawing' (A23) and 'produce, test and assemble soft prototype' (A24). Each of these activities have their own ICOMs. This will be further discussed in detail in Chapter V.

Summarily, product development stages can be divided into five main activities as shown below (refer to Appendix D.1 to Appendix D.8, represented by the boxes):

i) project agreement (denoted by A1)
ii) perform conceptual design (denoted by A2)
iii) perform detail design (denoted by A3)
iv) perform pre-production (denoted by A4)
v) perform production. (denoted by A5)

In this chapter, the detail activities presented by using IDEF0 are not elaborated. It will be discussed in Chapter V in proposing DFA implementation in product development stages.

5.8 Conclusion

This chapter has described the product development process for Ingress for a typical product. The interaction between the various parties involved that are Ingress, Proton and Katayama have also been elaborated. A detailed record of the activities of persons involved has been mentioned. The weaknesses of the existing design practice within the company and also between the other parties have been explained. An IDEF0 model detailing the activities and information flow between all the functions of the current product development process has also been constructed and shown.

CHAPTER VI

SAMPLE OF DFA ANALYSIS

6.1 Introduction

This chapter demonstrates the sample of DFA analysis conducted in the case study company to show the benefits of DFA.

6.2 Sample DFA Analysis Exercise Using DFA tool

It is important to conduct a pre- implementation DFA analysis exercise in order to indicate the nature and magnitude of savings that could be obtained should the company decide to adopt DFA. The objective is to convince the company that it is worth their time and effort if they adopt DFA into their existing practice. Many companies and their personnel are generally cautious and highly skeptical about adopting any new techniques and will resist changes vehemently. They will be less resistant and hesitant if they can see for themselves the advantages of adopting this technique.

Although a more complete quantification of benefits in terms of time and cost can only be derived after a thorough examination and evaluation of post DFA implementation, it is not possible to do so within the scope of this thesis. Hence this exercise is mainly demonstrative in nature and must be seen in that light.

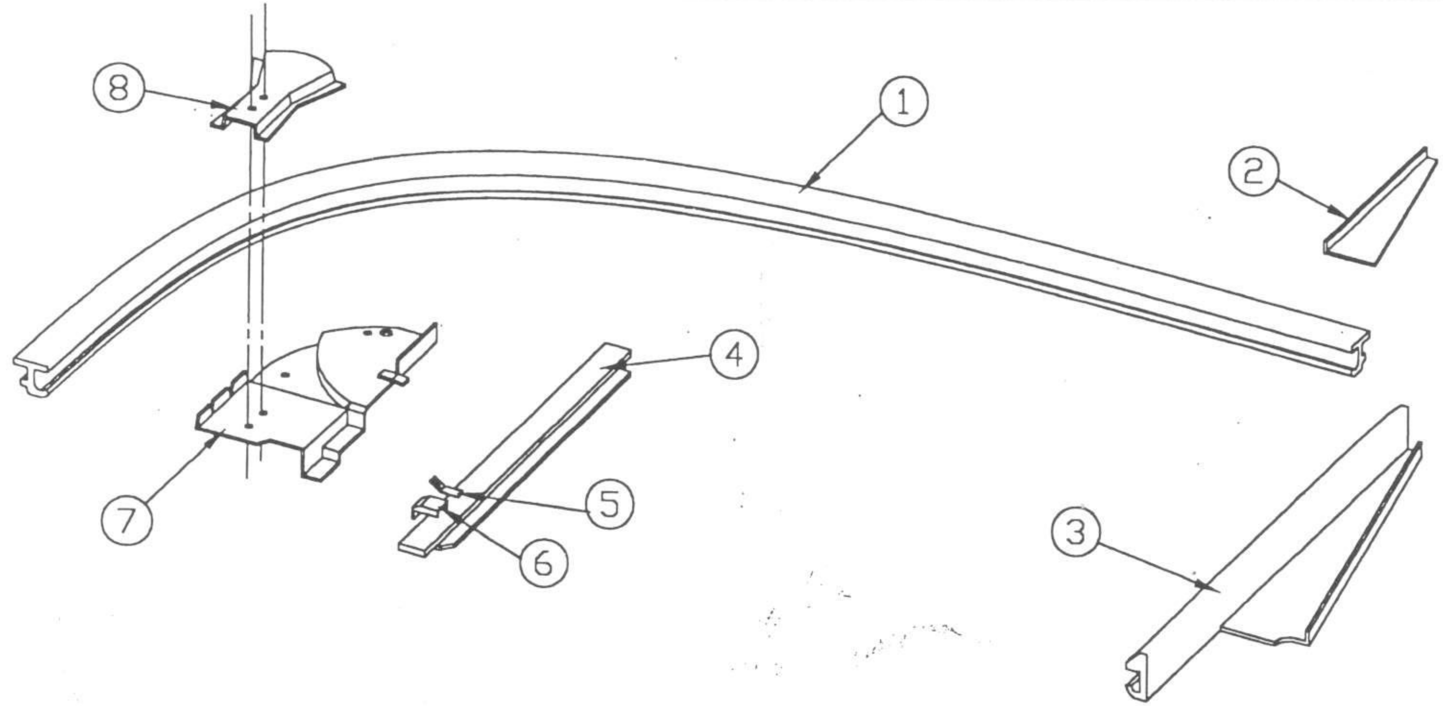
In this research, the author selects one product from a case study company, that is door sash as an example. The door sash is one of the components in a car door assembly.

The door sash consists of eight components or parts. Figure 6.1 shows the sketch of the door sash. Sash A is assumed as the basic part. Figure 6.2 shows the product structure of the door sash. Figure 6.3 shows the assembly flow chart for the existing door sash. The joining process used in the assembly is spot welding, Carbon Dioxide arc welding and plasma welding.

When a designer wants to apply DFA, the designer can do so in two major steps. The first steps, the designer needs to evaluate the assemblability of the product. In this example, the author has chosen a DFA computer software called TeamSET for the evaluation. The second step is to decide how to improve the assemblability of the product. This however, cannot be done by TeamSET. The designer needs to this based on his creativity. TeamSET can only assist by evaluating the assemblability of the redesigned product. The results may be compared to the previous design and improvement (if any) quantified.

6.3 TeamSET as a Tool of DFA analysis

TeamSET is used as a tool in the evaluation of assemblability. It uses the Lucas DFA method, which is one of the well- known tools in DFA.



NO	ITEM	UNIT
8	BRACKET B	1
7	BRACKET A	1
6	HARNESS BRACKET	1
5	FIXING BRACKET	1
4	C PILLAR	1
3	B PILLAR OUTER	1
2	B PILLAR INNER	1
1	A PILLAR (Sash A)	1

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FAKULTI KEJURUTERAAN MEKANIKAL

DESIGNED	ROZLINA BTE MD SIRAT	DATE	2001/10/10
CHECKED		DATE	
APPROVED		DATE	
DRAWN	ROZLINA BTE MD SIRAT	DATE	

PROJECT
GENERAL TOLERANCE _
TITLE SKETCH OF EXISTING DOOR SASH PRODUCT
SCALE : No scale
PAPER : A4
CLIENT
MATERIAL -
COLOR : -
DRAWING No.
REV. REV
PAGES 1

Figure 6.1: The sketch of the existing door sash.

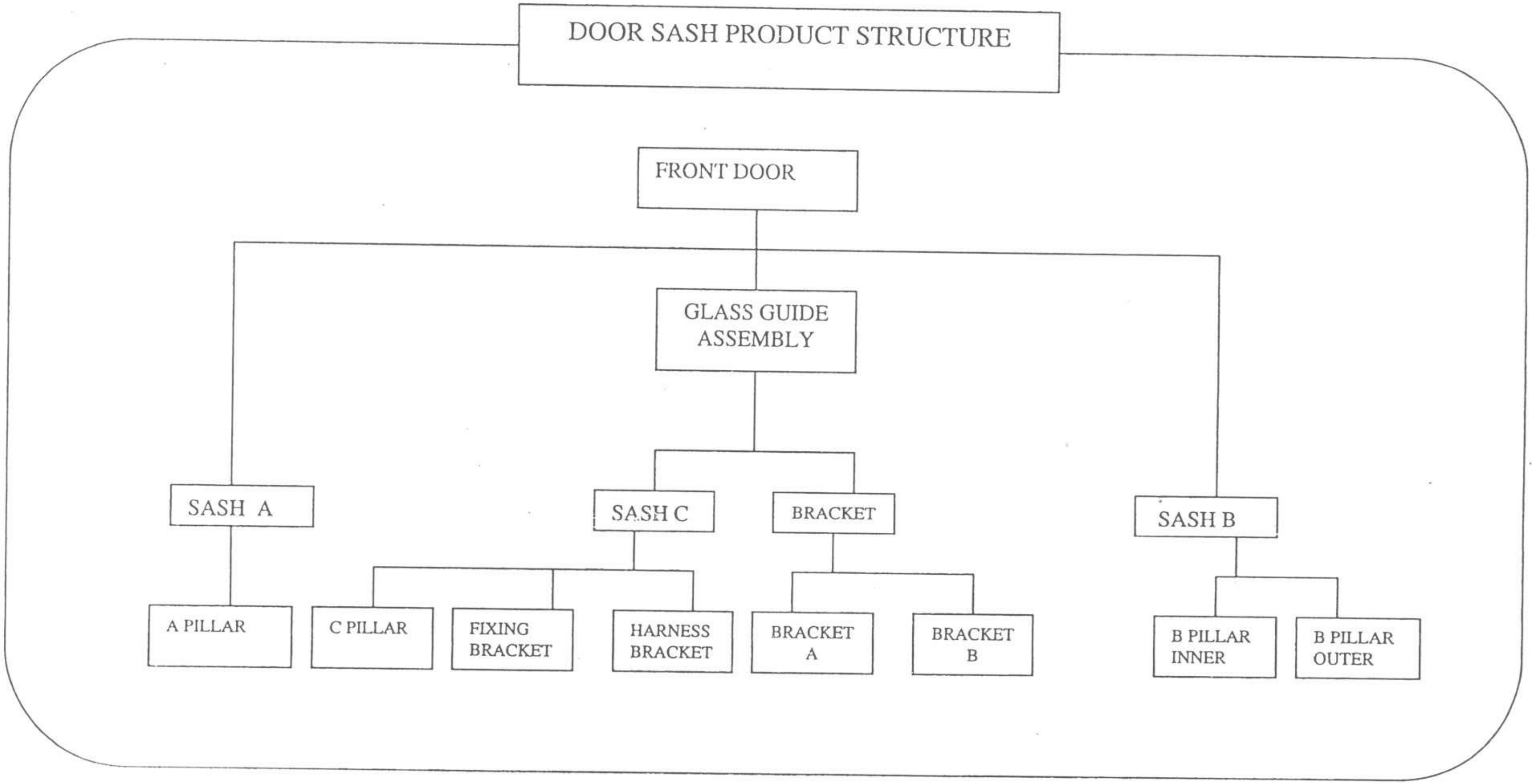


Figure 6.2: Product structure for existing door sash assembly .

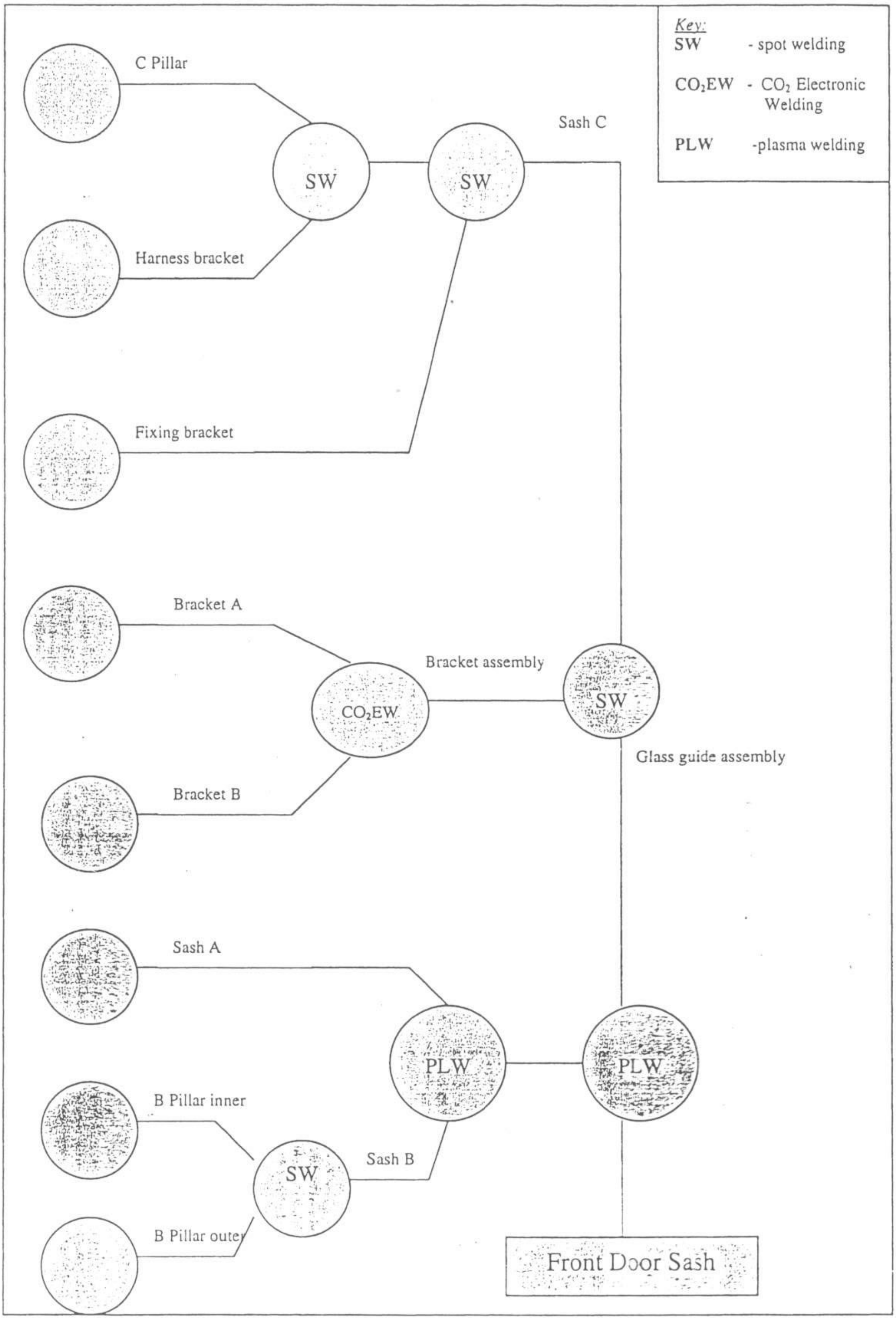


Figure 6.3: Assembly flow chart for existing door sash

TeamSET provides a package with six main applications. They are:

i) Quality Function Deployment (QFD)

ii) Control Concept Convergence (Con Con)

iii) Design For Assembly (DFA)

iv) Manufacturing Analysis (MA)

v) Failure Mode And Effect Analysis (FMEA)

vi) Design To Cost (DTC)

However, this thesis will only focus on the DFA application. The procedure to apply DFA is as shown in Figure 6.4.

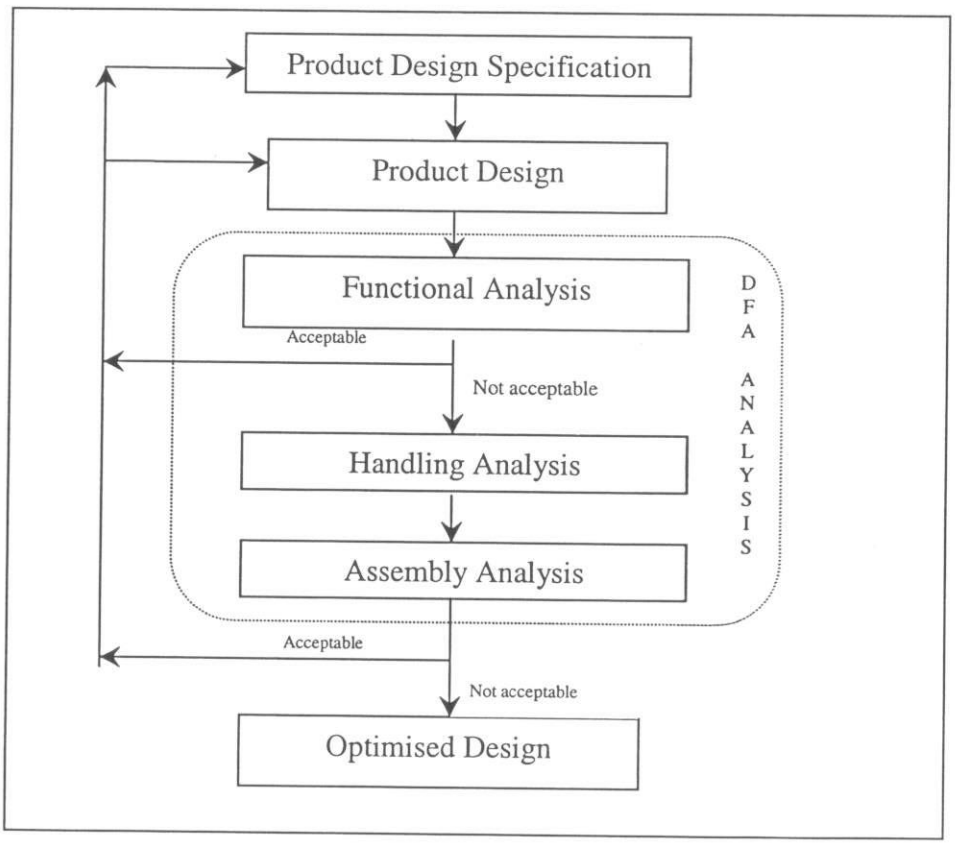


Figure 6.4: The DFA Evaluation Procedure by TeamSET (The CSC Manufacturing Industry Handbook, 1996)

TeamSET requires information on the product structure of the product to be analysed.

Then, from here, we can choose the required application. The interface is shown in Figure 6.5.

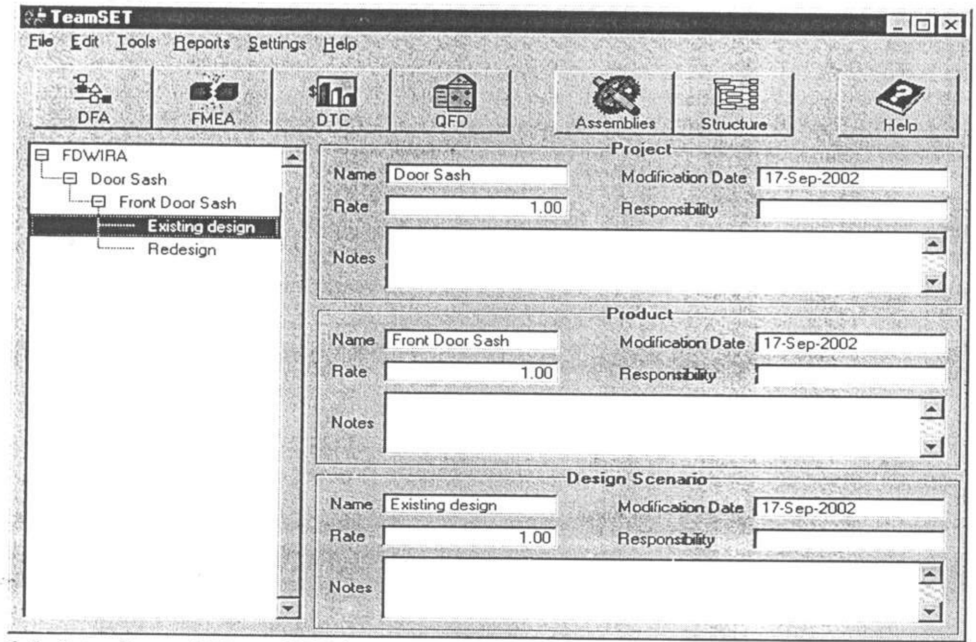


Figure 6.5: Interface of TeamSET in general.

6.4 Application of TeamSET Software

Figure 6.5 shows that the project's name is FDWIRA , the product is door sash. For this research, front door sash will be used as an example. The existing front door sash will be analysed and then a redesign will be proposed. Although the redesign can occur many times but in this example, it is shown once. If they can generate many design alternatives, the best design may be selected based on the results of the DFA analysis.

It also is assumed that in this example, DFA analysis is done in the conceptual design with minimum data. This means that the standard time. labor rate, the dimension and the cost need not be considered. Considerations given at this stage are the handling orientation, assembly orientation and functional analysis including the movement orientation. This is to show that DFA is still have the capable of evaluating and assisting the redesign exercise even in the early design stages when data is incomplete. If more information is available, better and more accurate analysis may be conducted.

A flow chart for existing design (refer to Figure 6.6 named as assembly report) is produced after designer select 'DFA' as the tool. In the flow chart, there are four analysis that can be conducted:

i. Functional analysis (shown as *FA*)
ii. Manufacturing analysis (shown as *MA*)
iii. Handling analysis (shown as *Hand.*)
iv. Assembly analysis (shown as *Assembly Flow*)

However, for this example, manufacturing analysis is not considered as it is not in the scope.

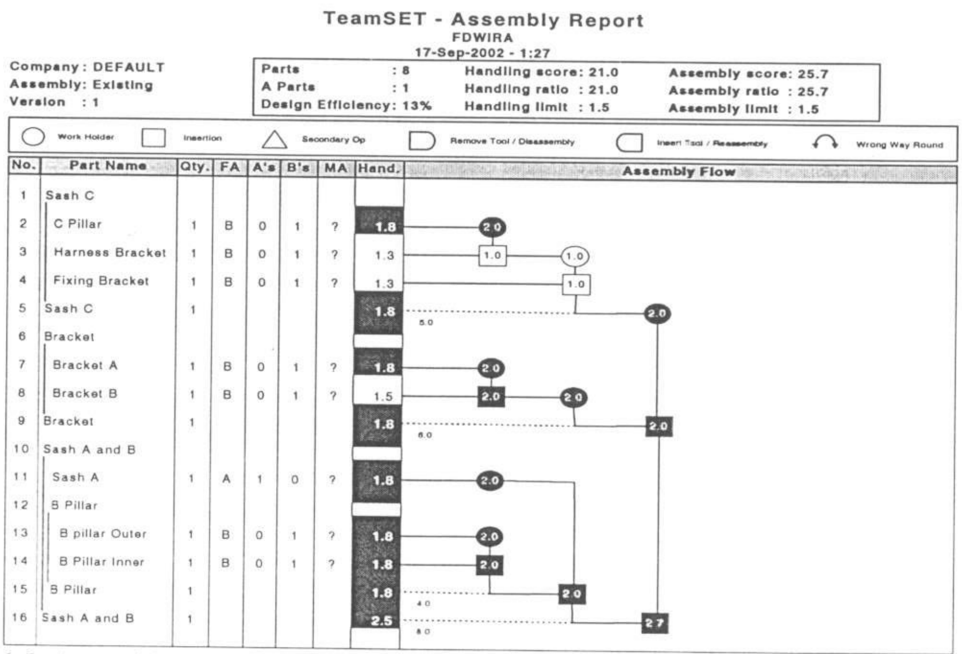


Figure 6.6: Assembly report for existing design.

In functional analysis, the company can determine which components are essential and which are not based on the product function (refer to Figure 6.7). It is used to reduce the parts count. The results of this analysis are given in the form of design efficiency. The target for an efficient design in DFA is a value of more than 60%. The existing design efficiency of the part is 13%.

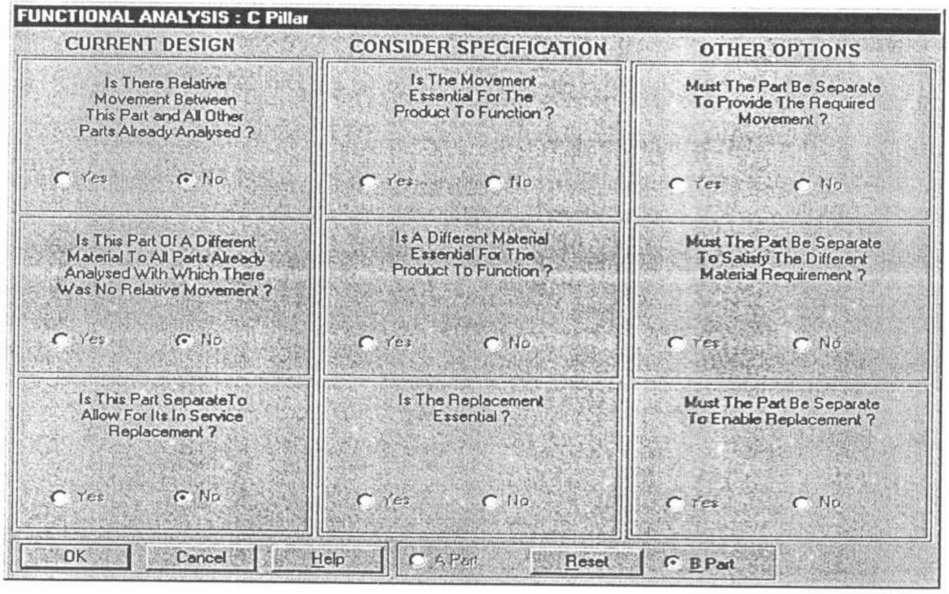


Figure 6.7: Functional analysis by TeamSET

Handling analysis is done to simplify the handling and orientation required for assembly. It will give the rate of the handling of the individual components from bulk to the point of assembly. Subsequently, it will identify any difficulties associated with the method of handling. The analysis will result in the handling ratio. A good handling ratio is a value less than 2.5. The assembly flow chart shows that the existing handling ratio is 21.0. Figure 6.8 shows the question that need to be answered for the manual handling analysis. The result will be shown in the column title 'FA' in Figure 6.6.

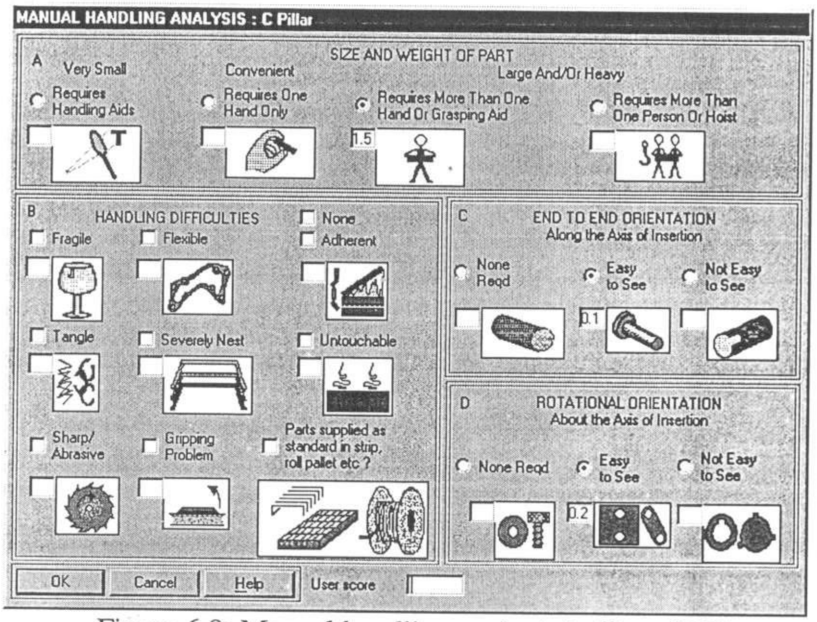


Figure 6.8: Manual handling analysis in TeamSET

Assembly analysis is used to simplify the assembly. It highlights inefficient assembly which may cause rework and product failures. Assembly analysis requires the designer to identify the insertion process as shown in Figure 6.9. For additional information, designer may also identify secondary operation as shown in Figure 6.10. The analysis will come up with an assembly ratio. A good assembly ratio has a value less than 1.5. The existing assembly ratio is 25.7 which is shown in the assembly flow chart.

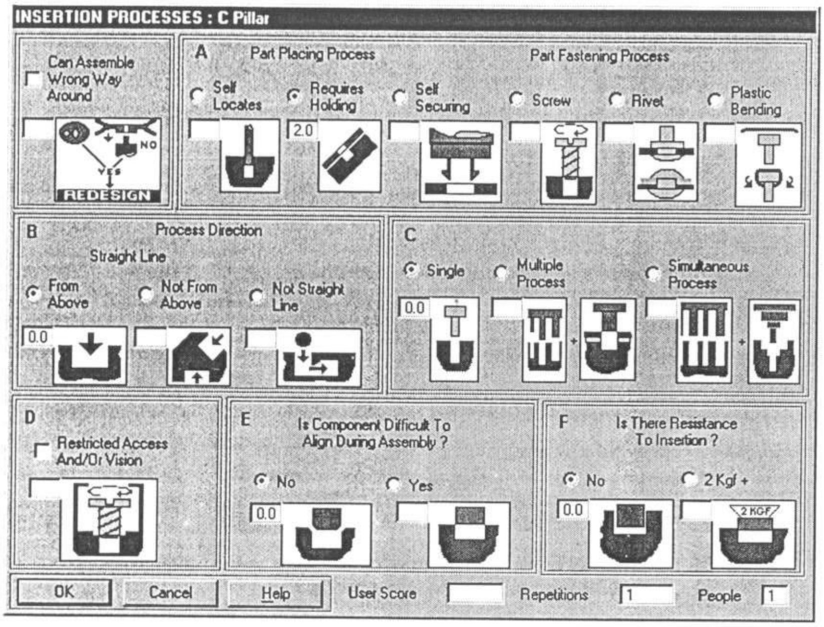


Figure 6.9: Insertion operation while assembly analysis

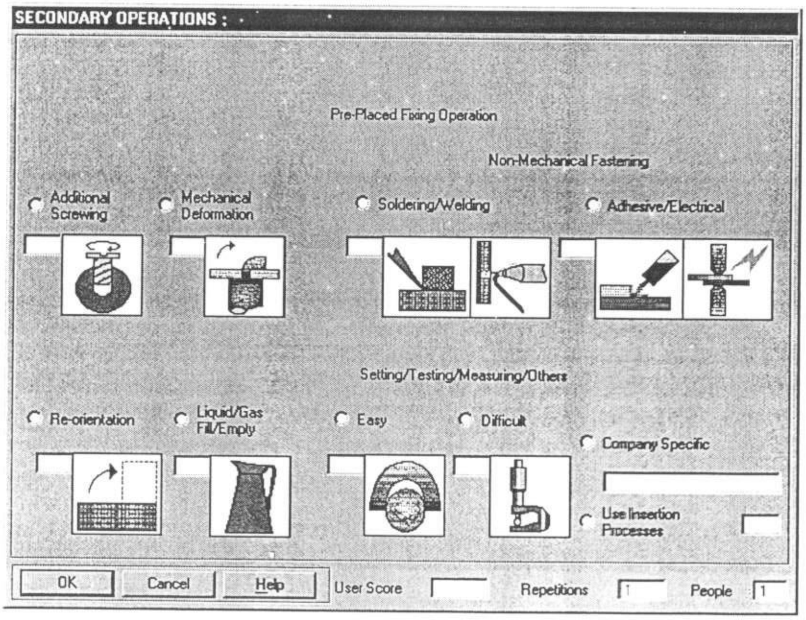


Figure 6.10: Secondary operation in assembly analysis

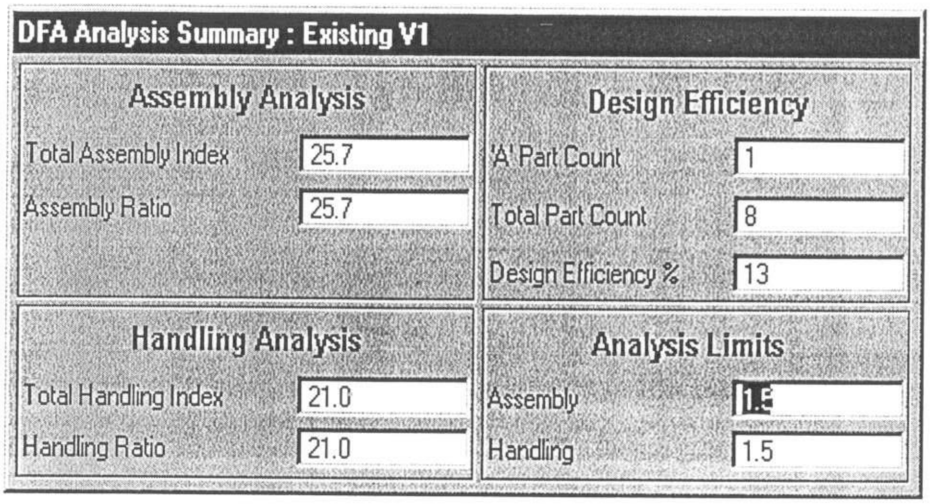


Figure 6.11: DFA analysis summary for existing design.

Overall, the DFA analysis summary is shown in Figure 6.11. It indicates that the existing design needs to be redesigned as the values of the results are below that required for a good assembly.

After redesign, the existing design data is compared to the redesigned data. Table 6.1 and Figure 6.12 show the redesigned door sash where the number of parts has been reduced from 8 to 6. The design efficiency is increased from 13% to 17%. The existing handling ratio is reduced from 21.0 to 15.2 after redesign. The existing assembly ratio is 25.7 and reduced to 20.0 after redesign. Time reduction is also shown in the analysis (refer to Table 6.1). The production time has been shortened (to 25%), so as the handling time (to 28%) and assembly time (to 22%). Consequently, the labor time shown has been reduced to 25%.

The redesigned door sash is shown in Figure 6.13. The product structure and assembly flow chart are shown in Figures 6.14 and 6.15 respectively.

Table 6.1 : The report of assembly comparison between existing door sash and redesign door sash by DFA

TeamSET –DFA Assembly Comparison

	Existing	Redesign 1	Improvements
Production time	46.7	35.2	25%
Handling time	21.0	15.2	28%
Assembly time	25.7	20.0	22%
Labor (time)	46.7	35.2	25%
Parts (A and B)	8	7	25%
B Parts	7	5	29%

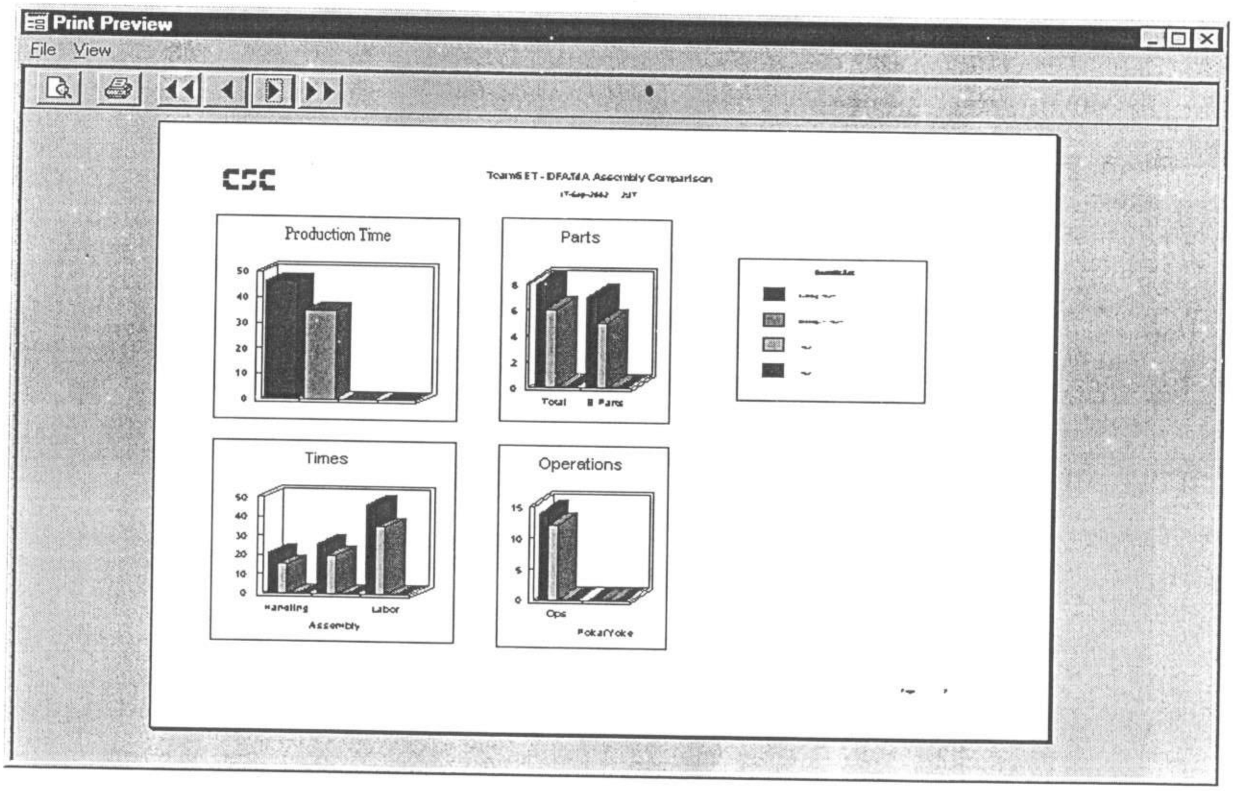
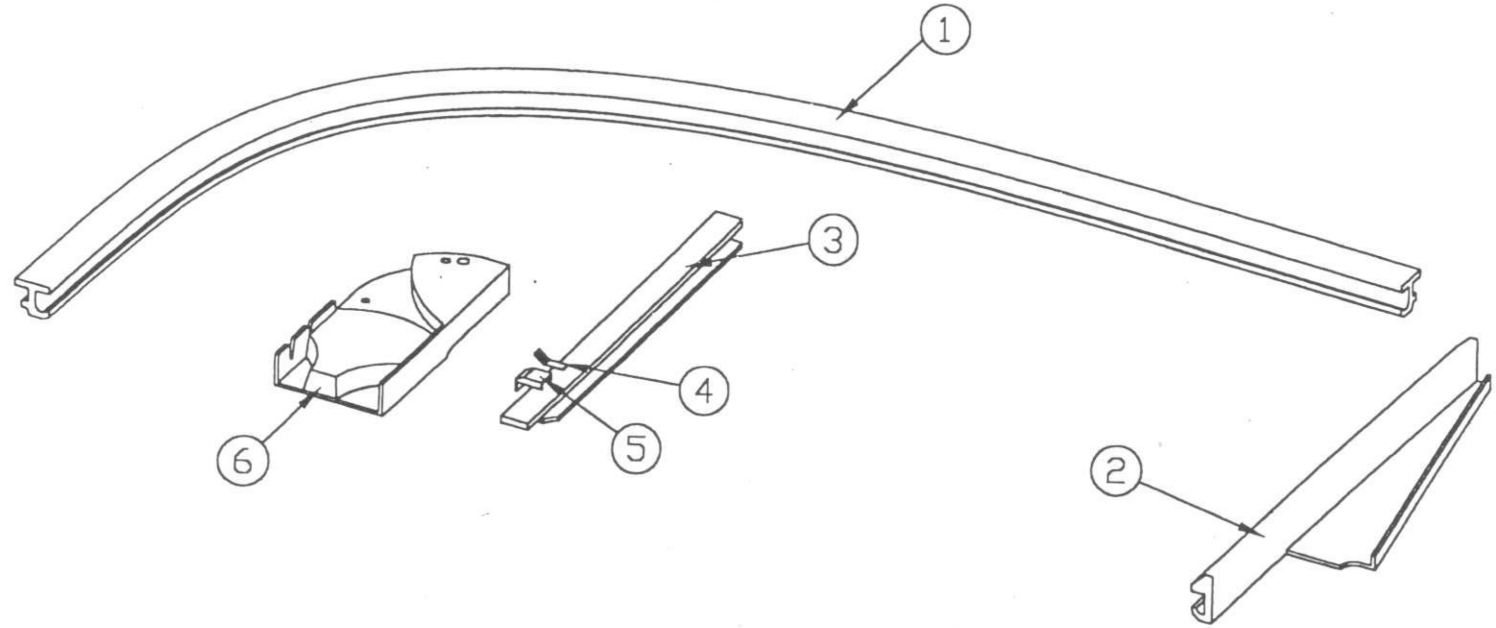


Figure 6.12: Histogram chart produced by TeamSET



NO	ITEM	UNIT
6	BRACKET	1
5	HARNESS BRACKET	1
4	FIXING BRACKET	1
3	C PILLAR	1
2	B PILLAR	1
1	A PILLAR	1

UNIVERSITI TEKNOLOGI MALAYSIA
FAKULTI KEJURUTERAAN MEKANIKAL

DESIGNED	ROZLINA BTE MD SIRAT	DATE	2001/10/10
CHECKED		DATE	
APPROVED		DATE	
DRAWN	ROZLINA BTE MD SIRAT	DATE	

PROJECT

TITLE: SKETCH OF REDESIGN DOOR SASH PRODUCT

CLIENT

MATERIAL: -
COLOR: -

GENERAL TOLERANCE -
SCALE: No scale
PAPER: A4
DRAWING No.
REV. REV
PAGES 1

Figure 6.13: The sketch of the redesigned door sash.

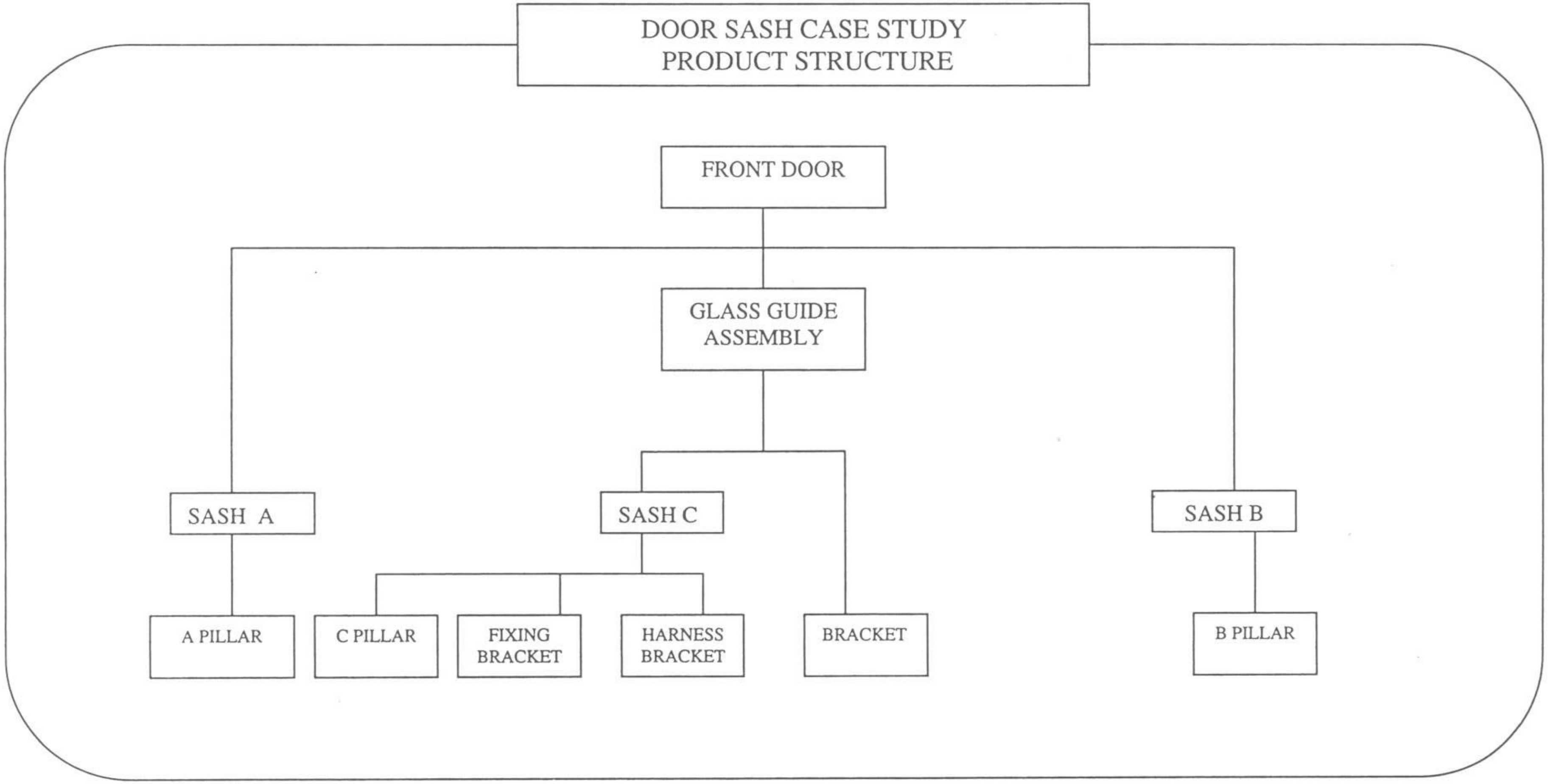


Figure 6.14: Product Structure for the redesigned door sash assembly.

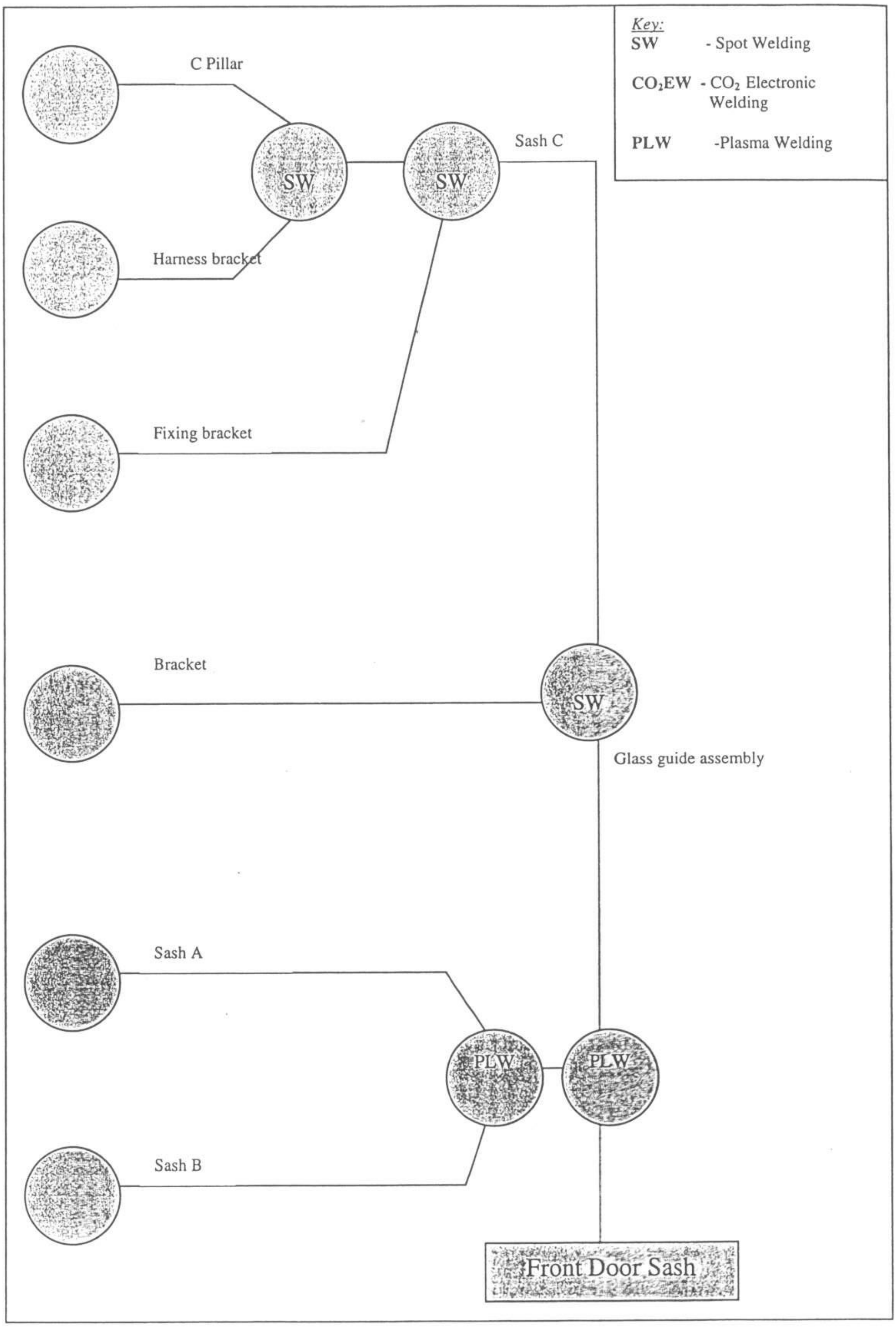


Figure 6.15: Assembly flow chart for redesigned door sash

The case of DFA technique, in particular the TeamSET software has proven to be quite effective and suitable as a tool to be used for DFA analysis.

6.5 Conclusion

The results of DFA analysis shows that TeamSET is capable of assisting a designer in evaluating assemblability of a product. Although the software cannot redesign the product, it can assist the designer by evaluating the redesign product and thus the improvement (if any) can be quantified. The software also shows that DFA can reduce assembly time and number of parts. Thus, a company can benefit from the implementation of DFA through savings in time and number of parts involved in assembly.

i) Conceptual design stage
ii) Detail design stage
iii) Pre-production stage
iv) Production stage

A company may implement DFA in any one or all of these stages. Figure 7.1 shows a proposed flowchart and indicates where DFA can be implemented in the product development stages. The impact of implementing DFA in each stage is discussed in the following section.

7.2.1 DFA In Conceptual Design Stage

Implementing DFA in this stage has its advantages and weaknesses. One of the advantages is that it is a pro- active process and involves low commitment and cost. During the conceptual design stage, the designer attempts to translate a given set of design requirements into some physical components and the assembly sequence such that the design requirements are satisfied. At this stage, the designer is not concerned with the detail but is more concern with the ideas of the actual product. Qualitative rules and guidelines related to product structure, assembly of compliant parts, assembly flexibility are applied to the selected concept. Redesign will be carried out if the selected conceptual design does not meet the assemblability rules and manufacturing rules. That is the reason why DFA must involve teamwork.

However, at this stage, the data required for design and analysis is always incomplete and sometimes fuzzy. Thus, implementing DFA analysis at this early stage requires the ability to deal with incomplete or fuzzy data. Hence , it may be necessary to redefine the DFA methodology to ensure its suitability for analysis using partially defined component geometry.

Chapter VII

PROPOSAL FOR DFA IMPLEMENTATION

7.1 Introduction

In this chapter, the proposal for DFA implementation is discussed. The result of a sample DFA analysis exercise that was carried out on existing part is reported. The possibility of evaluating the assemblability by DFA in the appropriate stages is explained. A framework is developed as a guideline for Ingress and IDEF0 is used in detailing the flow of information for implementing DFA. The roles of the persons assigned with the responsibilities for DFA implementation are also discussed.

7.2 Proposed General Framework For DFA Implementation In Product Development Process For Ingress.

The author has identified several stages within the company's product development where DFA can be implemented. Based on the product development cycle, DFA can be implemented in four stages that is:

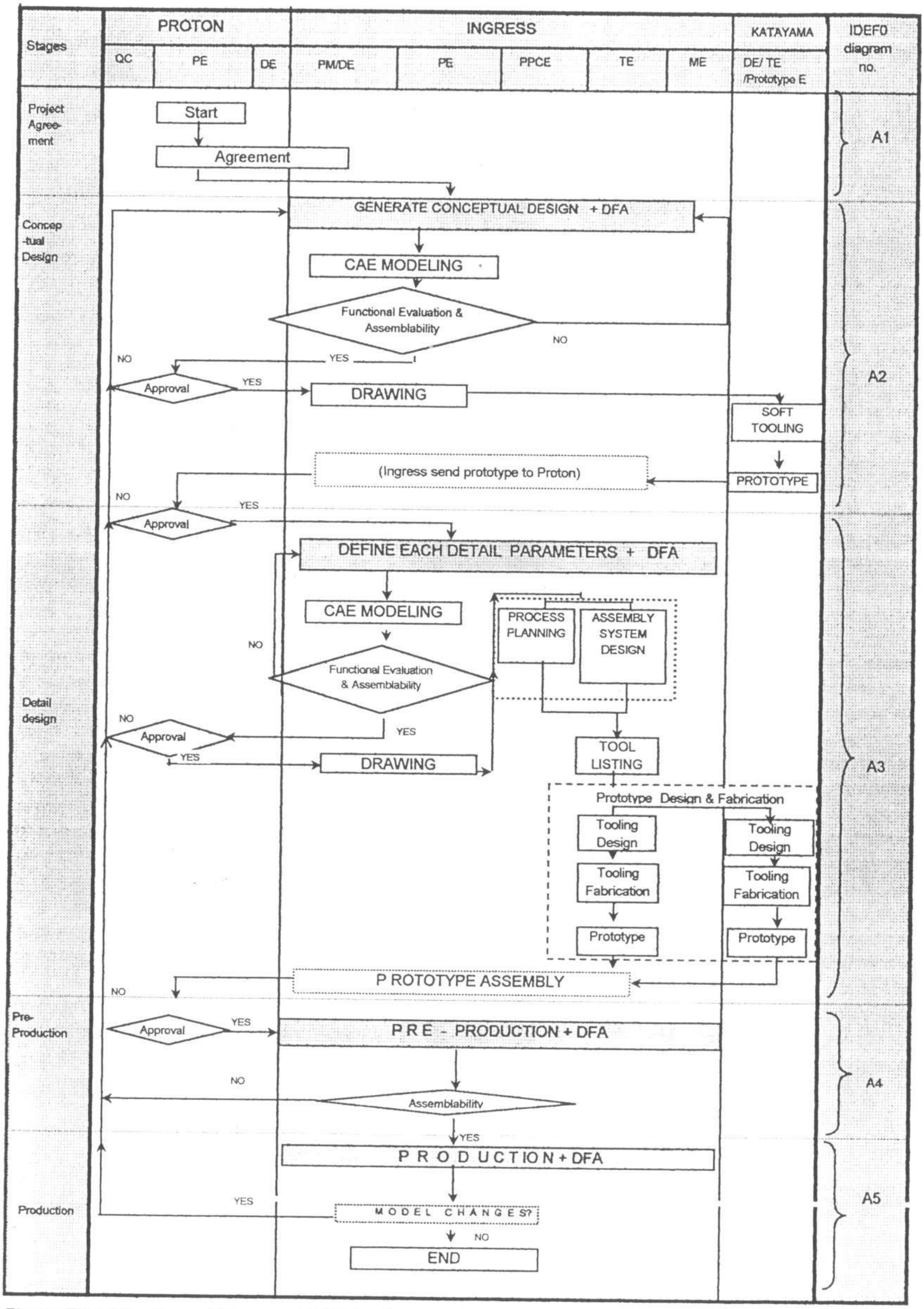


Figure 7.1 : Flowchart of Proposed DFA Implementation In Ingress's Product Development Cycle

The implication of implementing DFA in this stage have been identified as:

i) The DFA analysis must have the ability to deal with incomplete data. For example, the DFA analysis conducted on the door sash was based on estimated functional data, handling data, assembly data and flow chart.

ii) With the introduction of DFA, assembly sequence can now be considered in this early stage and this will enable designer to conduct functional analysis, manufacturing analysis, handling analysis and assembly analysis, allowing design improvements to be done at an earlier stage where total cost due to changes is minimum.

iii) In the existing practice (without DFA), Ingress used CAE modeling to evaluate the product design. With the introduction of DFA, Ingress can still utilize CAE modeling to assist in evaluating the design assemblability logic, something TeamSET is not capable of doing.

7.2.2 DFA In Detail Design Stage

At this stage, the data available is more complete and this eases the use of DFA. All the data from functional analysis, handling analysis, assembly analysis and flow chart can be traced more easily. The results of the analysis at this stage will be more accurate than in the previous stage. Validation of the results can be conducted more easily. If the company has not considered DFA in the conceptual design stage, then this is the next stage where the DFA analysis can be introduced and performed for the first time. There are also restrictions as to the constraints in obtaining design changes compared to all the other stages.

7.2.3 DFA In Pre-production Stage

At this later stage, the implementation of DFA will be less effective compared to the previous stages. At this stage, any change to the design will incur cost and time. Approval for the design changes must also be obtained first. However, sometimes changes to the product design may need to be done at this stage, for example, when customers requires minor modification of parts. So, this is where DFA can also play its role. The degree of changes may also vary. Although it is anticipated that normally all the modification at this stage may be minor, it cannot be discounted that the change may be major in certain circumstances.

7.2.4 DFA In Production Stage

Product changes may be initiated as the product gains maturity in the market place. To maintain market share, new product variants may be required. Minor modification and sometimes major modification may use existing data but if a complete model change is required then incomplete data may have to be used for analysis.

7.3 An IDEF0 Presentation for DFA Implementation In Product Development Stage

The implementation of DFA in each development stage will require information to evaluate the assemblability of product design. IDEF0 is used to show the information flow involved. The information flow in each stage will be discussed below. Refer Figure 7.2 for IDEF0 diagram A0. The system viewpoint is essentially the same as in the current state (refer to Figure 5.6 and Figure 5.7). The title is still "Perform Product Development".

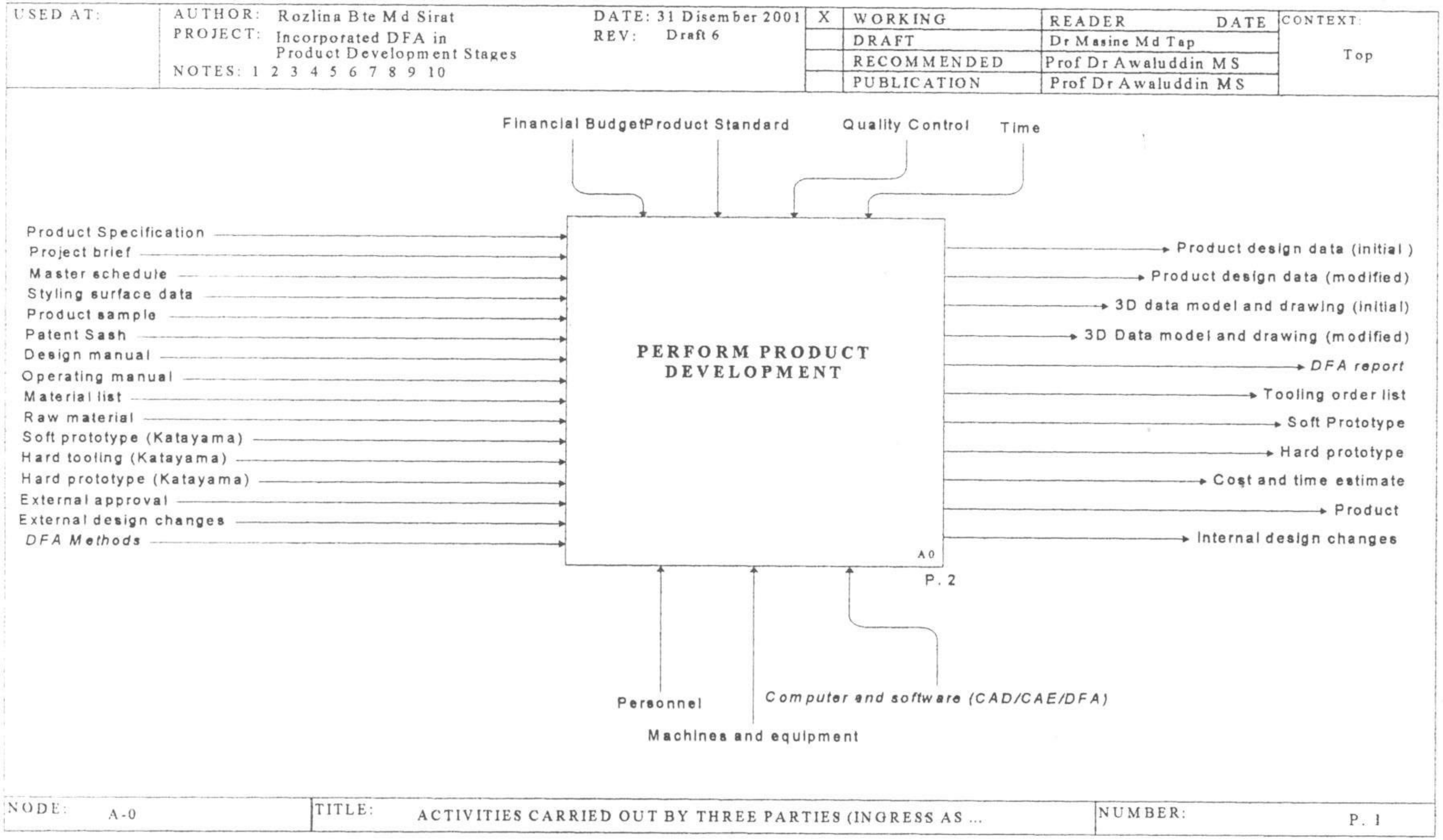


Figure 7.2: An IDEF0 shows the proposed incorporation of DFA in product developoment (general).

The product development is decomposed into five activities (refer Figure 7.3) and is reflective of the five stages of the product development cycle (Figure 7.1):

i) Sign project agreement (A1)
ii) Perform conceptual design and DFA (A2)
iii) Perform detail design and DFA (A3)
iv) Perform pre-production and DFA (A4)
v) Perform production and DFA (A5)

7.3.1 Information Flow In 'Sign Project Agreement' (A1)

In this stage (A1 in Figure 7.3), Ingress will sign the agreement after viewing the project brief, master schedule and styling surface data from Proton . A master schedule agreed by both parties is drawn out and styling surface data is suggested as a rough guideline in designing the product. Here no changes are envisaged for the existing practices. As mentioned above, Figure 7.2 shows the product development activities in overview and Figure 7.3 shows the stages involved in the product development respectively.

7.3.2 Information Flow In 'Perform Conceptual Design and DFA' (A2)

This stage has been decomposed to several functions (see Figure 7.4):

- Collect data (A21)
- Generate conceptual design (A22)
- Evaluate assemblability by DFA (A23)

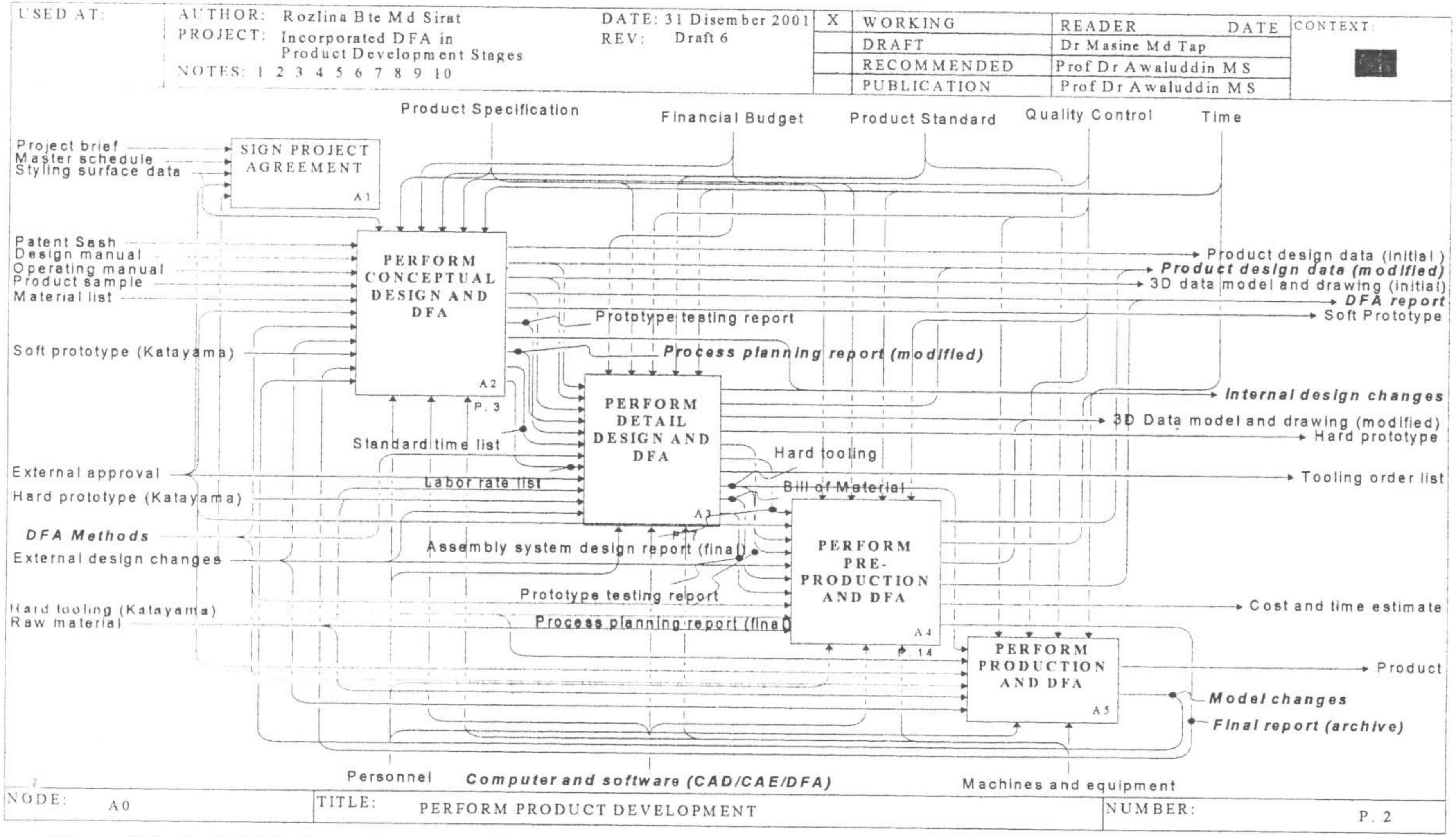


Figure 7.3: An IDEF0 shows the proposed incorporation of DFA in product development (detail).

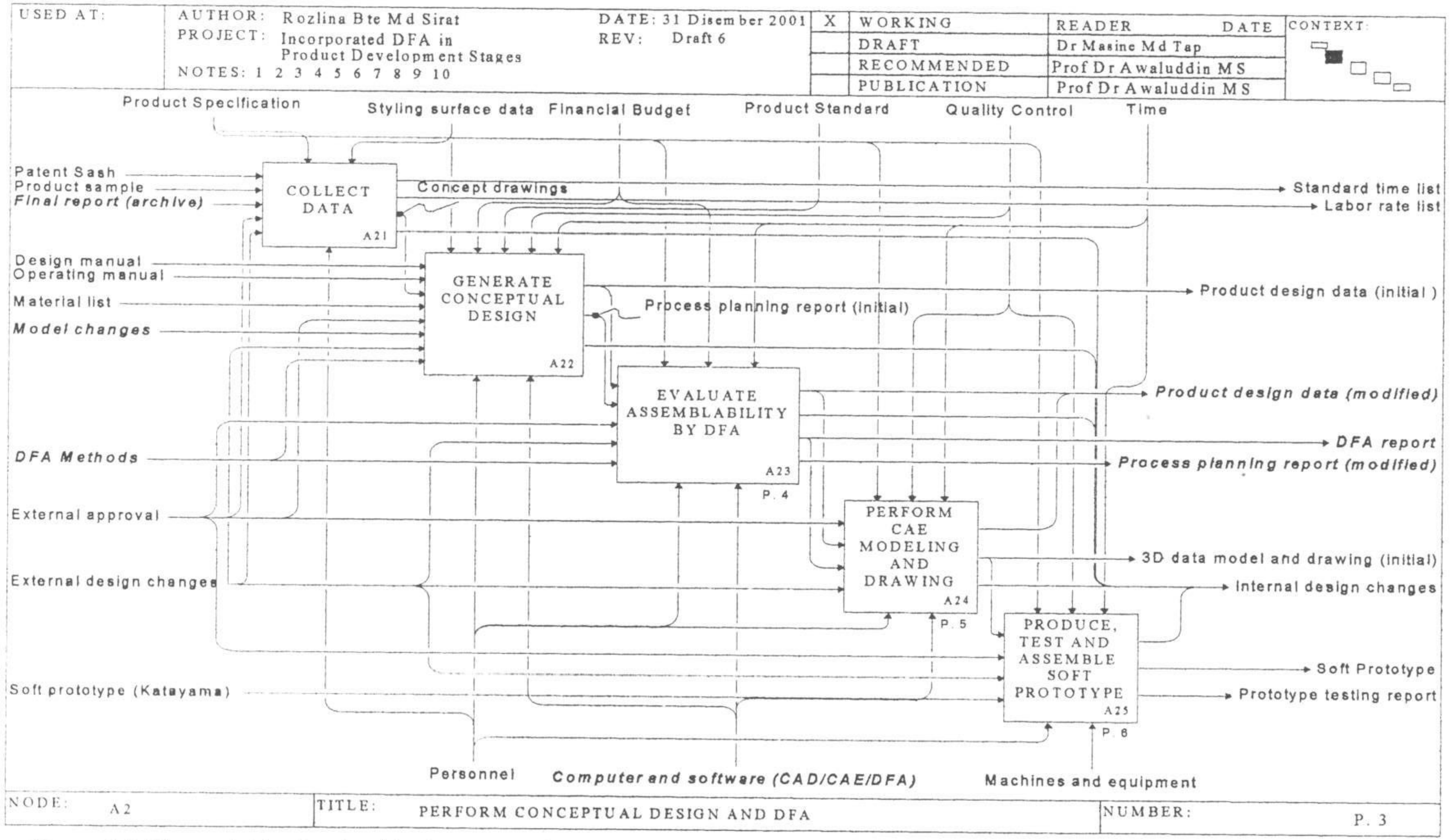


Figure 7.4: The activities involved in the proposed incorporation of DFA in conceptual design stage.

- Perform CAE modeling and drawing (A24)
- Produce, test and assemble soft prototype (A25)

The conceptual design stage begins with data collection (A21) followed by generation of product design (A22). The assemblability of the resulted product design will then be evaluated by using DFA (A23). Then, CAE modeling and drawing will be produced (A24) and sent to the detail design stage (A3). The prototype will be developed to be tested for their performance and assemblability (A25).

7.3.2.1 Collect Data (A21)

In this activity, data will be collected from a few sources such as other patent search and product sample. If it is a new product, it will be based on patent, reference book and analogy. Customer feedback can also be used as a source of ideas. Product specification from Proton and Ingress will be used as data and guidelines in generating the conceptual design. After considering data and feasibility, this is then passed to the following activity that is 'generate conceptual design' (A22). The data that will be the output from the activity are concept drawing, standard time and labor rate list.

7.3.2.2 Generate Conceptual Design and DFA (A22)

With data from the data collection activity, the project team will produce several concept drawings but only one will be selected (refer Figure 7.4). The concept drawing is selected based on the performance, environment, maintenance, competition, shipping, packing, quantity, quality, size, weight, ergonomic and also assemblability. Consideration is also given based on the design manual, operating manual and the material that will be used. The assemblability of product design will be evaluated by DFA. The product design data (initial) and process planning report (initial) will be sent to the detail design stage (A3).

The assembly planning (initial) is considered in this stage to get the alternative assembly sequence. The assembly planning includes the selection of assembly techniques and production equipments in terms of assembly rates, model mix and the critical assembly steps. However, to improve the assembly, DFA software is proposed for quantitative evaluation. Then, the DFA report is produced.

Model change occurs when required by Proton after the production stage or when Ingress forwards an idea based on the DFA result. This can happen when Proton or Ingress can justify the benefits of these changes even if it is quite late in the product development.

All these activities are controlled by product standard and quality control and constrained by the financial budget and time schedule.

7.3.2.3 Evaluate Assemblability By DFA (A23)

Figure 7.5 shows in detail the decomposition of activity 'evaluate assemblability by DFA'. It consists of :

- Evaluate first design (A231)
- Do redesign (A232)
- Make comparison (A233)

In the case of a new product, the company can generate more than one alternative in developing the product design. For the assemblability case, it will be

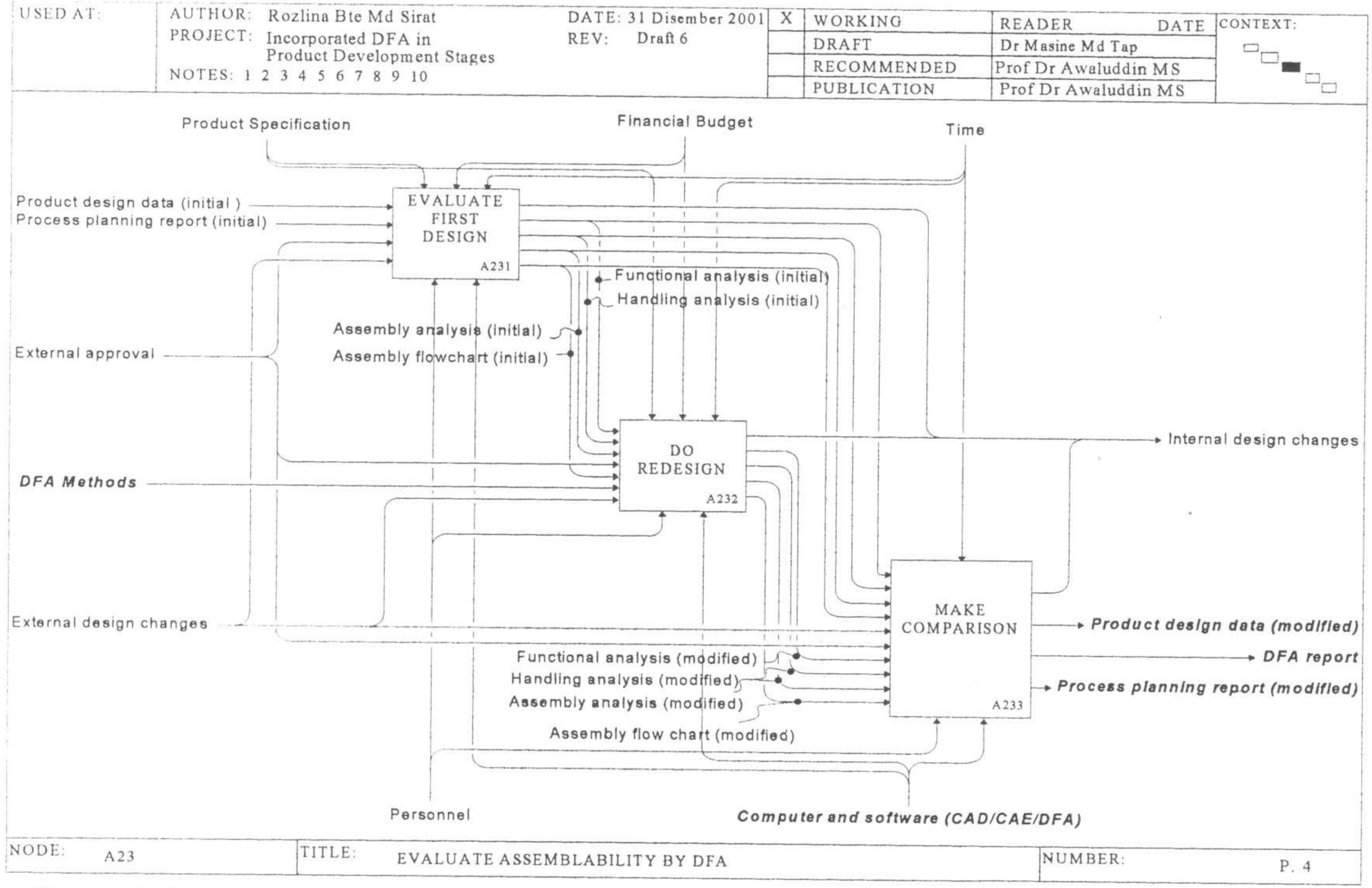


Figure 7.5: The decomposition of 'Evaluate Assemblability by DFA' in conceptual design.

evaluated by the project team. Assembly flowcharts are sketched and used to evaluate assemblability (this is called assembly planning as mentioned in section 7.3.2.2). The first alternative will be evaluated as a first design (A231). Then, the other alternatives are assumed as the redesign (A232). There could be more than one redesign activity. Each of them will go through functional analysis, handling analysis, assembly analysis and the assembly flowchart. Then, comparison (A233) will be done for all the designs. Here, the best design alternative based on the ratio or percentage of all the three analyses is selected.

All members, led by the Design Engineer (DE) need to contribute information and this information is used to answer questions on functionality, difficulty of assembly in handling and orienting, the assembly sequence and cost of component. Suggestion or other alternatives in the product assembly is also discussed by the team.

DFA report will be proposed and sent to the detail design stage. The selected product structure shown in the product design data (modified) will be done as a report and as an input to CAE modeling and drawing.

7.3.2.4 Perform CAE Modeling and Drawing (A24)

The activities of CAE modeling and drawing are decomposed into (refer to Figure 7.6):

- Model by CAE (denoted by A241)
- Evaluate assemblability (denoted by A242)
- Perform drawing (denoted by A243)

Product design data (modified) and DFA report are the outputs from A23 (evaluate assemblability by DFA). They will also now become the input to CAE modeling. After the product design is modeled, the initial 3D Data model will be

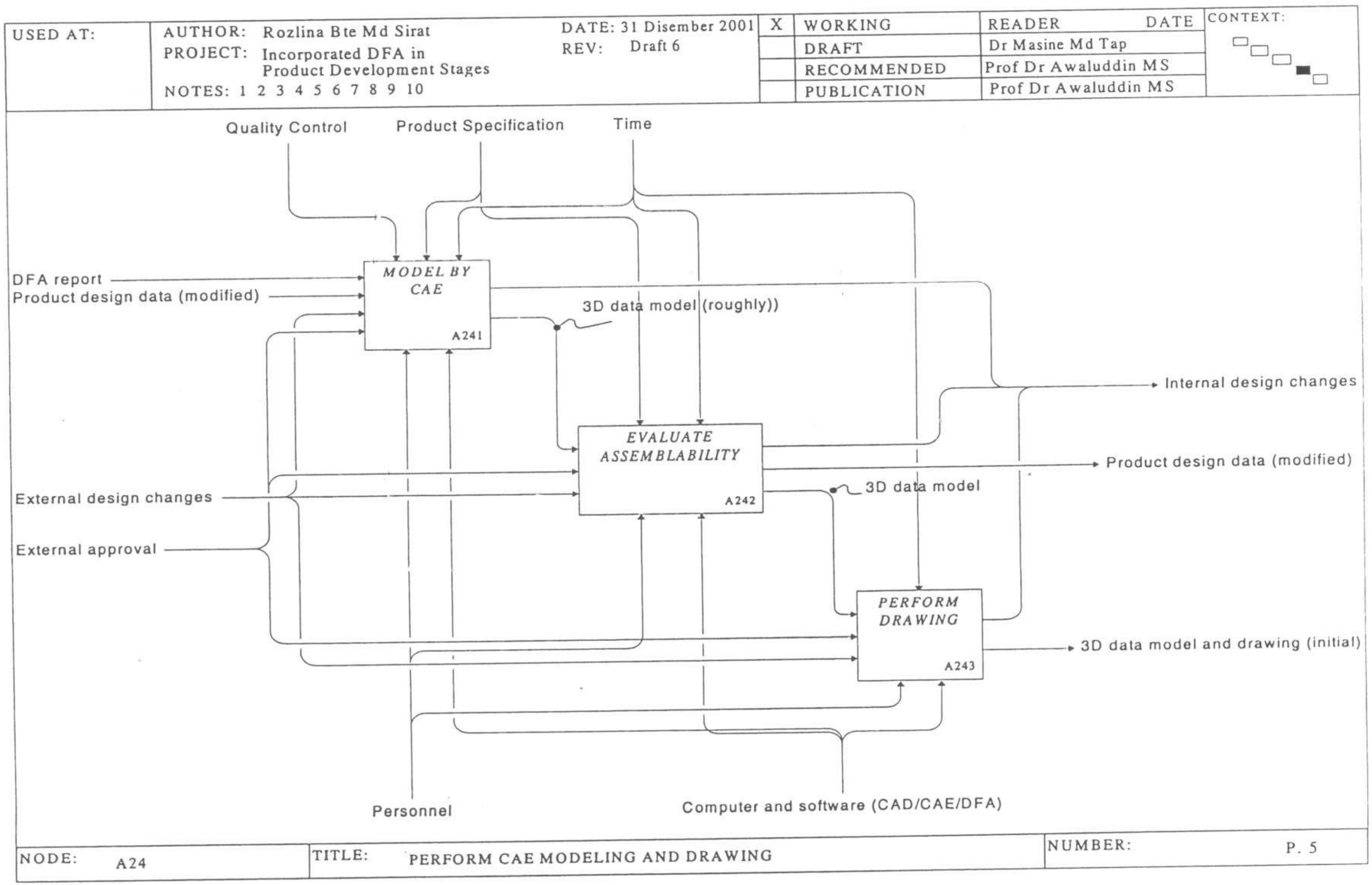


Figure 7.6: The decomposition of 'Perform CAE Modeling And Drawing' in conceptual design stage.

produced and assist the designers for the second time checking the evaluation of assemblability but for the logic and geometrically in A242. Drawings are then made (A243) and this will be used to make the soft prototype.

7.3.2.5 Build, Test and Assemble Soft Prototype (A25)

There are two ways of building a prototype. First is by producing the prototype in-house and second, Katayama will fabricate it and then ship to Ingress. For the case of in-house production, the prototype will be tested for assemblability and performance. Then, it will be assembled with the prototype fabricated by Katayama. After assembly, the prototype will be sent to Proton by Ingress (refer Figure 7.7).

7.3.3 Information Flow In 'Perform Detail Design and DFA' (A3)

In the detail design stage, five activities are carried out (refer Figure 7.8):

- Define detail parameters and DFA (A31)
- Perform CAE Modeling and Drawing (A32)
- Perform Assembly System Design And Process Planning (A33)
- Perform Tooling Design And Fabrication (A34)
- Build, Test and Assemble Hard Prototype (A35)

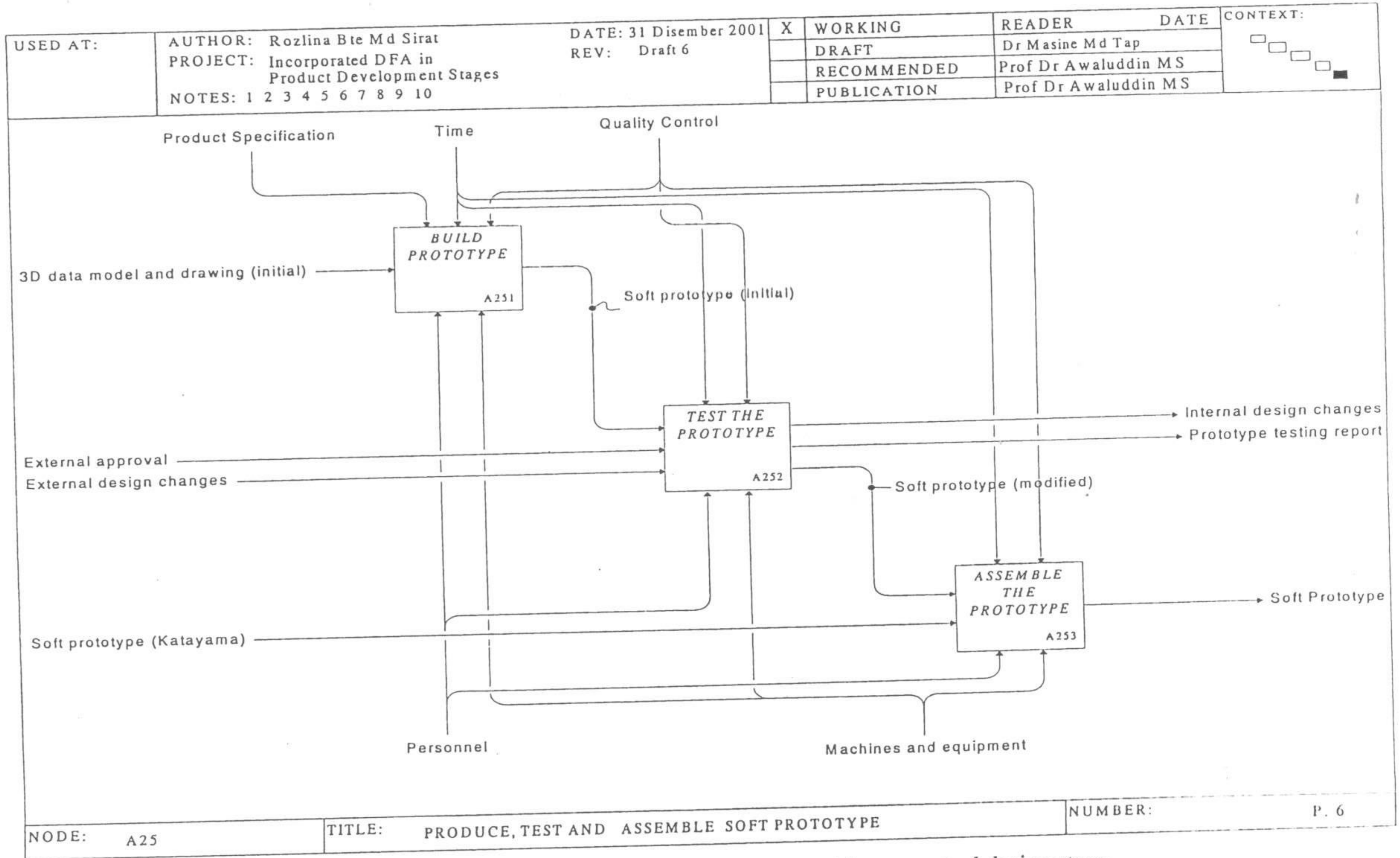


Figure 7.7: The decomposition of 'Produce, Test and Assemble Soft Prototype' in conceptual design stage.

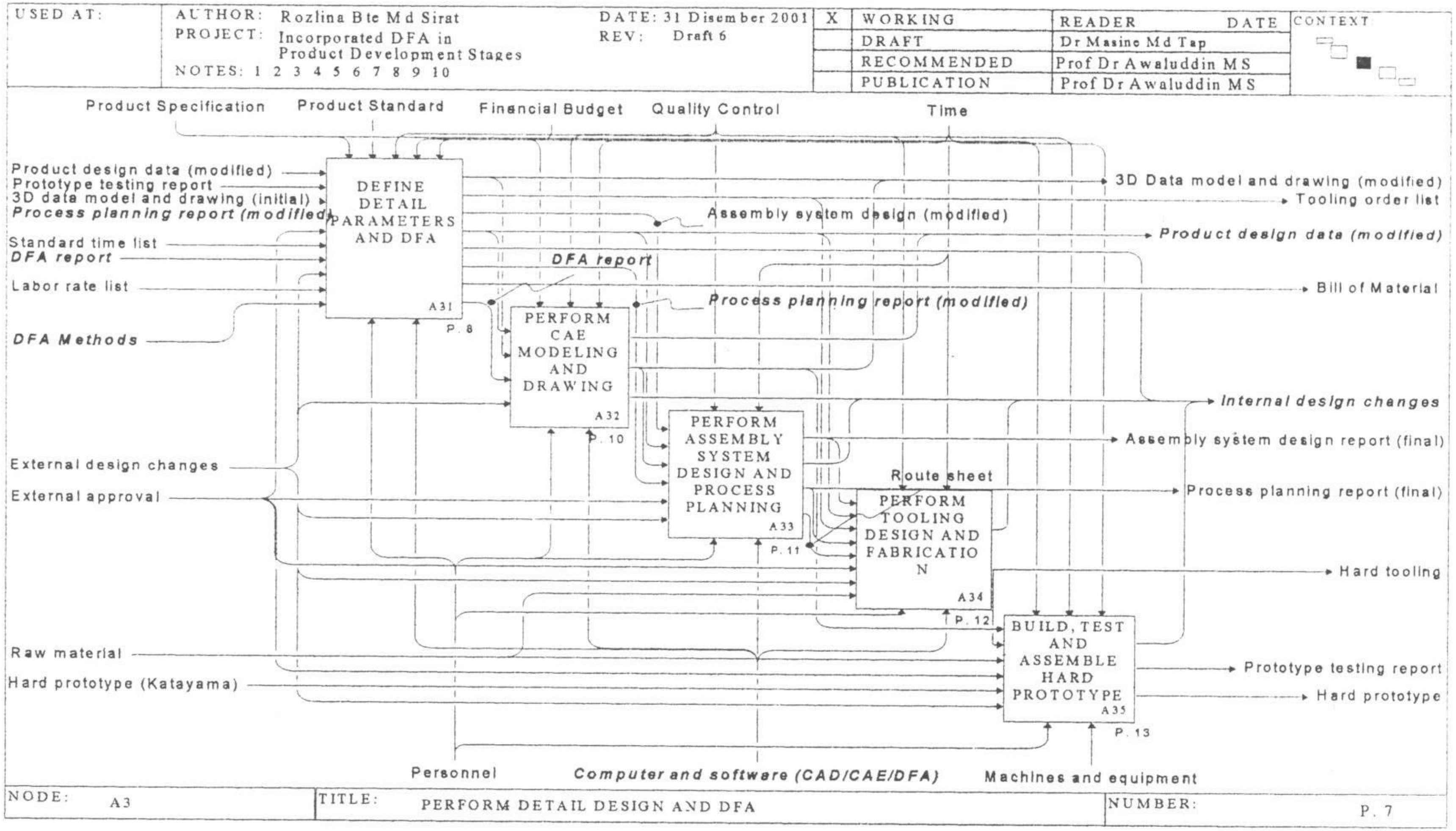


Figure 7.8: The activities involved in proposed incorporation of DFA in the detail design stage.

7.3.3.1 Define Detail Parameters And DFA (A31)

Further decompositions for this activity (refer Figure 7.9) are:

- Define detail parameters (denoted by A311)
- Evaluate assemblability by DFA (denoted by A312)

The detailed parameters are defined by considering a few factors (refer to A311 activity in Figure 7.9) and the target is to get optimum operation, low cost and low assembly time. These are shown in the DFA report. DFA report is used as a document because it has a record of assembly planning. Assembly planning is used as a guideline to design each product. Another output is product design data (modified).

The decomposition of 'evaluate assemblability by DFA' (A314) is shown in Figure 7.10. This might be the second time or the first time evaluation using DFA is made. However, the data used for the evaluation is more complete thus allowing the team to evaluate the design more efficiently. If this is the first stage in implementation of DFA, data and document is easy to access and better evaluation can be made. The results of this evaluation are from the functional analysis (initial), handling analysis (initial), assembly analysis (initial) and assembly flow chart (initial) for all the alternative designs. Then, a redesign will be done and another evaluation performed using functional analysis (modified), handling analysis (modified), assembly analysis (modified) and assembly flow chart (modified). Comparisons will be done and the best result based on the ratio or percentage will be selected. The data used in the evaluation by DFA in conceptual design (A23) can still be used here.

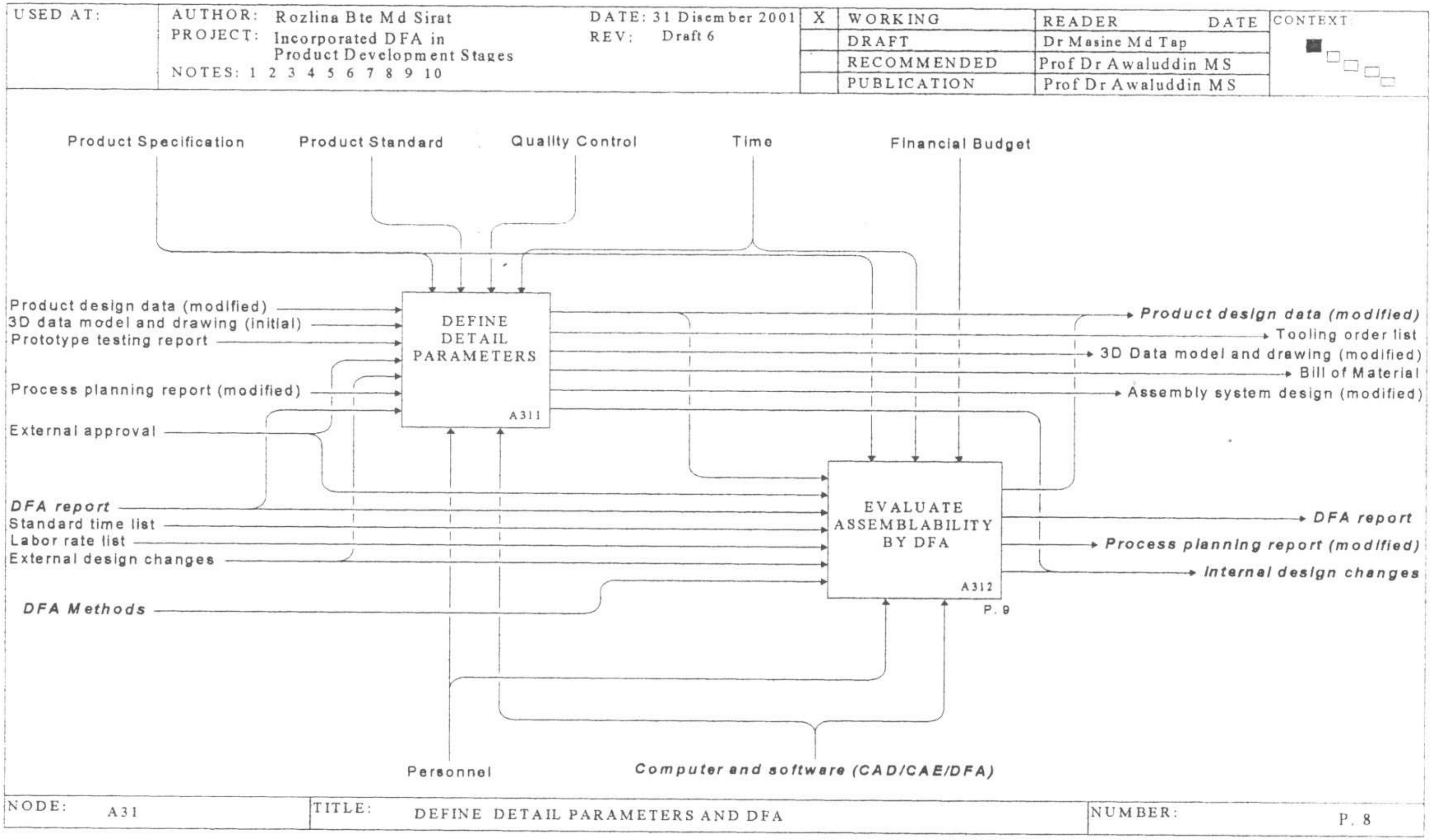


Figure 7.9: The decomposition of 'Define Detail Parameters and DFA' in detail design stage

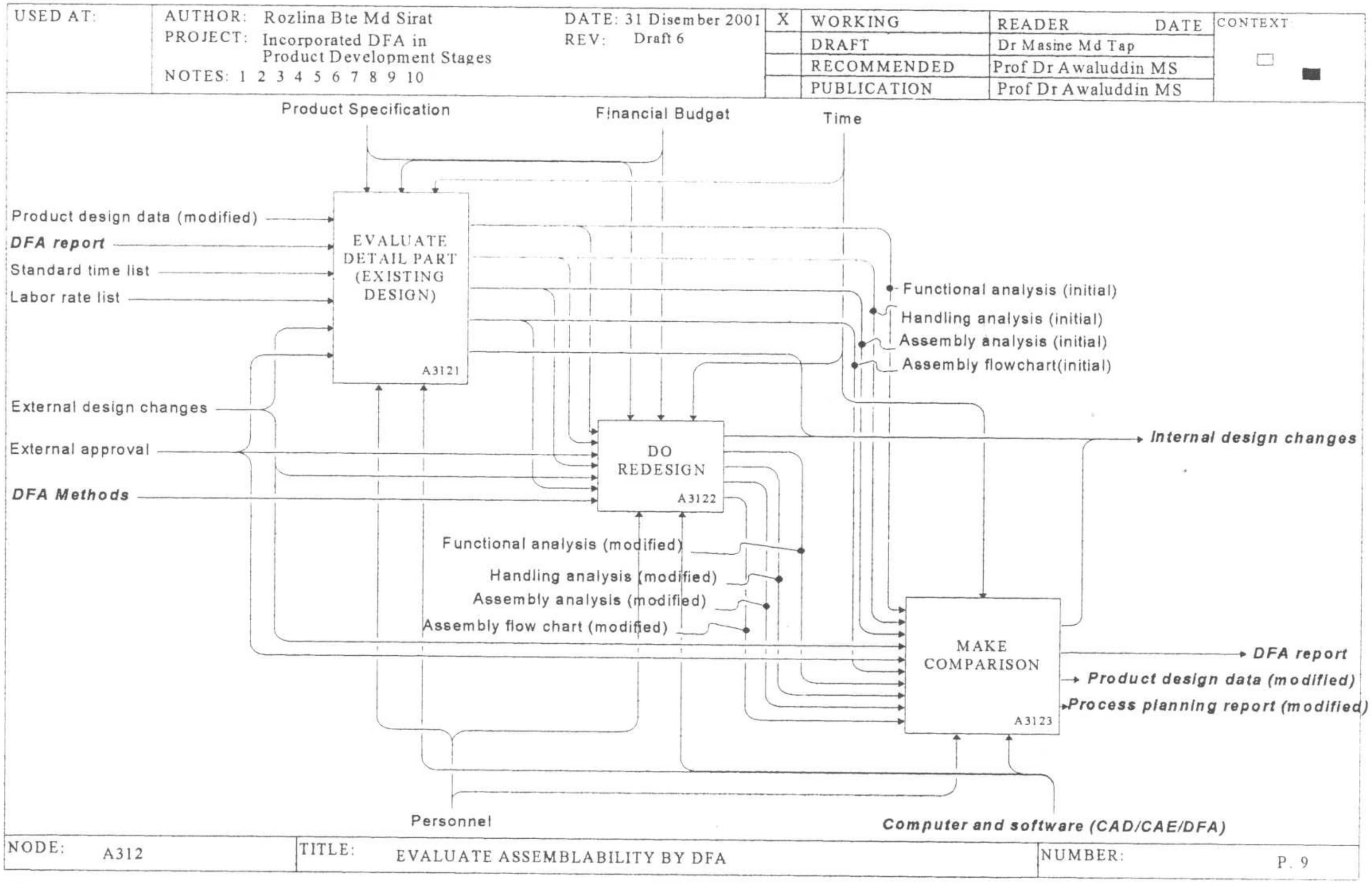


Figure 7.10: The decomposition of 'Evaluate Assemblability By DFA' in detail design stage.

7.3.3.2 Perform CAE Modeling And Drawing (A32)

CAE modeling and drawings will be conducted and this is similar to the process of CAE modeling and drawing in the conceptual design stage (refer Figure 7.11).

7.3.3.3 Perform Assembly System Design and Process Planning (A33)

Assembly system design and process planning can be done concurrently. Refer Figure 7.12, the 3D data model and drawing (modified) and product design data (modified) are some of the data required in carrying out assembly system design . Here, the design of assembly system is done by the Production Engineer. From this activity, assembly system design report is produced and sent to tooling design and fabrication activity. External design changes are also considered in this stage.

The Production Planning Engineer will perform the assembly system design and produces assembly system design report (final). The Product Planning And Control Engineer (PPCE) will do the process planning after considering the process planning report (2) and assembly planning in product design data (modified). Then, the process planning report (final) and route sheet will be produced. This will be used as information for further DFA evaluation if the team is still not satisfied with the design.

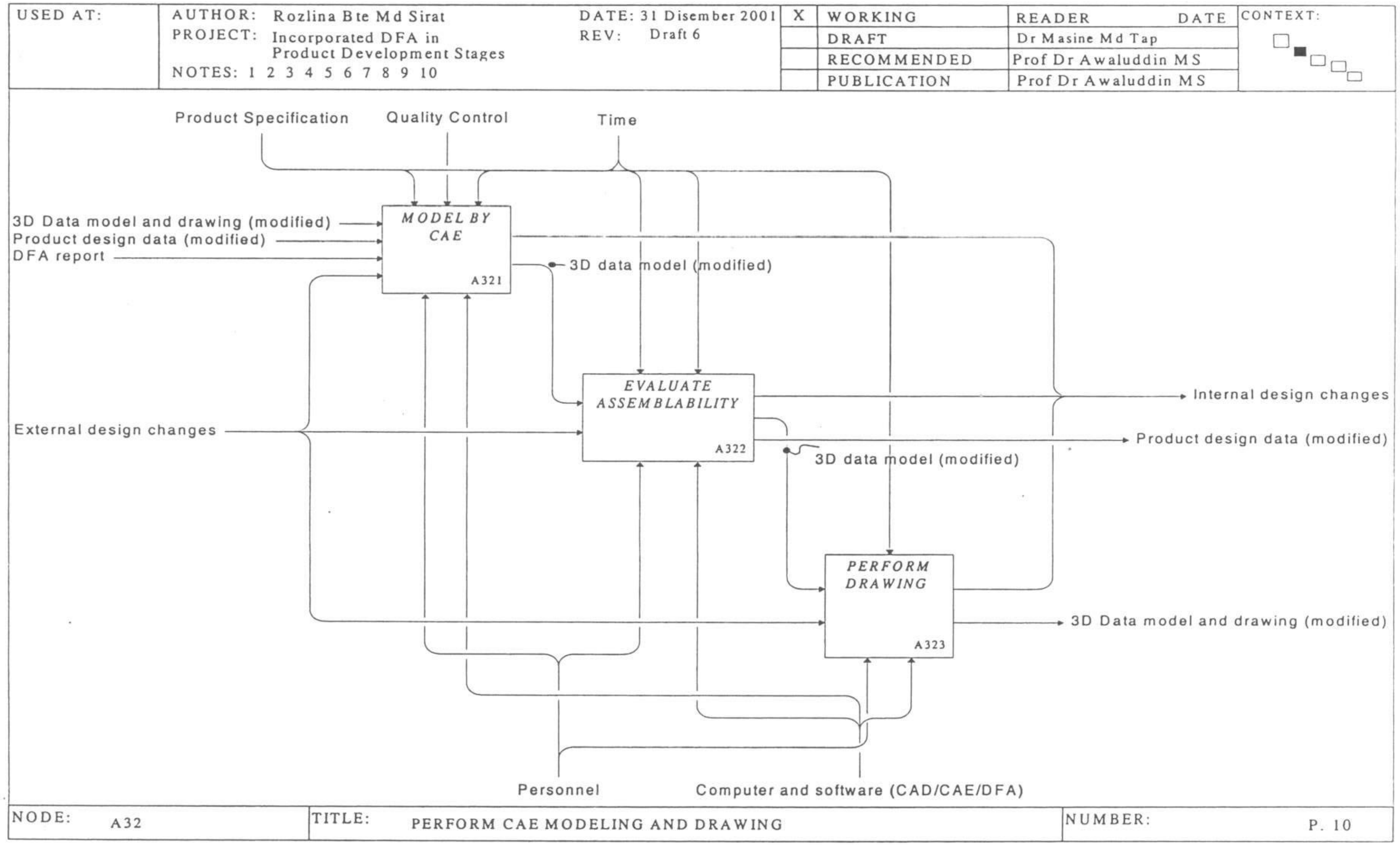


Figure 7.11: The decomposition of 'Perform CAE Modeling And Drawing' in detail design stage

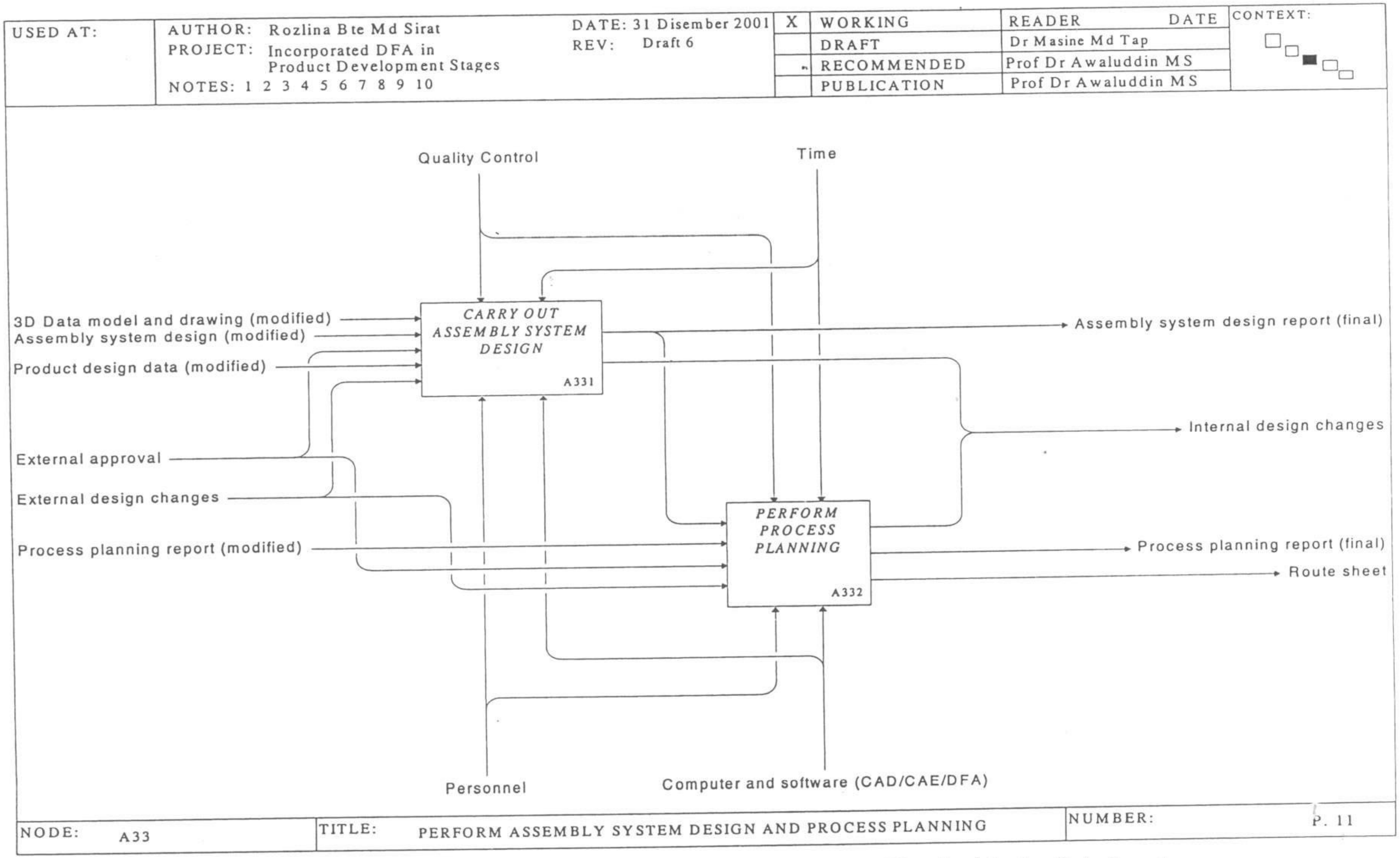


Figure 7.12: The decomposition of 'Perform Assembly System Design And Process Planning' in detail design stage

7.3.3.4 Perform Tooling Design And Fabrication (A34)

In terms of tooling, about 20% of it is designed and fabricated by Ingress and the rest is designed and fabricated by Katayama. Referring to Figure 7.13, the information needed to perform tooling design include product design data (modified), tooling order list, assembly system design report (final), process planning report (final) and route sheet.

7.3.3.5 Build, Test and Assemble Hard Prototype (A35)

Referring to Figure 7.14, the 3D data modeling and drawing (modified) which was produced by the A31 activity , will be used to build the prototype by the Production Engineer, assisted by the tooling engineer and Manufacturing Engineer. Raw material and hard tooling is included as input and will be involved in prototype building. If there are any request for design changes, it will go back to the appropriate function or stage. Katayama designed and fabricated 80% of the hard prototype and the rest is designed and fabricated prototype at Ingress for testing and assembly. A report will be produced and sent to pre-production activity. If the prototype fails, it will be made again by other alternative methods and tested until it is approved.

7.3.4 Information Flow In 'Perform Pre-production and DFA' (A4)

The implementation of DFA at this stage (see Figure 7.15) is not as effective as in the earlier stages. However, DFA may still be deployed in cases where minor modification is required by the client, in this case, Proton. Analysis is

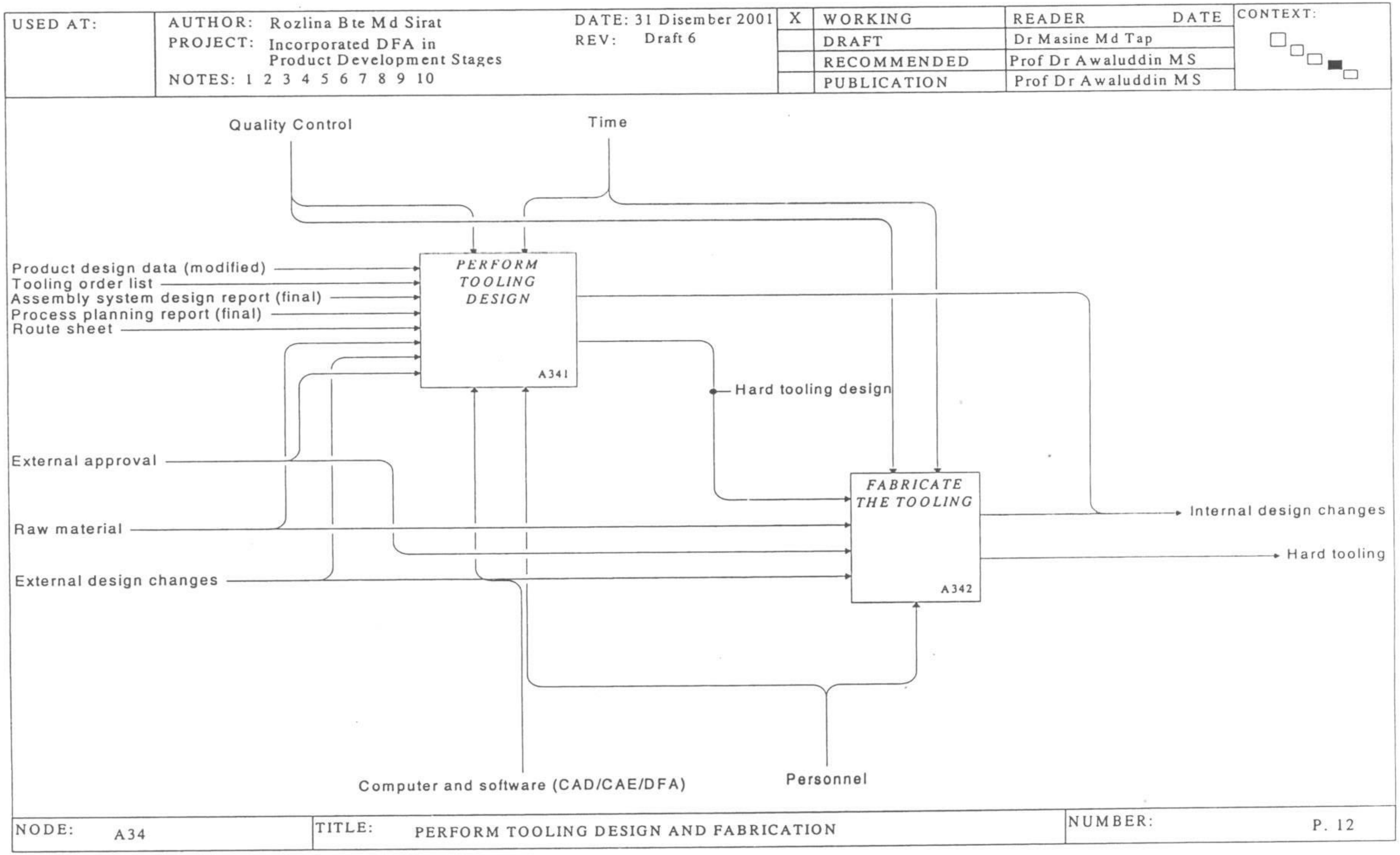


Figure 7.13: The decomposition of 'Perform Tooling Design And Fabrication' in detail design stage.

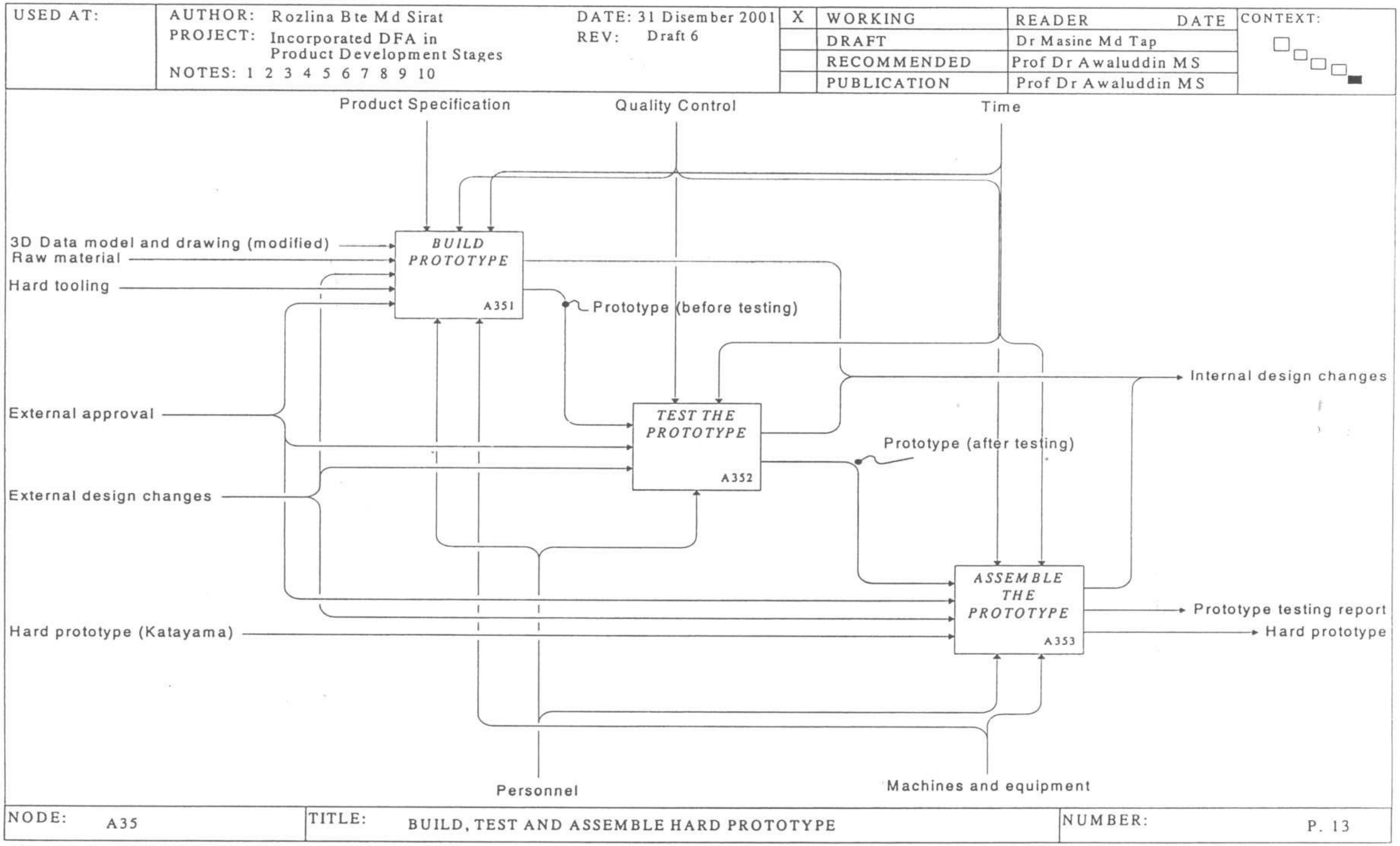


Figure 7.14: The decomposition of 'Build, Test and Assemble Hard Prototype' in detail design stage.

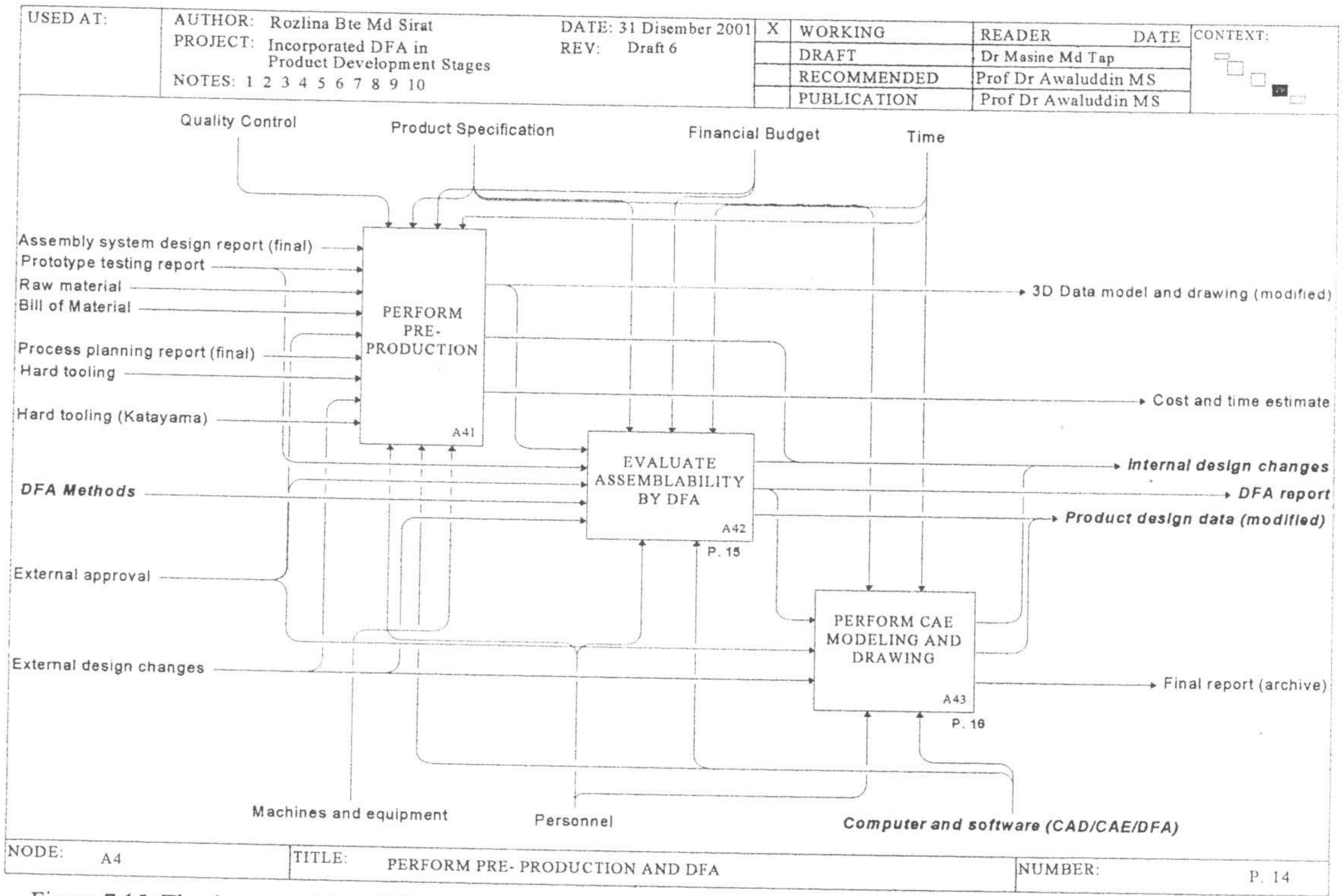


Figure 7.15: The decomposition of 'Perform Pre-Production and DFA' in product development stage.

easier at this stage because all data is already available. Three activities are involved in implementing DFA in this stage.

- Perform pre-production (A41)
- Evaluate assemblability by DFA (A42)
- Perform CAE modeling and drawing (A43)

Figure 7.16 shows the decomposition of 'evaluate assemblability by DFA' in pre-production stage. This figure is similar to Figure 7.5 in detail design stage.

Figure 7.17 shows the decomposition of 'perform CAE modeling and\drawing' in pre-production stage. This figure is similar to Figure 7.11 in detail design stage.

Any modification must be approved by Proton. This is because the changes will involve cost and time. In our case study, Ingress may only propose design changes but Proton must approve before it can be implemented. Any changes at this stage may affect the assembly system design, process planning, tooling design and fabrication, machines, tools and jigs.

7.3.5 Information Flow In 'Perform Production and DFA' (A5)

Model changes may occur after production has started (refer to Figure 7.3). These changes may cause the redesign of the product and thus the procedure of redesigning may revert back to conceptual design. This is also another chance to implement DFA because DFA can now be incorporated into the design changes.

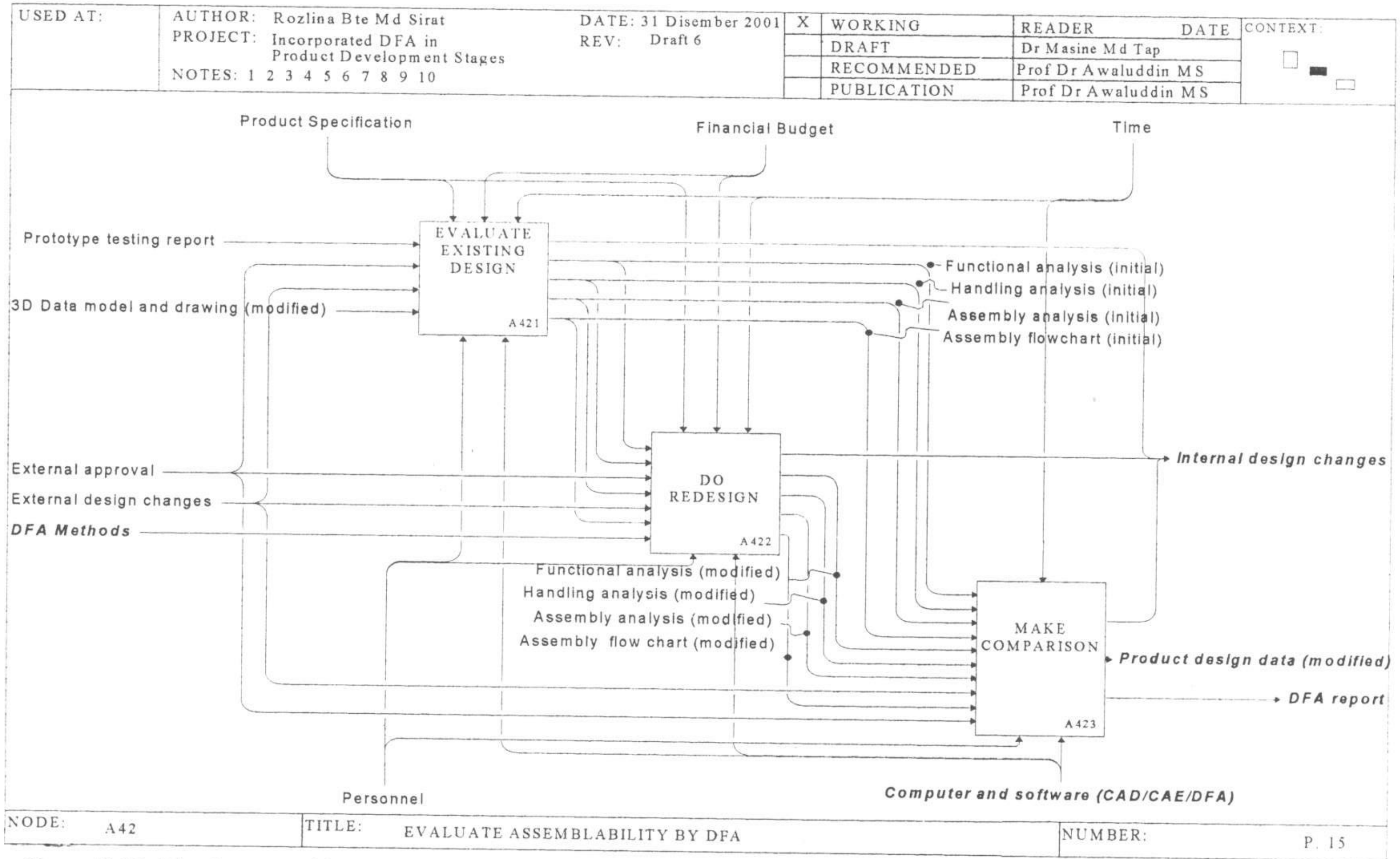


Figure 7.16: The decomposition of 'Evaluate Assemblability By DFA' in pre-production stage.

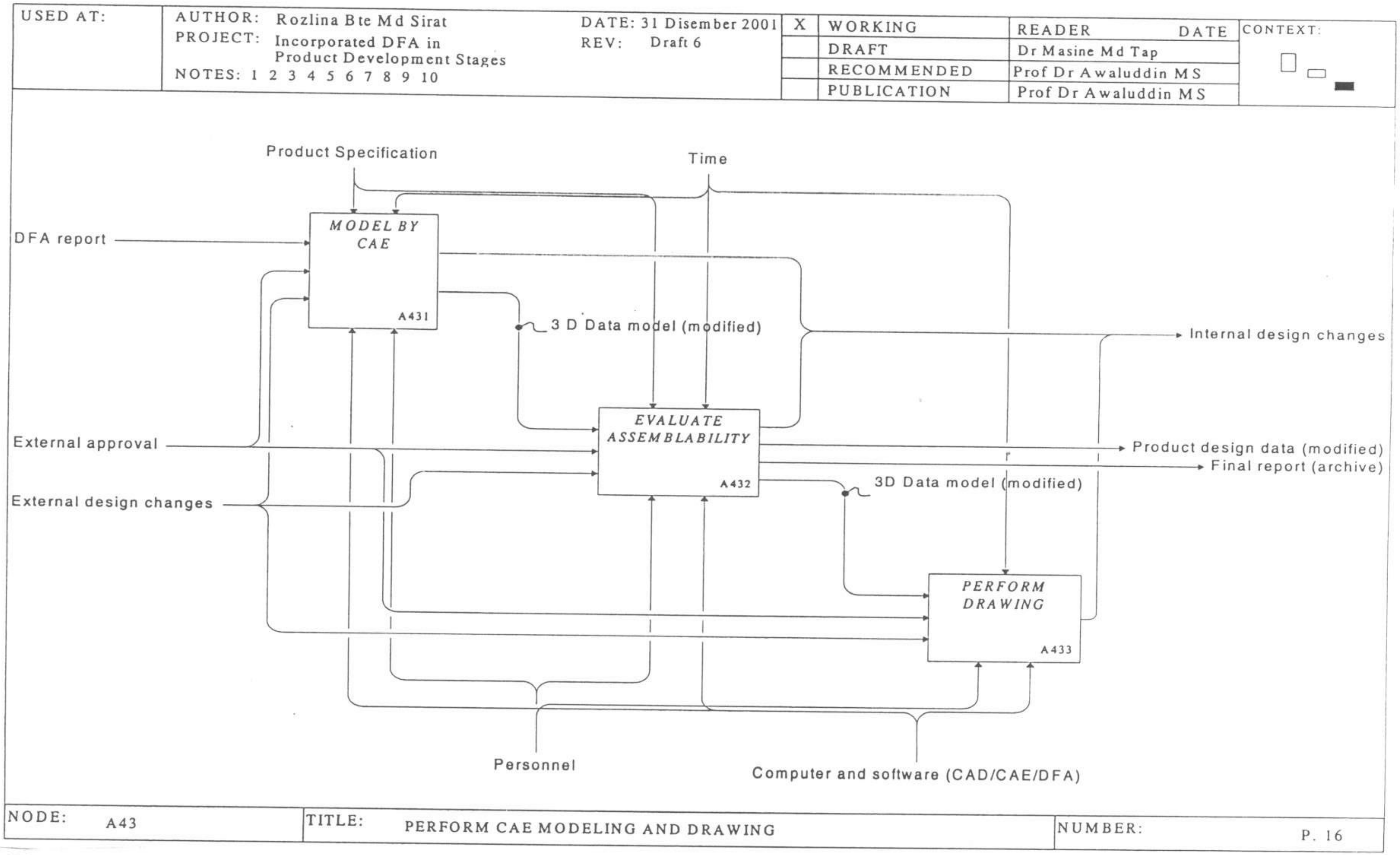


Figure 7.17: The decomposition of 'Perform CAE Modeling And Drawing' in pre-production stage.

Note:

Although the term 'product design data (modified)' is used repetitively, it does not indicate the same modified product design data but indicate the latest modified product design after each stage.

7.4 Project Organisation for DFA Implementation.

Table 7.1 shows the persons involved from all the three parties in producing a complete part. The three parties are Ingress, Proton and Katayama. The responsibilities in the hierarchical task from top to bottom level are determined to assist the company in implementing DFA. It also shows the suggested list of personnel responsible in implementing DFA at the suitable levels in the hierarchy. The highlighted sentences shown are to indicate the additional task due to the implementation of DFA.

Table 7.1: The Hierarchical Tasks from top to bottom level (proposed DFA implementation)

Level	*Specific Task*	*Company In Charge*	*Person In Charge*
Policy Making and Authorisation	-Approval and authorisation	Proton	Project Manager (PM), Design Engineer (DE), Quality Engineer (QE)
Project Management	-Acquire budget. **-Appoint DFA** **-Select DFA tools** **-DFA project schedule** -Review, analysis,	Ingress	Project Manager (PM), Design Engineer (DE)

	monitoring, conduct meeting, send staff to training.		
Project Implementation	-Produce design and product. -**Collect data related to DFA. Suggestion for assemblability based on their expertise in this field.**	Ingress	Design Engineer (DE), Production Engineer (PE), Product Planning and Control Engineer (PPCE), Tooling Engineer (TE).
Technical Support	-**Provide technical advice including design after considering DFA** and technical support to Ingress	Katayama	Design Engineer (DE), Prototype Engineer (Pro E)

In section 5.1, the hierarchy of tasks has been mentioned which consist of policy making and authorisation, project management and project implementation. Here, the tasks are reviewed to accommodate DFA implementation.

a) **Policy making and authorization:**

Initiate, terminate or start of project, make policies or approve and authorise any changes, similar as in the existing practice.

b) **Project Management**

The tasks are similar to existing activities (refer to Chapter 5). The additional tasks are:

i) Acquire budget and approval for DFA implementation.
ii) Appoint DFA project leader.
iii) Select and purchase appropriate DFA tools.
iv) Produce DFA project schedule.
v) Send staff to short training courses on using DFA, incorporate DFA activities into day-to day work, or invite external experts to give in-house training.
vi) Conduct meetings and always stress on the importance of assemblability optimization.
vii) Select area to conduct pilot study for implementation.

c) **Project Implementation**

- Perform activities of product design and manufacturing, review feedback information and make changes as or when necessary.

- Collect data related to DFA.
  For example, the process flow chart, assembly flow chart, the movement or function of the parts, handling orientation, assembly orientation and insertion orientation. The person in charge can also give suggestions on assembly based on their expertise in their fields.

d) **Technical Support**

Katayama acts as a consultant and is not involved directly to the case study. They are not directly involved when DFA is implemented in Ingress. However, their comments on proposed changes should be sought at least in the preliminary stages to act as check and balance to confirm the decision making process.

The team that Ingress used for product development is similar to the team before implementation of DFA. The difference is the role of each person in charge. Table 7.2 to Table 7.14 show the person responsible for DFA implementation in the product development stages. The highlighted sentences shown are to indicate the changes or addition needed due to DFA implementation.

7.4.1 Responsibilities In ' Sign Project Agreement'

The responsibilities of Person In Charge (PIC) in this stage are similar to the existing activity (refer to Section 5.5.1). Table 7.2 shows the detailed responsibilities for the parties involved in project agreement .

Table 7.2:Detail responsibilities for PIC during 'project agreement'.

Activity	Company In Charge	Person In Charge	Responsibilities
Project Agreement	Proton	Project Manager (PM)	Give the project brief and discuss the master schedule and sign agreement.
	Ingress	PM	Look into the financial budget, project brief and product specification that Proton required. Discuss the master schedule, make sure policies could be followed. Sign the project agreement .

7.4.2 Responsibilities In 'Perform Conceptual Design And DFA'

In the conceptual design stage, the Design Engineer (DE) is responsible for generating the product design to the customer's requirement. Here, DFA will be used to assist the team in evaluating the product design. Meetings and discussions are conducted between Ingress and Proton. Representatives from Ingress are PE, PPCE, with the DE acting as the leader. Proton is represented by its own DE and QCE.

The advantage of inviting representatives from Proton is to ease discussion and speed up the approval process. For example, when Ingress proposes a design idea, Proton may give its approval during the meeting. If Proton disagrees, Ingress may discuss the analysis behind the design idea and persuade Proton to approve. Modification may also be discussed and introduced to Proton's satisfaction.

One of the analyses used behind the design idea is the DFA analysis. DFA can effectively analyse the ease of assembly of the products or components. It can ensure consistency and completeness in its evaluation of product assemblability, eliminate subjective judgment from design assessment, allow free association of ideas, enable easy comparison of alternative designs, ensure that solutions are evaluated logically, identify assembly problem areas and suggest alternative approaches for improving the assembly of products. Table 7.3 to Table 7.5 show the detail responsibilities during conceptual design.

Table 7.3:Detail responsibilities for PIC during 'Generate conceptual design' in conceptual design stage

Activity	Company In Charge	Person In Charge	Responsibilities
Generate conceptual design	Proton	Design Engineer	Discuss the product design and the feasibility of the design with Ingress. Approve the design after discussing with Project Manager (Proton).
	Ingress	Project Manager	Give briefings to team members on Proton's requirements. Control the flow of the design process, then approve the design (internally). Conduct discussion with Proton about the design

		Design Engineer	Start designing the conceptual design; sketch on paper and roughly estimate design performance. **Leader in using DFA. From the assemblability evaluation, identify the weak points in the product design. Look at the design efficiency through functional analysis to reduce the part count.**
		Production Engineer	Analyze and set production targets for all lines. Formulate a tentative process plan for the proposed product design. Should also consider the special steps required such as service, safety, and quality control. Identify the material and discuss the product design and manufacturing. **Assembly sequence is needed in this stage to identify the major steps in assembly. Do the conceptual assembly sequence/ planning that considers the part mating theory of DFA. The handling and orientation of assembly will be suggested, followed by insertion and secondary operation analysis**
		Tooling Engineer	Update information on tooling. Identify needs for new tooling. Plan the tooling and equipment for early ordering to avoid delays in the project later.
		Manufactu -ring Engineer	Provide information on the availability of machine. Decision on machinery, costing and process selection. Suggestions on component cost reduction. Contribute to the formulation of the new product concept of what is and what is not feasible from a manufacturing viewpoint. Look at the weak point of product design after considering DFA (in manufacturing viewpoint).

Table 7.4: Detail responsibilities for PIC during 'Perform CAE Modeling And Drawing' in conceptual design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
CAE Modeling and Drawing	Proton	Design Engineer	Approve the CAE modeling.
	Ingress	Design Engineer	Evaluate the assemblability logic using CAE modeling. Discuss with Proton about the design and the analysis produced by the design team. Generate alternatives in assembly design.

Table 7.5: Detail responsibilities for PIC during 'Build, Test And Assemble Soft Prototype' in conceptual design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Prototype	Ingress	Design Engineer	Sent information to Katayama to be used for the prototype fabrication. Produce prototype. Test performance of the prototype. Assemble the prototype from both Ingress and Katayama.
	Katayama	Design Engineer	Design and fabricate the soft tooling and produce the prototype. Then sent the prototype to Ingress.

7.4.3 Responsibilities in 'Perform Detail Design And DFA'

In the detail design, the same persons in conceptual design still sit together for meetings and discussions. The exact parameters will be defined, process planning and assembly system design will be identified, the assemblability will be evaluated, and tooling list will be listed, followed by the building of the prototype. The evaluation in assemblability in this stage is more complicated and thorough.

Production Engineer (PE) will give suggestions on whether to manufacture the parts or components or to buy them. He also provides information on manpower requirements, the process involved in manual assembly such as inserting, handling parts and the difficulties of matching. Assembly system design is to be determined by Production Engineer (PE) and Product Planning and Control Engineer (PPCE). PPCE will produce the Standard Operating Procedure (SOP) to be used in building the assembly flow chart, and assist in generating ideas on assembly sequence. The Design Engineer (DE) will contribute in giving ideas on part mating theory and the function of the product in terms of movement. He also acts as a leader in selecting the optimum design analysis. Tables 7.6 to 7.11 show the detailed responsibilities for the companies involved during the detail design stage.

Table 7.6: Detail responsibilities for PIC during 'Define detail parameters' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Define Detail Parameters	Proton	Design Engineer	Have regular discussions and meetings with Ingress. Approve the design.
	Ingress	Project Manager	Control the flow of the design and any problems in the scheduling. Hold discussions with Proton on detail design. **Ensure that the team contributes ideas to support DFA utilization. Report to senior management on DFA implementation.**

		Design Engineer	Elaborate on the design and fix the parameters and accuracy for each component. Detail calculation for strength and performance. **If this is the first implementation of DFA, use the steps similar in conceptual design. If it is the second DFA implementation, the data will be more complete. Elaborate the design and fix the parameters and accuracy for each component. Act as a leader in using DFA. Prepare the DFA report which consists of part list, analysis, assembly flowchart , comparison of the existing design and the redesign and manufacturability.**
		Production Engineer	Coordinate discussions on matters related to quality. Suggest either to buy the part or produce it. Identify the detail product design for every part and component. Identify the best method in producing the product and give suggestions on the material chosen by DE. Make sure the parts are easy to manufacture. Work closely with Manufacturing Engineer (ME) on product configuration and dimension that affect tooling. **Do the detail assembly sequence that considers the part mating theory of DFA. Evaluate DFA in terms of their assembly process; suggest the best method in assembly sequence flowchart from the Production Engineering view point.**
		Product Planning and Control Engineer	To review periodically the holding stock level for all raw materials, WIP, finished goods and consumable items. Provide figures on in-plant inventories.
		Tooling Engineer	**Look at the logic of redesign.** Determine the tooling used and identify the tooling that need to be made. Estimate the tooling cost.

		Manufactu-ring Engineer	Estimate equipment and facility cost and lead-time. Identify the machine that is suitable for the process. Determine the labor rate for each of the parts. Suggest the best method in assembly sequence process. Evaluate the assembly flow chart that the Production Engineer suggested. **Determine the producibility of the product. Determine the detail process planning for each of the parts or components that will be made and the accuracy. Suggest the best method for the assembly sequence process.**

Table 7.7: Detail responsibilities for PIC during 'Perform CAE Modeling And Drawing' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
CAE Modeling and Drawing	Proton	Design Engineer	Approve the CAE modeling
	Ingress	Design Engineer	Evaluate the assemblability logic using CAE modeling. Discuss with Proton about the design and the analysis produced by the design team. Generate alternatives in assembly design.

Assembly system design and process planning are done by different PIC but is done concurrently . Refer Table 7.8 and Table 7.9.

Table 7.8: Detail responsibilities for PIC during 'Perform Assembly System Design' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Assembly System Design	Ingress	Production Engineer	Determine the assembly system design based on the product design. Discuss this with Design Engineer. By using the assembly planning that has been produced in conceptual design, modify assembly sequence and make sure it is reliable.
		Product Planning and Control Engineer	Responsible for the labor needs, inventories and production schedule capacity.

Table 7.9: Detail responsibilities for PIC during 'Perform Process Planning' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Process Planning	Ingress	Product Planning and Control Engineer	Discuss with Manufacturing Engineer the process involved and the machines required. Determine production time, labor, inventory etc. By using the process planning that has been produced in the conceptual design, identify and modify the process planning (final) which covers the detail parts and come out with a report that will be used for pre-production stage.
		Manufac-turing Engineer	Determine the process layout and provide suggestions for the process .

Table 7.10: Detail responsibilities for PIC during 'Tool listing' and 'Tool design and fabrication' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Tool listing, design and fabrication	Ingress	Tooling Engineer	List the tools required for the process of the product. **The tool could be listed after DFA is done**. Design and fabricate tools. Request support from Katayama.
	Katayama	Tooling Engineer	Design and fabricate tools required by Ingress.

Table 7.11: Detail responsibilities for PIC during 'Build, Test and Assemble Prototype' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Prototype	Proton	Design Engineer and Quality Control Engineer	Evaluate the performance and assemblability of the prototype sent by Ingress..
	Ingress	Project Manager	**Send DFA results to Katayama for comments.**
		Production Engineer	Discuss the design and fabrication of the prototype with other engineers . Assemble the prototype from Katayama and Ingress.
		Tooling Engineer	Check tool and machine needs in each process before fabricating the tooling for the prototype.

		Manufactu-ring Engineer	Verify the machine needs in processing the product in the shop floor.
	Katayama	Design Engineer and Prototype Engineer	Fabricate the prototype for Ingress. **Act as tooling consultant. This consultancy may need to consider DFA implementation practiced by Ingress.**

7.4.3 Responsibilities In 'Perform Pre-production And DFA'

The person in charge and the responsibilities for DFA implementation in pre-production is the same as in the detail design stage. As mentioned in 7.3.4, after pre-production, minor modifications may be required by the customer. The PE, PPCE and QCE by this time have enough experience to identify the weaknesses of the existing product design. Thus, they can design and evaluate the assemblability in a shorter time. However, any changes will affect factors such as machines, jigs, tools etc. The detailed responsibilities are shown in Table 7.12.

Table 7.12: Detail responsibilities for PIC during pre-production stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Pre-production	Proton	Project Manager and Design Engineer	Discuss the problems that appeared in the product. **Look at the logic of redesign at this stage.**
	Ingress	Project Manager	Control the flow of the design and hold discussions with Proton regarding pre-production and production.

		Design Engineer	**Redesign the existing design. Identify the parts that can be changed and reduced. Ask for the opinions of other departments** because any changes at this stage will affect assembly cost and time.
		Production Engineer	Make sure the process of product follows the determined process sequence. **In the implementation of DFA, he needs to suggest a better process through the assembly sequence chart.**
		Product Planning and Control Engineer	Suggest better machines and processes that can ease assembly. Evaluate assembly flowchart from PPCE view point.
		Tooling Engineer	Fabricate tools; give some suggestions regarding modification of products.
		Quality Control Engineer	Ensure product quality.

7.4.4 Responsibilities In 'Perform Production And DFA'

Model changes will require the product development cycle to go back to the conceptual design stage. Thus, the responsibilities and the personnel involved are also similar to those in the conceptual design. Table 7.13 shows the detail responsibilities in this stage.

Table 7.13: Detail responsibilities for PIC during 'production' stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Production	Proton	Project Manager	**Discuss with Ingress the possibility of model changes or any requirement from Ingress.**
	Ingress	Project Manager	Control the flow of the design and hold discussion with Proton regarding the required design changes. **Discuss with the design engineers about the weaknesses of the existing product or new marketing issues from the technical view point .**
		Design Engineer	**Identify the weaknesses of the existing product. Study the future model changes based on customer requirements and conduct discussion with Project Manager**.

As a conclusion, in DFA implementation, the responsibility of Project Manager from Ingress is to act as an advisor to the team. The Design Engineer of Ingress contributes in giving data for functional analysis and assembly flow chart, and then makes decisions based on the results of these analyses. The Manufacturing Engineer considers giving the criteria for manufacturing based on DFA analysis. Finally, the Product Planning and Control Engineer contributes by giving the data required for handling analysis and assembly analysis. The Design Engineer, acting as the leader, will do the overall analysis and make the decision either to redesign or not. Katayama will assist with their expertise and give some suggestions in assembly, while Proton will evaluate and approve the design.

7.5 Training Requirements

The team must have some training to efficiently implement DFA and understand their responsibilities. They must also receive enough information so that they can appreciate the DFA program's objectives. They need to learn and to cooperate on a team basis. They should be provided with as much as possible on the technical and how-to-do-it instructions as it is practical to do so. Some of them at least will need to acquire skills in some of the tools or method needed to support the project . The author therefore propose that Ingress adopt the two types of training methods suggested by Bralla (1996). They are:

a) Attitudinal training

This training is on team orientation and team spirit. Staffs are trained on how to conduct brainstorming sessions and meetings.

b) How-To-Do Training

This training is to teach participants on how to apply DFA tools and guidelines. However, not all the team members need this training. Some DFA know-how may already reside in some key-team members. However, training is needed for those on the team that may not have the required experience or skills.

Ingress is fortunate to have a small team because it is easier to manage the DFA project implementation. In spite of its size, each team member has a variety of skills. For example, the design engineer may have had experience in manufacturing before being a design engineer. This experience in manufacturing will be valuable in assisting the design engineer in understanding and evaluating the effects of various manufacturing factors on the product design.

7.6 Database Information System For DFA

To obtain efficient implementation of DFA, it is an additional bonus if a Database Management Information System (DBMS) to support DFA can be developed. This is because in real life, there may be some problems in accessing the data needed for analysis, such as:

i) It may be difficult for the team to obtain certain data such as detail parameters, tolerance data, the process of product and tooling in one document that is easy to access. Each project has its own data and this may be scattered in various documents and locations. The data is important if the project team intend to get the result, as accurate as possible.

ii) Some information is stated in symbols and codes. Not all persons can understand these symbols and codes.

iii) The IDEF0 diagram may assist by showing where the information originates and is stored but retrieving the information must be done manually.

For this reason, a DBMS should be developed for assisting in providing some data or documents in an integrated manner. This is an advantage because the document can be retrieved faster and easier without further need to refer to more documents.

An example of the information system for DFA could be seen in Appendix D.1, which is developed by Salim and Rapiei (2001). The information system covers every department so that the person in charge can easily obtain the needed data.

The data that can be accessed by the proposed DBMS information system of DFA are:

- *Part list*

  Consists of material, weight, thickness, length, tool used.
- *Process planning*

  Consists of name of equipment involved and standard time.
- *Tooling*

  Consists of machine, process involved, cost per part, part name.
- *Cost*

  Consists of cost of material, child part, components etc.

The DFA software needs the data such as the part list, process planning, the tool used and the cost to estimate if any changes is required. The other data is provided just to assist the team if they want further information.

7.7 Conclusion

In this chapter, the results of a sample DFA Analysis Exercise based on an existing. product are presented. The proposed DFA framework for the company has been detailed out and task changes with respect to every involved parties in the implementation has been clearly spelt out. The IDEF0 diagrams for the proposed framework has also been presented. The author has also proposed two additional recommendation:

i) DFA training requirements

ii) DFA **D**ata**b**ase **M**anagement Information **S**ystem (DBMS)

which can further enhance and facilitate the use of DFA analysis within the company. The framework is applicable to SMIs regardless of their design practices.

CHAPTER VIII

DISCUSSIONS

8.1 Introduction

This chapter discusses the findings of this research. Some key issues of DFA implementation are covered. The key issues are:

a) The need for DFA project implementation preparation.
b) The need for a structured approach.
c) Factors considered in DFA implementation framework:
    i) Design practices.
    ii) Decision –making structure.
    iii) The generic nature of the implementation framework.
    iv) The need for using computer – assisted DFA software tools.
d) The amount of changes due to DFA implementation.
e) The need of human factor in implementation.
f) Advantages and limitations of the proposed framework.

8.2 The DFA Implementation Framework As Preparation

From the survey done in Malaysia (Rozlina et al, 2000), many companies are interested in implementing DFA in their companies but are not confident that their company is ready for DFA. One reason could be that there are no guidelines on the factors that need to be considered in preparation for DFA implementation. DFA implementation must be viewed as a project in itself and the approach must be developed as a project approach.

The author has proposed a DFA project implementation phases that may be used as a guideline in the planning and preparation of DFA implementation. The components of the proposed structure involved four phases:

i) ***Requirements specification***

- Prepares company in considering the factors needed before implementing DFA. For example, the company needs to identify the objective of implementing DFA and the constraints that may hinder DFA implementation in the company. The company needs also to study its own design practice and identify the various external parties or companies involved. Study needs to be made on previous case studies of DFA implementation by other companies so that the company may benefit from experiences of others.

- The company needs to survey the various tools and methods of DFA available in the market. Then the company needs to identify the DFA tools that are suitable to be used with the tools and method already in use in the company.

ii) ***Design Of DFA Framework***

- Prepares company for the additional iterative design and redesigning process involved due to DFA in the product development.

iii) *Implementation Of The DFA Framework*

- Prepares company for the factors that are required or needed to assist in implementing DFA. The factors include functional integration, implementation of the software tool, training relevant to DFA implementation and information system that may assist the implementation.

iv) *Assessing The Framework (And Change)*

- Prepares company to be able to do assessment of DFA analysis. The results of the analysis may indicate that design changes are required. The company must be prepared to make these changes. These changes may cause changes to be made in other areas such as tooling, machines, jigs and fixture. Any feedback is also considered during the assessment.

The proposed structure can be used as a checklist for DFA implementation. With the checklist, companies may prepare themselves for the various effort, requirements and changes required for a successful DFA implementation. This project structure may be used in conjunction with the DFA implementation structure.

8.3 The Need For A Structured Approach

The design of the implementation involves changes in procedures, method of operations, task and information. This is a complex process. A general framework (Figure 7.1) has been developed. By studying the case study's activities, the involvement of three parties are shown concurrently and the general activities are highlighted to the parties involved. However, the proposed general framework did not adequately detailed the activities and the flow of information required. There is a need to adopt a more structured and systematic approach that can assist management to handle the implementation process. In the case study, IDEF0 was used to facilitate understanding of the implementation process. The advantages of IDEF0 are:

i) It becomes easier to represent functional operation in a hierarchical and structured manner and to clearly define the nature of their relationship in graphical form.

ii) It proved to be a useful teaching and instructional tool to the manufacturing company staff in understanding how the implementation can be carried out.

iii) The model captures activities, resources, information and mechanisms in a structured manner, which can be referred upon later on when new products, systems or changes have to be accommodated.

iv) Consistency checks can be carried out with respect to information flow and functional responsibilities.

Although the author used IDEF0, other SADT approaches may be used in its place. The important factor that needs to be considered is that the chosen approach must be able to show clearly all the activities involved and the flow of information and the input and output of each activity because this will act as the road map for the company.

8.4 The Factors Considered in DFA Implementation Framework

The factors that need to be considered in DFA implementation framework are:

8.4.1 Design Practices

The design activities practiced by the company intending to implement DFA need to be determined. This is because it can affect the success of the implementation.

A company may do its own product design and manufacture in house. If this is the case, then a company may have easy control of how the product development process are conducted. Thus, implementing DFA in this environment should involve participation and corporation from within the company itself.

However, a company may have to interact with other parties in its product development process. This may be in the form of interaction between a client, a manufacturer, a vendor or a consultant. It is difficult for a product to be made as simple as possible because several companies or parties may be involved in its design and manufacture. For example, Company A may be the party that manufactures or assembles the main product while Company B may be the party contracted to design and manufacture one of the components of the main product.

Five types of relationship in design practice have been identified (Rozlina et al, 2000) such as client-manufacturer/ assembler (subcontractor), client-manufacturer/ assembler (vendor), consultant-manufacturer/ assembler, stand alone manufacturer/ assembler and hybrid alliances. Each design practice has different impact on the relationship that occur in design-manufacturing activities.

This is important because the implementation of DFA in such an environment would require commitment, effort and cooperation from all parties. The role and responsibilities of each party need to be identified and information flow and guidelines need to be clear. Otherwise, the benefits of DFA may not be reaped. As a conclusion, the parties involved and their role must be clear so that full commitment can be given when DFA is adopted.

8.4.2 The Decision-Making Structure

The product development may involve many cycles of designing and redesigning before final approval is given. Decisions need to be made at various stages on the viability of the product design. A rigid and serial decision- making structure will only increase delay and cost especially when more than one party are involved.

A lot of delays, cost and time problem arise due to communication problems and awaiting approval. Much of these problems could be averted if the rigid serial based activities could be made concurrent. For example, all parties are integrated into the product development right from the start and work as a team, thus cutting down on a lot of unnecessary time.

Adopting DFA requires closer interaction between various parties involved as this will help to overcome these delays. If DFA is adopted but no changes were made in the way each party communicates, the full benefits of DFA may not be realized. For example, one party may suggest design changes with the application of DFA. However, if approval is required from the client and if this approval takes too much time and effort to obtain, then the suggested design may be abandoned. Thus, the full benefit of DFA implementation is lost due to delays in communication and decision-making.

Thus the decision-making structure needs to be studied to improve the communication and decision-making process. For this purpose, a hierarchy of person from up to bottom level is identified (Table 7.1). By showing this, it will help the company in strategic planning. Some Tables of Person-in-charge are presented to highlight the concurrent task among the arties involved. This is done as a team in Concurrent Engineering environment.

8.4.3 The Generic Nature Of The Product Development Stages

DFA need to be implemented within the product development stages. The author has designed a DFA implementation framework consisting of several stages:

i) Project agreement
ii) Conceptual design,
iii) Detail design,
iv) Pre- production and
v) Production

Although this framework was developed based on the case study company, the framework may be used by other companies who are involved in product development cycle. Some slight modifications may be required and this is to be expected.

A company may implement DFA in any of the stages aforementioned but the earlier a company applies DFA in the product development cycle, the more benefits it can get.

8.4.4 The Need For Using Computer -Assisted DFA Software Tool

DFA analysis may be done manually or by using a DFA tool (software). There are two methods to conduct manual analysis. One method is to analyse the assemblability of product design qualitatively, that is, by principle rules of assembly. Another method is by analyzing the assemblability of the product design by calculating various factors considered in DFA, for example, assemblability, functionality and handling analysis. These approaches are not considered practical or suitable in a product development with a very tight schedule.

However, there are DFA tools or software available on the market to assist in evaluating the assemblability of a product design. Some examples are Boothroyd Dewhurst DFA software, Lucas DFA software, IPA Stuttgart, Hitachi Assemblability Evaluation Method (AEM) and TeamSET. The use of computer software is more practical, can avoid mistakes and cut down on cost and time.

This research used TeamSET to evaluate assemblability of the design. This is done through functional analysis to determine design efficiency, handling analysis to simplify handling and orientation of product, and assembly analysis to simplify assembly. These results indicate to the designers the amount of improvement or redesign that need to be done.

Other tools may also have similar ways to quantify assemblability and assist designers in designing for ease of assembly and reduce assembly cost and time. These may be used by companies to assist them in DFA analysis.

The case study example of DFA analysis using TeamSET was conducted with minimum available data. It shows that analysis can be with minimal information. When the redesigned product was evaluated, marked improvement was observed with more information, more accurate results and improvement may be gained.

However, the implementation of DFA does not merely mean buying a DFA tool and using it to evaluate assemblability. It requires other considerations such as a suitable implementation framework, implementation structure and other key issues discussed in this chapter. DFA tool may only assist the analysis and evaluation that needs to be done and may also assist designers in arriving at the optimum product design.

8.5 The Amount Of Changes Due To DFA Implementation Framework

The required changes of DFA implementation based on the framework have been outlined in detail. The results show that in some tasks, no changes in job functions and responsibilities are needed but in some tasks, the modifications may be major. This framework will be a good reference and guide to companies wishing to implement DFA and who wants to see what changes it may require for them to make. Planning for changes can be greatly facilitated. It shows that overall, minimum changes are required. Tables 8.1, 8.2 and 8.3 detail out the extent of changes.

Thus, the company may still maintain most of its existing activities, tools (software) and staff. DFA is incorporated into these activities to assist the company in achieving the objectives of DFA and reap the benefits that DFA offers.

8.6 The Need of Human Factor In Implementation

Human factor is important in the implementation of DFA. The success of the implementation depends on the acceptance and support of those involved, from top management to the practitioners of DFA.

DFA implementation needs full- hearted commitment from top-level management to succeed. Managers have to ensure harmony in the working environment. They need to be considerate to their staff especially in the early stages of DFA implementation, as their staff needs to learn and get use to DFA. Managers need to morally and financially support and obtain the necessary facilities and effort in the implementation.

Training is another human side that is important to the success of DFA implementation. Managers need to be educated and trained to manage changes in

Table 8.1: Comparison Of An Existing Design Activity And DFA Implementation in a Case Study Company (Based On The IDEF0) - Case For A 2 : Perform Conceptual Design

	ACTIVITY	INPUT	OUTPUT	CONTROL	MECHANISME
EXISTING	1. Collect Data 2. Generate Conceptual Design 3. Perform CAE Modeling and Drawing 4. Produce, Test and Assemble Soft Prototype	- Patent Sash - Product sample - Final report (archive) - Design manual - Operating manual - Material list - Model changes - Soft Prototype (Katayama) - External design changes - External approval/ Approval	- Product Design Data (initial) - Process Planning Report - 3D Data Model and drawing - Internal design changes - Soft prototype - Prototype testing report - Standard time list - Labor rate list	- Product Specification - Product Standard - Styling surface data -Financial budget - Quality Control - Time	- Personnel - computer and software (CAE/ CAD)
DFA IMPLEMENTATION	1. Collect Data 2. Generate Conceptual Design 3. Evaluate Assemblability By DFA 4. Perform CAE Modeling and Drawing 5. Produce, Test and Assemble Soft Prototype	Same as above.	Same as above but with the addition of: - DFA Report	Same as above	Same as above but with the addition of: - DFA tool.

Table 8.2 : Comparison Of An Existing Design Activity And DFA Implementation In A Case Study Company (Based On IDEF0) - Case For A3 : Perform Detail Design

	ACTIVITY	INPUT	OUTPUT	CONTROL	MECHANISME
Existing	1. Define Each Detail Parameters 2. Perform CAE Modeling and Drawing 3. Perform Assembly System Design and Process Planning 4. Perform Tooling Design And Fabrication 5. Build, Test and Assemble Hard Prototype	- Product design data (initial) - 3D data model and drawing (initial) - Process planning report - Standard time list - Labor rate list - Raw material - Hard prototype (Katayama) - External design changes - External approval	- Product design data (modified) - 3D Data model and drawing (modified) - Tooling order list - Bill of material - Assembly system design report - Process planning report - Prototype testing report - Hard prototype	- Product specificaton - Product standard - Financial budget - Quality control - Time	- Personnel - Computer and software (CAE and CAD) - Machines and equipment
Proposal	1. Define Each Detail Parameters and DFA 2. Perform CAE Modeling and Drawing 3. Perform Assembly System Design and Process Planning 4. Perform Tooling Design And Fabrication 5. Build, Test and Assemble Hard Prototype	Same as above but with the addition of: - DFA report	Same as above but with the addition of: - DFA report	Same as above	Same as above but with the addition of: -DFA tool

Table 8.3 :Comparison Of An Existing Design Activity and DFA Implementation In A Case Study Company (Based On IDEF0) -Case For A4: Perform Pre- Production

	ACTIVITY	INPUT	OUTPUT	CONTROL	MECHANISME
EXISTING	1. Perform pre-production	-Assembly system design report - prototype testing report - Raw material - Bill Of material - Process planning report (final) - Hard tooling - Hard tooling (Katayama) - External design changes - External approval	- cost and time estimate - final report (archive)	- Product specification - Quality control - Financial budget - Time	- Machines and equipment - Personnel - Computer and software (CAE/CAD)
PROPOSAL	1. Perform Pre-production and DFA	Same as above but with addition of: - 3D Data model and drawing (4) - assembly flow chart report	Same as above but with addition of: - Product design data (modified) - 3D data model and drawing (final) - DFA report	Same as above.	- as above but with addition of: DFA tool

the product development. The staff using DFA needs to be trained on how to use DFA software and about part mating theory. Those involved need to understand the importance of the role they play and the responsibility they carry in making the implementation a success. However, the responsibility that they need to carry out for DFA must also be accompanied by authority. Without the authority to command the resources required for DFA, they will not be able to fulfill their responsibilities and DFA implementation may be doomed to fail.

The benefits of DFA to a company has been discussed and proven by many authors. However, the benefits to the staff themselves should be highlighted to encourage and motivate them to use DFA. Motivation to staff in using DFA may be in the form of financial or non- financial rewards. Without motivation, it will be difficult to get full support and commitment from those involved.

8.7 Advantages And Limitations Of The Proposed Framework

The main advantages of the proposed framework are as follows:

i) Completeness and level of detail

The framework as proposed covers the product development stages and identifies where DFA can be implemented, job redesign, persons responsible and their functions. The flow of information and interactions between parties both within and outside of the company are detailed out. Thus the framework can be easily customised and modified by any SMI company possible implementing DFA.

ii) Use Of IDEF0 Modeling Methodology

The use of IDEF0 as a vehicle to model the framework in its entire detail brings with it many benefits to the companies as mention previously. It serves as a teaching aid and also allows the database information system to be easily developed in order to support DFA analysis. Customisation of the framework may be made by companies by using the IDEF0 model.

iii) Flexibility of implementation

The framework is flexible in the sense that it allows companies to choose at what point they wish to introduce DFA within the product development and what changes are necessary. Hence, companies can use the framework to implement DFA according to their requirements and capabilities.

The main limitations of the framework may be due to its:

a) Lack of validation.

In order to validate the framework, two main approaches may need to be conducted. The first is to conduct a complete implementation exercise and then do post-implementation evaluation. This was not possible within the scope of this research. The second step is to carry out similar case study exercises in other SMIs in order to confirm its validity. However, this is also not possible. The author only managed to validate her proposal by discussing with the relevant personnel at Ingress and getting their agreement as to its practicality.

b) Still requires expert advice on implementation

Although the framework simplifies the implementation process in companies with people who already understands DFA, the vast majorities of companies are still unaware and may not understand how to implement the framework. Therefore expert advice must still be sought.

8.8 Conclusion

The various findings and contributions of the author to the development of the proposed framework has been presented and discussed. Advantages and limitations of the framework have also been given. The framework has taken many considerations in developing a suitable DFA implementation framework. Overall, the framework proposed can be a guideline in DFA implementation.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

9.1 Introduction

This chapter summarises the conclusions on the project that has been carried out. Recommendations for further work are also made.

9.2 Research Findings

The objective of this project was to develop a framework for implementing DFA in Malaysian SMIs. This objective has been satisfied by the following findings and proposals:

1) A study carried out by the author amongst Malaysian SMIs has indicated a range of design activities and some identified problem that they faced in implementing DFA.

2) A literature survey of previous frameworks have led to the development of a proposed DFA framework which was adapted from previous work. This framework is generic in nature and companies can adopt this framework for their own purposes.

3) The author also identified four major phases within the product development where DFA can be implemented. The relative benefits and impact of their introduction in each of these stages has also been discussed.

4) The use of computer assisted DFA software tool was used to demonstrate the use of the technique for a case study product.

5) The author carried out a case study at an existing Malaysian SMI. Its current product development activities are analysed and detailed out and changes required for DFA implementation were proposed in great detail. The use of IDEF0 also greatly assisted the development and understanding of the framework for its implementation.

6) A project approach for DFA implementation was proposed by the author and its details elaborated.

7) Some issues with respect to ensuring success of DFA implementation was also discussed.

8) The advantages and limitation of the framework was also analysed.

9.3 Summary Of Contributions

Some contributions of the project are:

i) Five types of design practice in Malaysian industries have been identified from the survey done.

ii) The information about DFA implementation in Malaysian industries and the barriers facing the industries in adopting DFA has been highlighted based on the survey.

iii) A proposed DFA Implementation Preparation has been developed to help companies prepare for DFA implementation.

iv) A general flowchart for incorporating existing activities and another for proposed activities after considering DFA have been developed.

v) IDEF0 Based frameworks for existing activities and another for proposed DFA activities have been built.

vi) Identified changes in responsibilities of personnel involved as a result of DFA implementation.

9.4 Recommendations For Future Work.

The recommendations for future work are:

i) Development of a database management information system for DFA implementation.

A database information system for DFA implementation should be developed. The system should consist of a database of information relevant to DFA such as material list, part list, tooling and cost. This information must be made available or easily accessible to key personnel, involved in the application of DFA. With the system DFA users may not waste too much time searching for data necessary in DFA analysis and application.

ii) Further case studies for validation

A more detailed validation of the proposed DFA implementation framework could be done by implementation. The progress of implementation needs to be monitored. Post implementation assessment should be made to validate the framework. However it is difficult to have such assessment. Thus, the validation of the framework is done by discussing the framework with the person involved in the case study company. The other way is to carry out the actual case study. This could be done in the future.

For example, the DFA implementation framework should be applied in other types of SMIs. This is to verify that the framework is also applicable to other SMIs involved in design and assembly. The framework should be implemented, the progress monitored and the results of the implementation compared with the situation before DFA was implemented. This comparison will verify the actual effectiveness of the framework in improving the efficiency of assembly and quantify the benefits that can be gained by using DFA. It is believed that the research has indeed achieved its objective of providing guidelines and framework for DFA implementation in Malaysian SMIs and hopefully will be of used to them.

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Appendix A.1

UNIVERSITI TEKNOLOGI MALAYSIA

KARUNG BERKUNCI 791
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FAKULTI KEJURUTERAAN MEKANIKAL

RUJUKAN KAMI (OUR REF.): utm.24/ 25.11/ 3/ 163 jld.2( )

RUJUKAN TUAN (YOUR REF.):

Dear Sir,

QUESTIONNAIRE ON DESIGN FOR ASSEMBLY (DFA)

I am the project leader of the Research Group in Design For Assembly (DFA). An introduction to DFA is enclosed. As part of the work, we need to review the application of this important tool in Malaysia.

2. Specifically the objectives of the attached questionnaire are:

a) to identify to what extent DFA is being applied in Malaysian industries.
b) to identify the problems companies face in using DFA method.
c) to identify to what extent DFA is suitable for Malaysian industries.

3. We would appreciate it very much if you could assist us by completing the attached questionnaire and returning it to us. Even if you do not use DFA or even if you are not familiar with it, please fill up the relevant parts of the questionnaire because we need responses from non- users to obtain a complete profile and to identify impediments to its adoption in Malaysia.

4. We give you our assurance that all responses will be treated confidentially and used only for aggregate analysis.

Thank you very much for taking the time to assist us in our work to enhance competitiveness of Malaysian industries.

Yours Sincerely,

(PROF. DR. AWALUDDIN B. MOHAMED SHAHAROUN)
Department Of Manufacturing And Industry
Faculty of Mechanical Engineering
Universiti Teknologi Malaysia.

Appendix A.1 (continued)

Appendix:

Traditionally, the attitude of designers has been "we design it- you build it" or "the over-the-wall" approach. One way of overcoming this attitude is to consult manufacturing and assembly engineers at the design stages. The resulting teamwork avoids many of the problems that arise.

Design For Assembly (DFA) is a core software tool for concurrent engineering work. It is not only quantification of assembly time and labor cost, but also provide a challenge to simplify the structure of products and thereby reduce parts costs as well as assembly costs. Companies have recorded million of dollars in savings by applying DFA at the early stages of product design. This tool is a must for those wishing to maintain or improve competitiveness.

Extra time spent early in the design stage is more than offset by the savings in time when modelling or prototyping takes place. Thus in addition to reducing product costs, the application of DFA shortens the time to bring the product to market.

DFA has generated a revolution in design practices, not because it usually reduces assembly cost, but because it has a far greater impact on the total manufacturing cost of a product. The reason is that DFA simplifies the product structure, reduces the number of parts and thereby reduces the total costs of the parts. However, in order to judge the effects of DFA at the early design stage, companion methods for parts cost estimation were developed.

Yet, in spite of the many success stories, the major barrier to DFA implementation is human nature. People resist new ideas and unfamiliar tools, or claim that they have always taken manufacturing into consideration during design. The DFA methodology challenges the conventional product design hierarchy, and it reorders the implementation sequence of other valuable manufacturing tools, such as SPC and Taguchi methods.

In conclusion, it would appear that every design organisation will have to adopt DFA philosophy and apply cost quantification tools at the early stages of products design in order to remain competitive in the future.

Adapted from Boothroyd Dewhurst Inc.
(one of the DFA software companies)

Appendix A.1 (continued)

GUIDE: Please tick (/) the appropriate boxes . **You can tick more than one box.**

PART A (Company's profile)

Company's name: ______________________________________

1. Your position in company:
a) Managing director. ☐
b) Design manager. ☐
c) Manufacturing manager. ☐
d) Other. (please state: ____________________) ☐

2. Company's product type:

a) furniture ☐
b) plastic ☐
c) electric ☐
d) electronic ☐
e) chemical ☐
f) ship ☐
g) metal ☐
h) textile ☐
I) rubber product ☐
j) oil palm product ☐
k) road transportation ☐
l) mechanical and engineering ☐
i) others.(please state: ____________________)

3. Company's ownership:
- local : ____________%;
- foreign : ____________%

4. Market for your products:
a) local ☐
b) export ☐
c) both ☐

5. Company's shareholder fund:
a) less than RM 500,000 ☐
b) between RM500,000 and RM 2.5 million ☐
c) RM 2.5 million and above. ☐

6. Your annual sales turnover:
a) less than RM 10 million ☐
b) more than RM 10 million but less than RM 25 million. ☐
c) more than RM 25 million. ☐

7. How long has the company been in operation?
a) 1-5 years ☐
b) more than 5 years but less than 10 years ☐
c) 10 years and above ☐

8. How many workers does your company employ?
a) less than 50 full time workers ☐
b) 50- 75 full time workers ☐
c) more than 75 full time workers ☐

9. What is the nature of operations in your company?
a) assembly
b) production
c) assembly and production

10. Where do your company get its main components?
a)manufactured in- house
b) subcontracted out.
c) bought off-the-shelf.

11. What percentage by cost of your components are subcontracted or bought off-the-shelf?
a) 0-25%
b) 25 - 50%
c) 50 - 75%
d) 75%-100%

12. How often does your company change its products range?
a) once every 5 or more years
b) once every 2 or 4 years
c) once every year
d) twice a year
e) more than twice a year

13. Does your company has a design department?
a) Yes
b) No

14. The design of new product is usually done by:
a) Parent company
b) customer
c) In-house
d) External consultant

15. Who are involved in the design activities at your company?
a) subcontractor
b) in-house manufacturing engineer
c) in-house design engineer
d) external consultant/ designer
e) client

16. Are you aware of any one of the techniques below frequently used during the design stage?
a) Quality Function Deployment
b) Taguchi methods
c) Design of Experiments

17. Does your company employ Quality Function Deployment for any project invoving new product design ?
a) Yes
b) No

18. Which of the design activities below normally conducted by your organization?
a) New product design
b) New process design
c) Product design modification
d) Process design modification

19. What priority is given to the following according to the importance in your company?
Please rank : 1-critical 2- less critical 3-not critical 4-not relevent
a) cost
b) quality
c) performance
d) ease of assembly
e) others (please state: ____________________________)

PART B

20. Please state three (3) of your most profitable products?
a) ____________________________
b) ____________________________
c) ____________________________

21. Amongst the three (3), which one has the highest added value? Describe the product briefly.
____
____
____

Based on question no. 21 please answer no.22 to no. 33.

22. What percentage does the product contribute to total sales?
a) less than 25%
b) 25 - 50%
c) 50 - 75%
d) 75 - 100 %

23. What are the activities carried out in your company?
a) initial design → final design → prototyping → manufacturing → assemble

b) initial design → evaluate ease of assembly/ manuacturing → final design → manufacturing → assemble

c) others (please state: ____________________________)

24. How many components/ subassemblies are needed to complete the product?
a) less than 5 components
b) 5-10 components
c) 10-20 components
d) more than 20 components.

25. For this product, what is the average number of units that your company produces per month?
a) < 1500 units
b) 1500 - 15000 units.
c) 15000 - 3 000 000 units.
d)more than 3 000 000 units.

26. What is/ are the method/s you use for assembly?
a) Manual.
b) Robotic
c) Automatic assembly machine.
d) Others. (Please state: ____________________________)
e) not relevant.

Appendix A.1 (continued)

27. Do you use the following?
a) special jigs and fixture
b) special tool
c) precision assembly

28. What is the average percentage of defective assemblies ?
a) less than 5%
b) 5-10%
c) 10-15%
d) more than 15%

29. During the assembly operation what kind of problems usually occur?
a) some of the components become entangled
b) difficulty in positioning the components accurately
c) difficulty in joining the components
d) others. (please state: ______________________________)

30. What type of joints do you use?
a) bolts and nuts
b) screws
c) snapfit
d) twist snap
e) rivet
f) Others.(Please state: ______________________)

31. Please rank the most common/ preferred type of joint.
1- most often 2- often 3- seldom 4-rare
a) bolts and nuts
b) screws
c) snapfit
d) twist snap
e) rivet
f) others.(Please state: ______________________)

32. Are the majority components symmetrical ?
a) Yes
b) No

33. The question and answers above (22-32) are based on your chosen best value added product. Are these answers reflective of the rest of your products?
a) yes
b) no

34. Have you ever heard of Design For Assembly (DFA)?
a) yes
b) no

35.. Does your company use any DFA method?
a) yes
b) no

Instruction:

*If **yes,** please answer **Part C.***
*If **No or Not sure**, please answer **Part D.***

Appendix A.1 (continued)

PART C (Answer only if DFA is implemented in company)

36. How long has DFA technique been implemented in your company?
a) less than 1 year.
b) 1-5 years.
c) more than 5 years

37. How long did it take to implement DFA in your company?
a) less than 1 year
b) 1-5 years
c) more than 5 years
d) still in progress
e) have given up attempt to implement DFA

38. What type of DFA technique you use?
a) Lucas
b) Hitachi method
c) IPA Stuttgard
d) Boothroyd Dewhurst
e) Others (please state: ______________________)

39. Do you use computer aided DFA?
a) yes
b) no

40. How much did you invest to purchase the initial software?
a) RM10 000- RM 50 000
b) RM 50 000- RM100 000
c) RM100 000- RM 500 000

41. What is the total cost of the system when implemented?
a) RM 50 000- RM100 000
b) RM100 000- RM500 000
c) RM500 000-RM1million

42. To what extent has it been used?
a) for all products
b) for major products
c) for very specific products

43 If yes, what type of computer do you use?
a) personal computer
b) workstation
c) mainframe

44. How did you first come to know about DFA?
a) from other companies
b) from DFA vendor
c) from in-house engineers
d) from subcontractors
e) Others. (please state: ______________________)

Appendix A.1 (continued)

45. How was DFA techniques implemented?

a) Establish formal techniques. ☐

b) Subcontract to external consultants. ☐

c) Send staff to short training courses. ☐

d) Invite external experts to give outside training. ☐

e) Recruit DFA specialist. ☐

f) Compile DFA handbooks. ☐

g) Incorporate DFA activities into day –to- day work. ☐

46. What are the problems faced during DFA implementation?

a) Difficulty in understanding DFA manual/ software system ☐

b) Difficulty in implementing DFA ☐

c) Lack of specialist in DFA ☐

d) Management does not support DFA ☐

e) Consume a lot of time to implement ☐

f) Too costly ☐

g) Others (please state____) ☐

47.Please indicate the benefits you have gained or hope to gain from using DFA technique?

	very important	important	not important
a) Reduced lead time			
b) Reduced total cost.			
c) Reduced number of parts to assemble.			
d) Help to improve competitiveness			
e) Increased sales			
f) Improved teamwork.			
g) Others:______________________________			

48.Other comments:____

____

____

Thank you

PART D: (Answer only if DFA is not implemented yet or not sure it is implemented)

49. If you have not used any DFA techniques, what are the reasons why they are not used.

a) Have never heard of it ☐

b) We do not understand what DFA is all about. ☐

c) We are not sure how relevant / beneficial it is. ☐

d) We are worried about the high risk/ cost of DFA ☐

e) Management does not support DFA ☐

f) Business is good enough, therefore no need for DFA ☐

g) Others. (please state: ______________________) ☐

50. DFA technique has many advantages. Which of these advantages could interest your company:

	very important	important	not important
a) Reduce lead time			
b) Reduce total cost			
c) Reduce parts to assemble			
d) Able to improve company's competitiveness			
e) Increase sales			
f) Improve teamwork			

51. Would you be interested to implement DFA in your company?

a) yes ☐

b) no ☐

52. In your opinion, what are the suitable aids to succesfully implement DFA in your company? (based on your company's capability)

a) Provide software that can be used easily and cheaply ☐

b) Invite external experts to give in-house training ☐

c) Provide user friendly DFA methodology and training manuals ☐

d) Recruit DFA specialist or engineers who know about DFA ☐

e) Establish a formal technique ☐

f) Compile DFA handbooks ☐

g) Others. (Please state:______________________)

53.Other comments: ______________________

____

____

Thank You

Appendix B.1

SMIDEC: The definition of SMI.

SMIDEC **eligibility**

who's eligible

- SMIs engaged in manufacturing activities
- Incorporated under Companies Act 1965
- Companies with shareholder's fund of below RM 2.5 million
- At least 70% of the shareholders are Malaysian
- Priority will be given to SMIs which manufacture or intend to manufactureproduct(s) promoted under the Promotion of Investments Act (PIA) 1986 aswell those who participate in the ILP.

definition of SMIs

Small and Medium Industries (SMIs) New Definition :
For The Manufacturing Sector : Effective 18 January 1998

- SMI is defined as a company with not more than 150 employees and with an annual sales turnover of not exceeding RM 25 million

- Administratively, the demarcation between small and medium :

Small Company : a company with full time employees of not more than 50 and with an annual sales turnover of not more than RM 10 million;

Medium Company : a company with full time employees between 51 to 150 employees and with an annual sales turnover of more than RM 10 million to RM 25 million.

Small Scale Industries (SIs)

Manufacturing establishments employing between 5 to 50 employees (inclusive)or with shareholders fund up to RM 500,000 (US$ 200,000).

Medium Industries (MIs)

Manufacturing establishments with shareholders fund between RM 500,000(US$ 200,000) to RM 2.5 million (US$ 1.0 million) or employing between50 to 75 (inclusive) full-time employees.

for enquiries...

Appendix C.1

i) Detail responsibilities for PIC during 'Project agreement' stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Project Agreement	Proton	Project Manager	Give the project brief and discuss the master schedule and sign agreement.
	Ingress	Project Manager	Look into the financial budget, project brief and product standard of Proton's requirement. Discuss the master schedule and sign the agreement.

Appendix C.2

i) Detail responsibilities for PIC during 'Generate conceptual design' in conceptual design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Generate Conceptual Design	Proton	Design Engineer	Discuss the product design and the feasibility of the design with Ingress. Approve the design after discussion with Project Manager (Proton).
	Ingress	Project Manager	Give briefings to team member on Proton's requirements and control the flow of the design process, then approve the design (internally). Conduct discussion with Proton about the design.
		Design Engineer	Start designing the conceptual design; sketch on paper and rough evaluation of the design. Estimate performance .
		Production Engineer	Analyze and set production targets for all lines. A tentative process plan for the proposed product design is formulated. Consideration for special steps required for production such as service, safety, and quality control. Identify the material and discuss the product design and manufacturing.
		Tooling Engineer	Update information on tooling. Identify needs for new tooling. Plan the tooling and equipment for early ordering to avoid delays to the project.
		Manufactu -ring Engineer	Provide information on the availability of machines. Decision on machinery, costing and process selection. Suggestions on component cost reduction. Contribute to the formulation of the new product concept of what is and what is not feasible from a manufacturing viewpoint.

AppendixC.2 (continued)

ii) Detail responsibilities for PIC during ' CAE Modeling' and 'Drawing' in conceptual design stage.

Activities	Company In Charge	Person In Charge	Responsibilities
CAE Modeling and Drawing	Proton	Design Engineer	Approve the CAE modeling
	Ingress	Design Engineer	Evaluate the assemblability logic using CAE modeling. Discuss the design with Proton and the analysis produced by the design team. Generate alternatives in assembly design.

iii) Detail responsibilities for PIC during 'Soft tooling design and fabrication' and 'Soft prototype design and fabrication' in conceptual design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Soft tooling and Prototype	Ingress	Design Engineer	Send information to Katayama to be used for the prototype fabrication. Build prototype by soft tooling. Test the prototype for the performance. Assemble the prototype from both Ingress and Katayama.
	Katayama	Design Engineer	Fabricate the prototype by using soft tooling. Then sent the prototype to Ingress.

Appendix C.3

i) Detail responsibilities for PIC in 'Define detail parameters' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Define Detail Parameters	Proton	Design Engineer	Have regular discussions and meetings with Ingress. Approve the design.
	Ingress	Project Manager	Control the flow of the design and solve any problems related to the scheduling. Hold discussions with Proton about the detail design.
		Design Engineer	Elaborate on the design and fix the parameters and accuracy of each component design. Detail calculation for strength and performance.
		Production Engineer	Coordinate discussion on matters related to quality. Suggest either to buy the part or make it. Identify the detail product design for every part and component. Identify the best method in producing the product and assist Design Engineer in choosing the suitable material. Make sure the parts are easy to manufacture. Determine the detail assembly sequence. Work closely with Manufacturing Engineer on product configurations and dimensions that may affect tooling.
		Product Planning and Control Engineer	To review periodically holding stock level for all raw materials, W I P, finish goods and consumable items. Provide information on in-plant inventories.
		Tooling Engineer	Determine the tooling used and identify the tooling that needs to be made. Estimate the tooling cost.

Appendix C.3 (continued)

		Manufacturing Engineer	Estimate equipment and facilities cost and lead- time. Identify the machine that is suitable for the process. Determine the labor rate for each part. Suggest the best method in assembly sequence process. Evaluate the assembly flow chart that the production engineer suggested.

ii) Detail responsibilities for PIC during 'CAE Modeling' and 'Drawing' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
CAE Modeling and Drawing	Proton	Design Engineer	Approve the CAE modeling
	Ingress	Design Engineer	Evaluate the assemblability logic using CAE modeling. Discuss with Proton about the design and the analysis produced by the design team. Generate alternatives in assembly design.

iii) Detail responsibilities for PIC during 'Process Planning' in the detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Process Planning	Ingress	Product Planning and Control Engineer	Discuss with manufacturing engineer the process involved and the machines required. Determine production time, labor, inventory etc.
		Manufacturing Engineer	Determine the process layout and provide suggestions for the process.

i) Detail responsibilities for PIC in 'Define detail parameters' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Define Detail Parameters	Proton	Design Engineer	Have regular discussions and meetings with Ingress. Approve the design.
	Ingress	Project Manager	Control the flow of the design and solve any problems related to the scheduling. Hold discussions with Proton about the detail design.
		Design Engineer	Elaborate on the design and fix the parameters and accuracy of each component design. Detail calculation for strength and performance.
		Production Engineer	Coordinate discussion on matters related to quality. Suggest either to buy the part or make it. Identify the detail product design for every part and component. Identify the best method in producing the product and assist Design Engineer in choosing the suitable material. Make sure the parts are easy to manufacture. Determine the detail assembly sequence. Work closely with Manufacturing Engineer on product configurations and dimensions that may affect tooling.
		Product Planning and Control Engineer	To review periodically holding stock level for all raw materials, W I P, finish goods and consumable items. Provide information on in-plant inventories.
		Tooling Engineer	Determine the tooling used and identify the tooling that needs to be made. Estimate the tooling cost.

Appendix C.3 (continued)

iv) Detail responsibilities for PIC during 'Assembly System Design' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Assembly System Design	Ingress	Production Engineer	Determine the assembly system design based on the product design. Discuss this with the Design Engineer.
		Product Planning and Control Engineer	Responsible for the needed labor, the capacity of product and time estimates for certain products and inventory.

v) Detail responsibilities For PIC during 'Tool listing' and 'Tool design and fabrication' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Tool listing, design and fabrication	Ingress	Tooling Engineer	List the tools required for the process of the product. Request support from Katayama. Design and fabricate the tools needed.
	Katayama	Tooling Engineer	Design and fabricates the tools required by Ingress.

Appendix C.3 (continued)

vi) Detail responsibilities for PIC during 'Prototype design and fabrication' in detail design stage.

Activity	Company In Charge	Person In Charge	Responsibilities
Prototype Design and Fabrication	Proton	Design Engineer and Quality Engineer	Evaluate the performance and assemblability of the prototype sent by Ingress.
	Ingress	Production Engineer	Discuss the design and fabrication of the prototype with other engineers. Send the prototype needed to Katayama.
		Tooling Engineer	Check tool and machine needs in each process before fabricating the tooling for the prototype.
		Manufacturing Engineer	Verify the machine needs in processing the product in the shop floor.
	Katayama	Design Engineer	Design and fabricate the prototype for Ingress .

Appendix C.4

i) Detail responsibilities for PIC during 'Pre-production' stage.

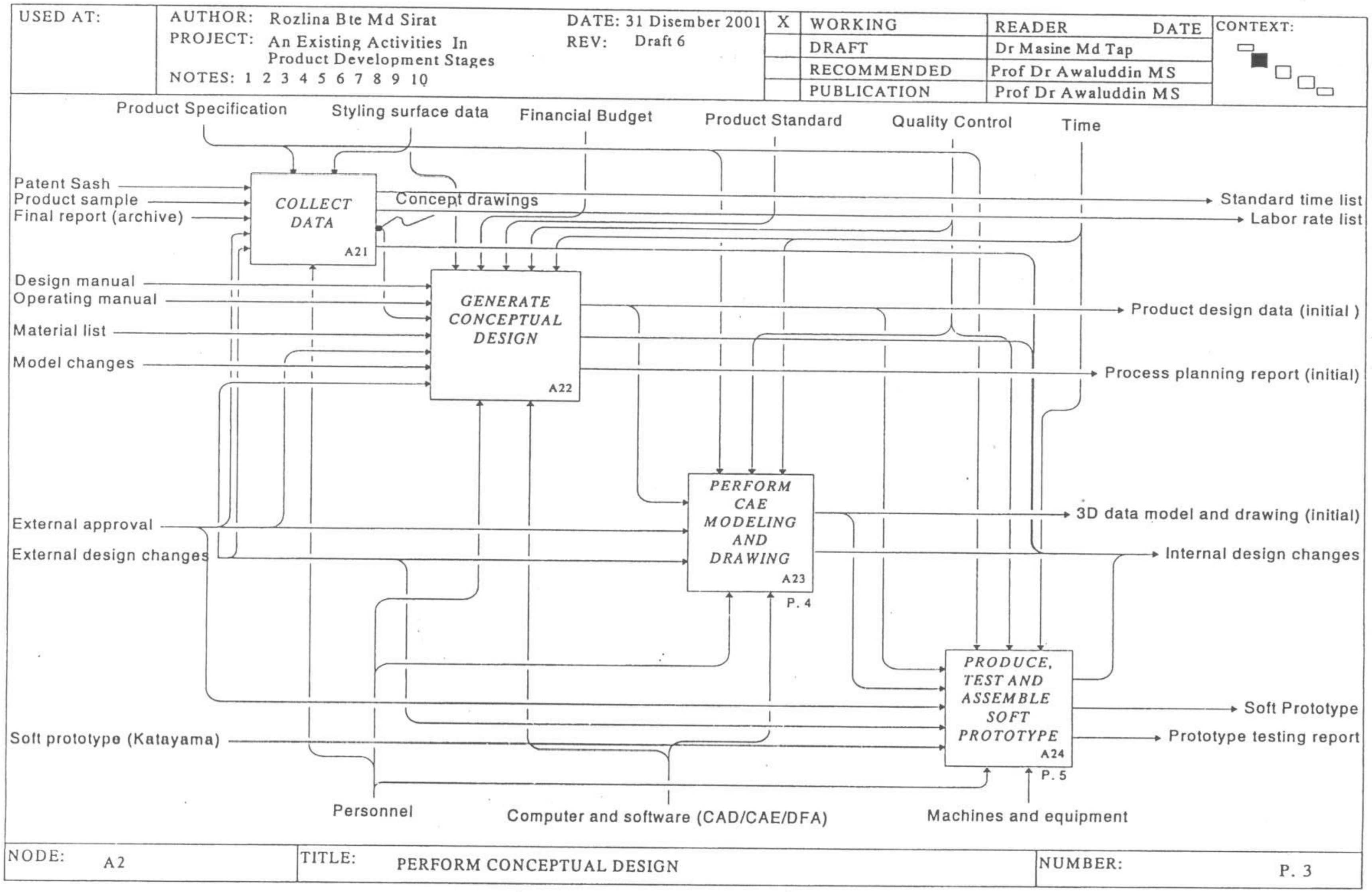
Activity	Company In Charge	Person In Charge	Responsibilities
Pre-production	Proton	Project Manager and Design Engineer	Discuss the problems that appeared in product.
	Ingress	Project Manager	Control the flow of the design and hold discussions with Proton about the pre-production and production.
		Design Engineer	Identify any problems in the product especially the design and performance.
		Production Engineer	Make sure the process of production follows the determined production sequence.
		Product Planning and Control Engineer	Suggest better machines and processes that can ease assembly. Evaluate assembly sequence flowchart from the point of view of PPCE.
		Tooling Engineer	Fabricate tools; give suggestions regarding modification of product.
		Quality Control	Ensure product quality.

Appendix C.5

i) Detail responsibilities for PIC during 'Production' stage.

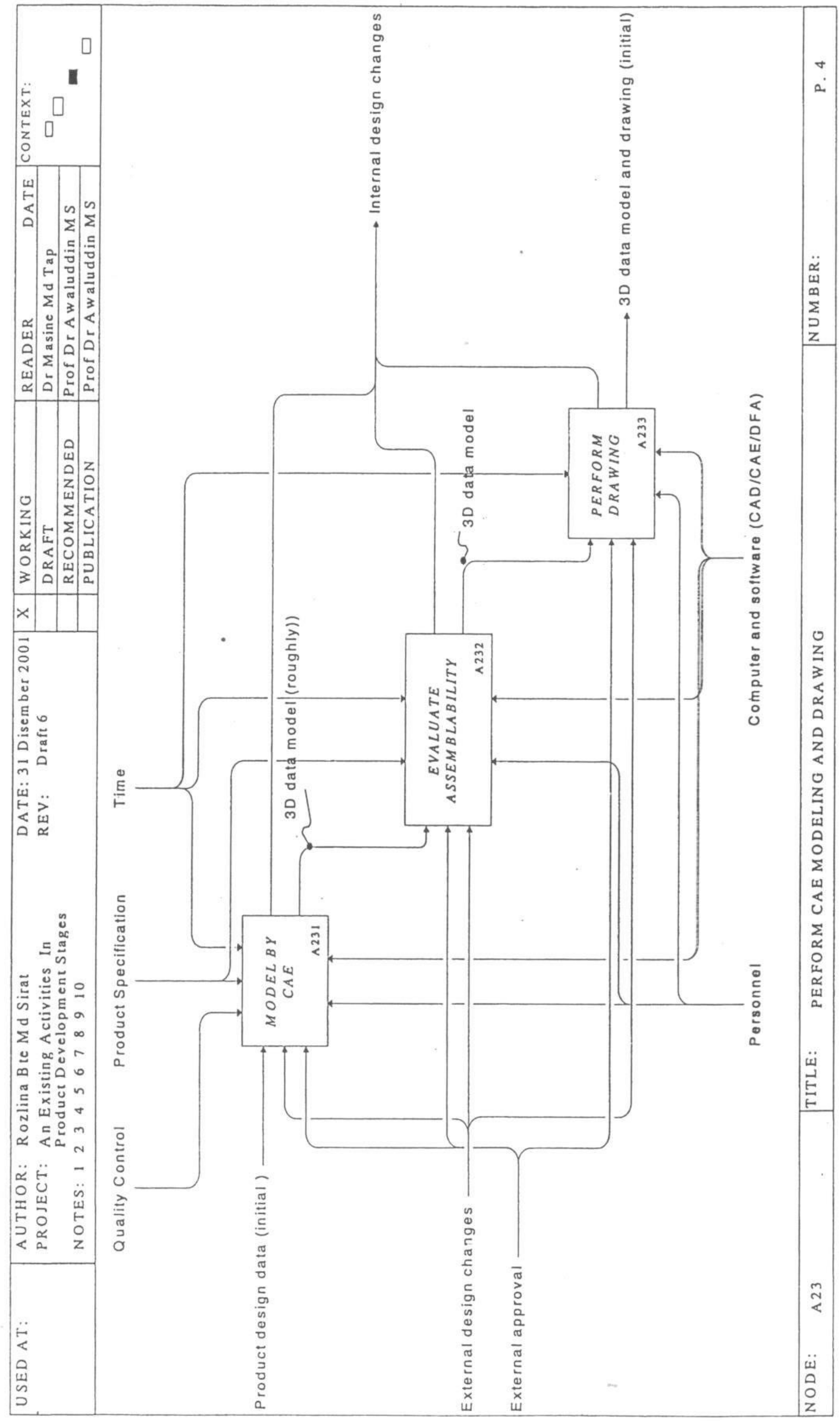
Activity	Company In Charge	Person In Charge	Responsibilities
Production	Proton	Project Manager	Discuss with Ingress the possibilities of model changes and recommendations.
	Ingress	Project Manager	Control the flow of the design and hold discussion with Proton regarding the required design changes .
		Design Engineer	Identify the weaknesses of the existing product. Study the future model changes according to customer requirements and discuss the model changes with Project Manager.

Appendix D.1

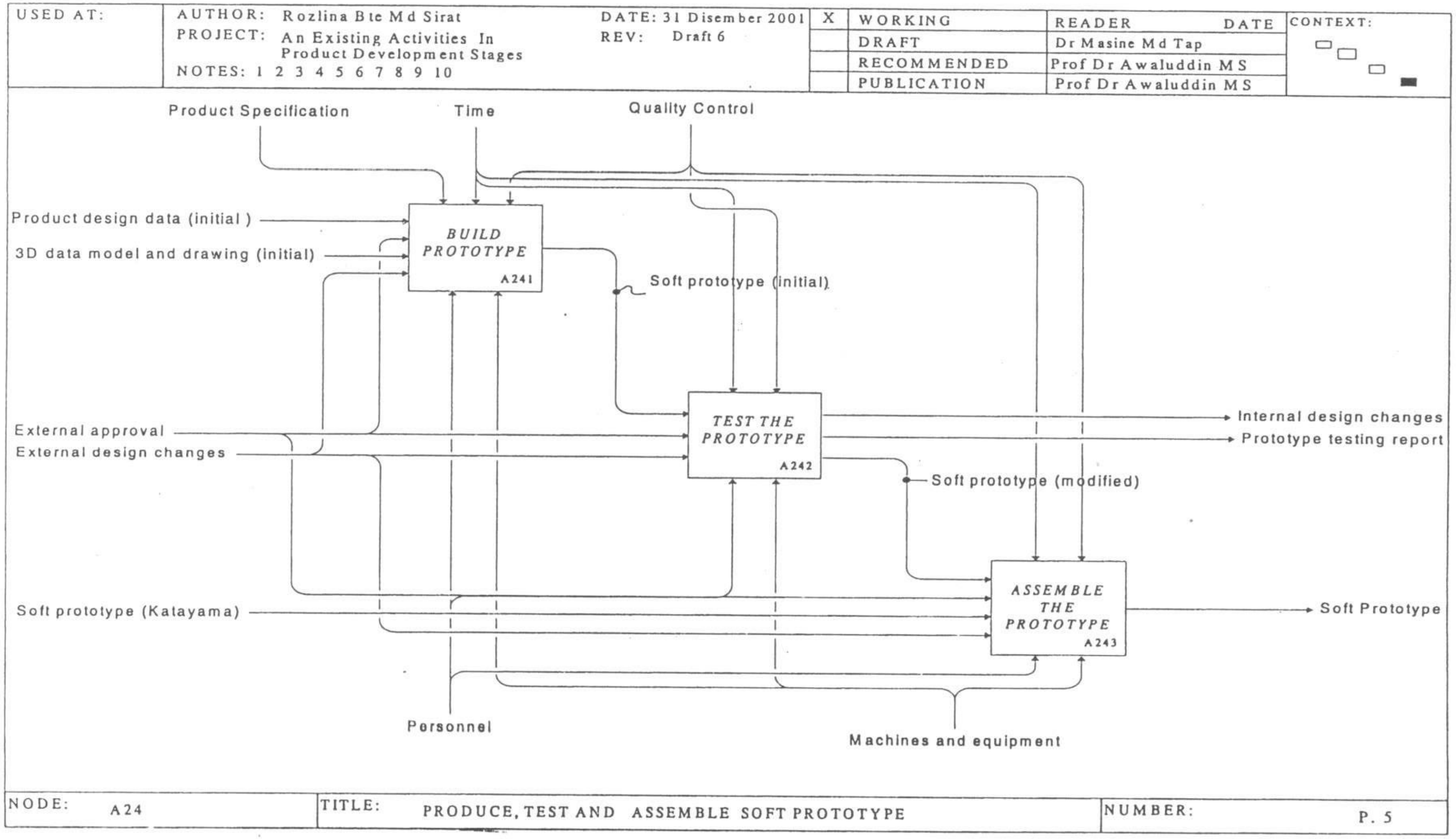


Appendix D.1: The decomposition of 'Perform Conceptual Design' in product development stage.

Appendix D.2

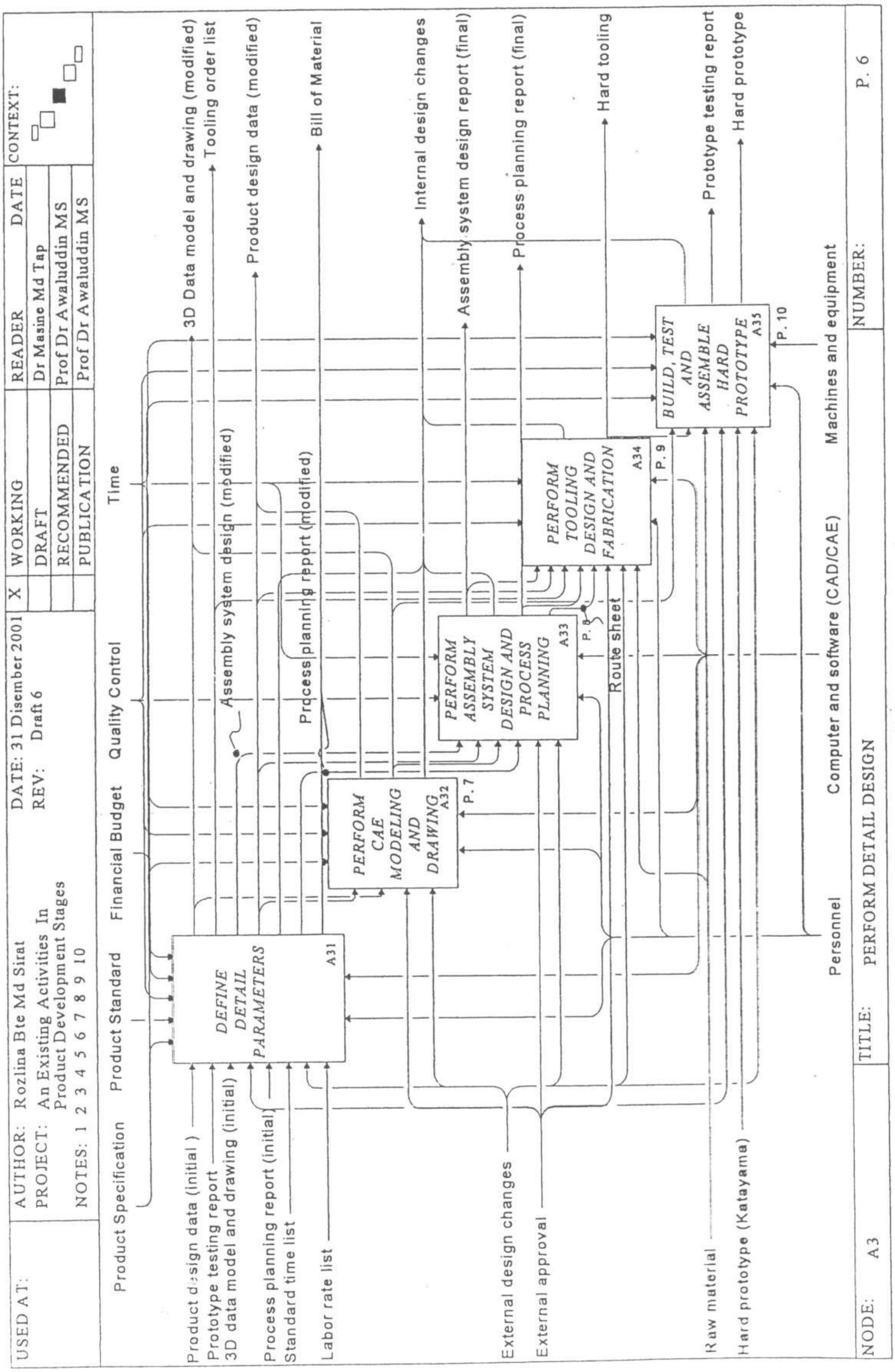


Appendix D.2: The decomposition of 'Perform CAE Modeling And Drawing' in conceptual design stage.

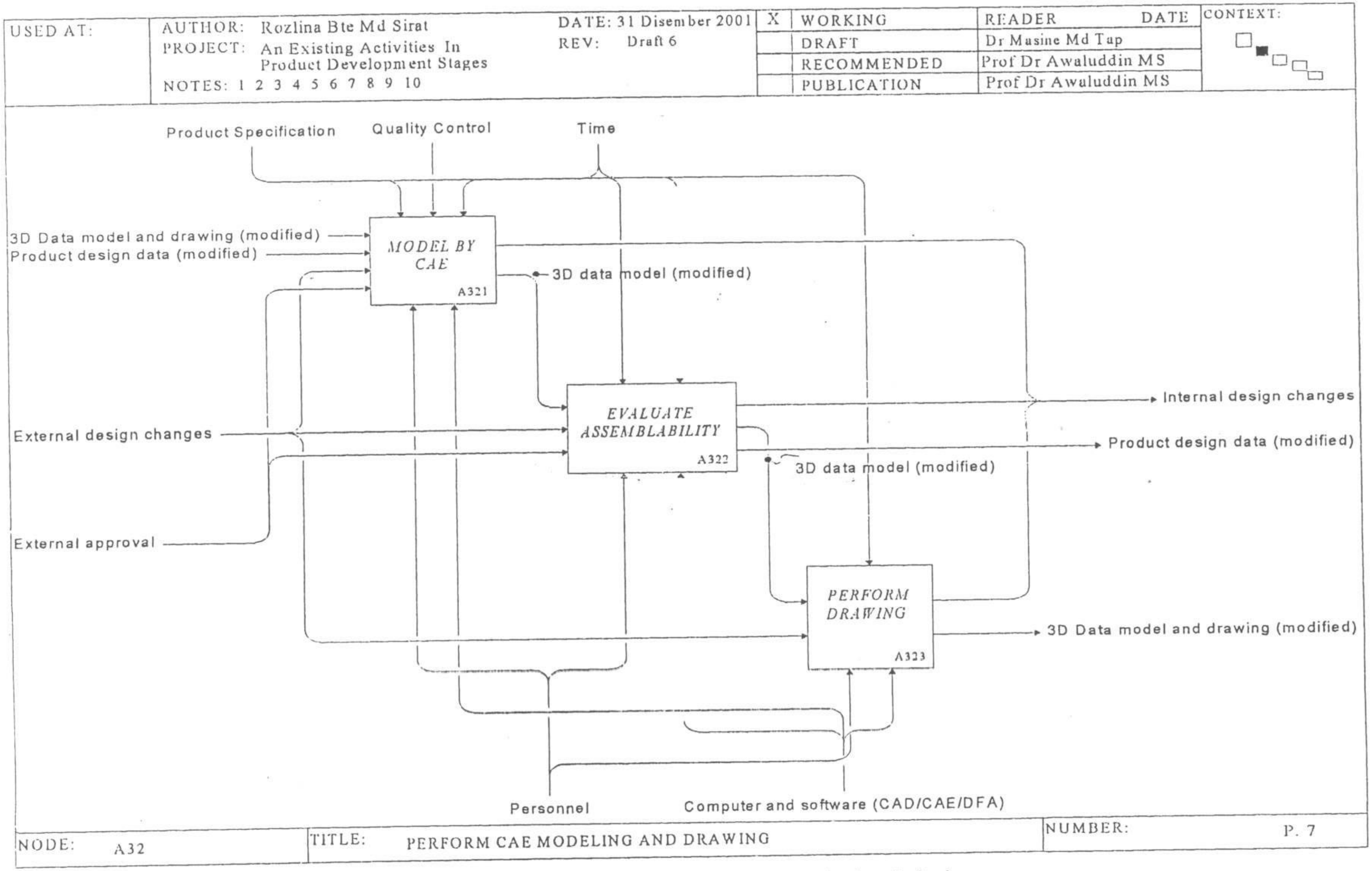


Appendix D.3 : The decomposition of ' Build, 'Test and Assemble Soft Prototype' in conceptual design stage.

Appendix D.4

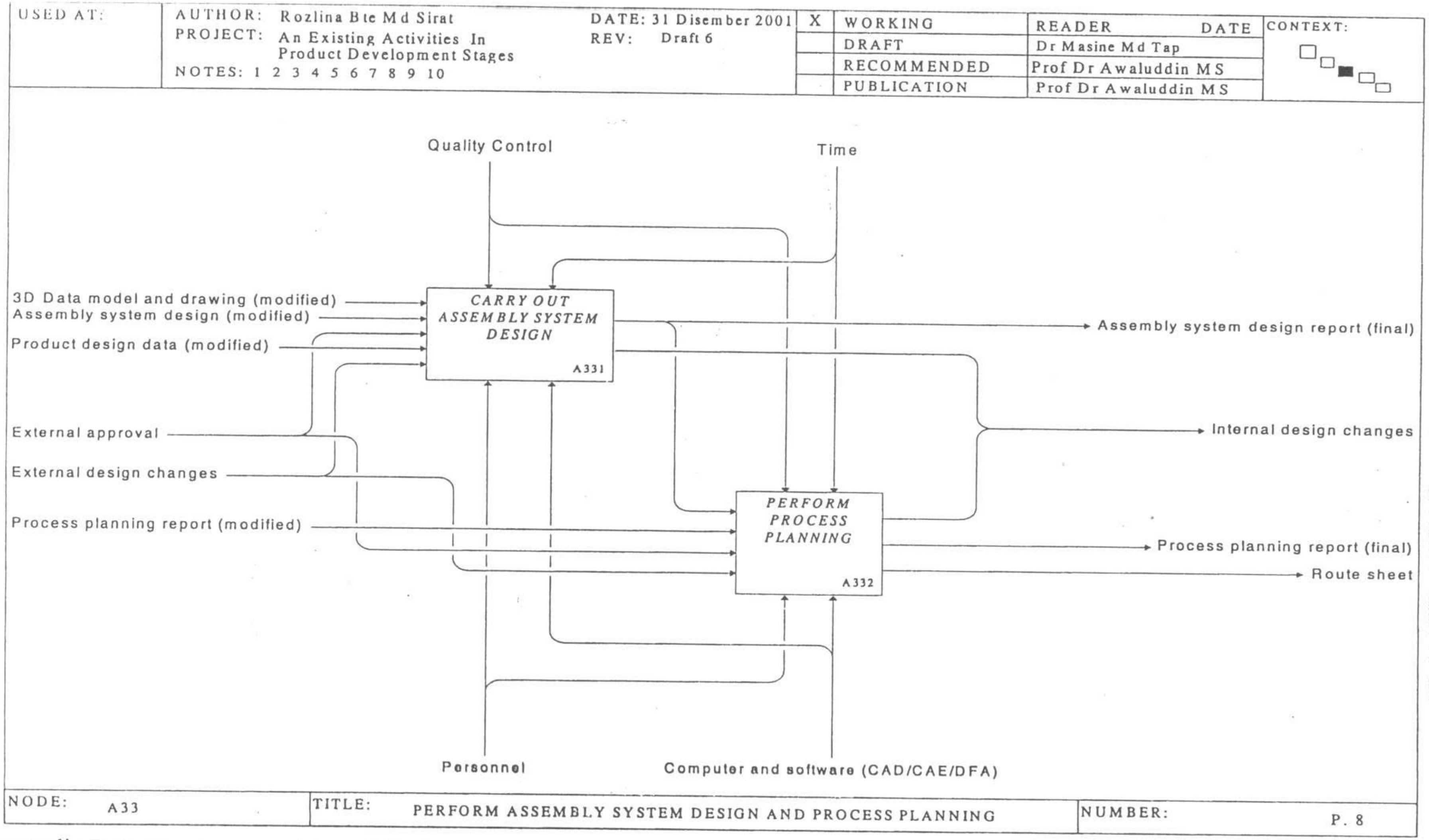


Appendix D.4 : The existing activities involved in the detail design stage.

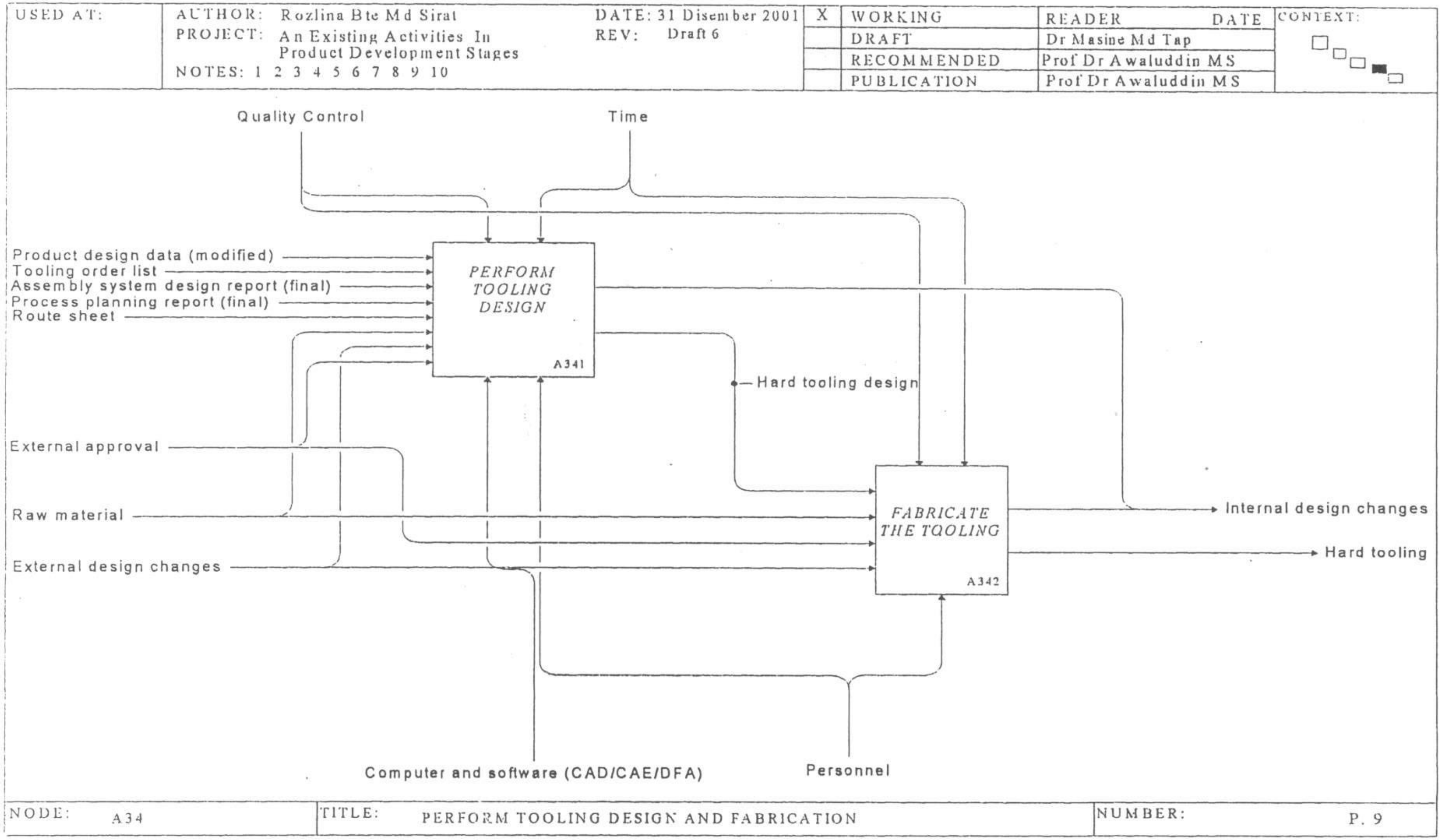


Appendix D.5 : The decomposition of 'Perform CAE Modeling And Drawing' in detail design stage.

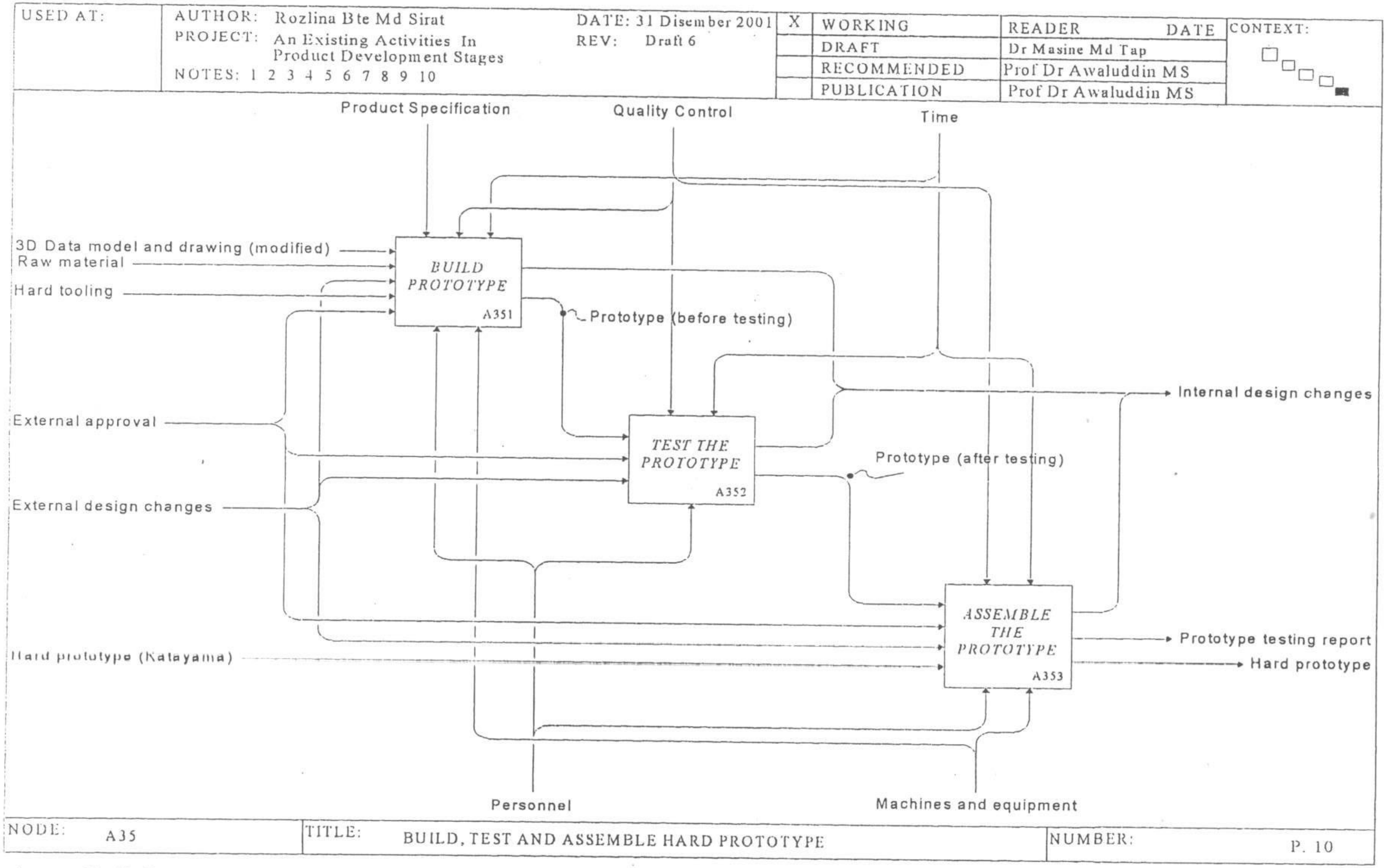
Appendix D.6



Appendix D.6 : The decomposition of' Perform Assembly System Design And Process Planning' in detail design stage.



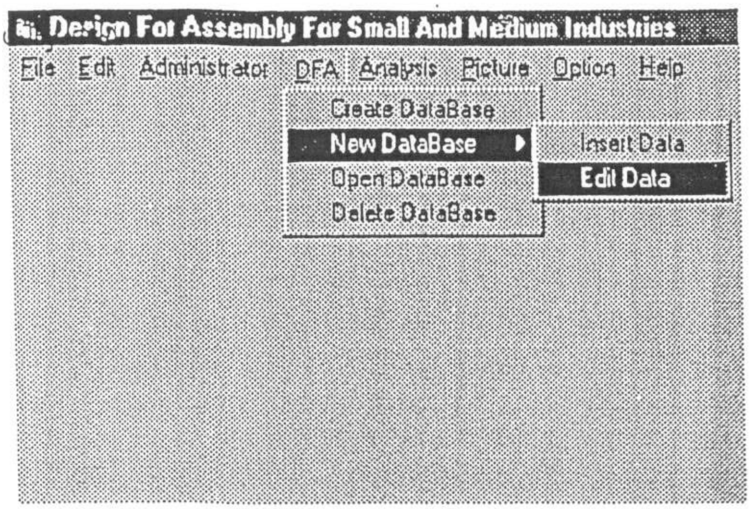
Appendix D.7 : The decomposition of 'Perform Tooling Design And Fabrication' in detail design stage.



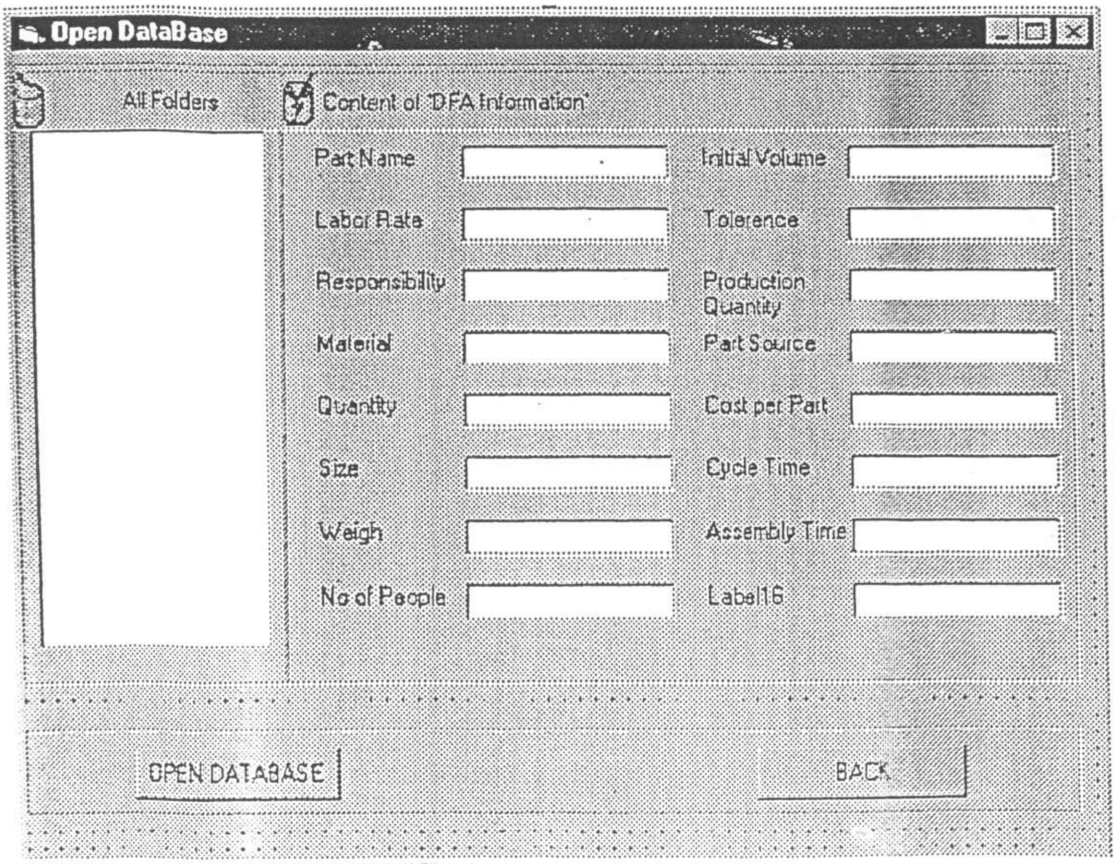
Appendix D.8 : The decomposition of 'Build, Test And Assemble Hard Prototype' in detail design stage.

An information system of DFA:

The example of **D**ata**B**ase **M**anagement Information **S**ystem (DBMS)

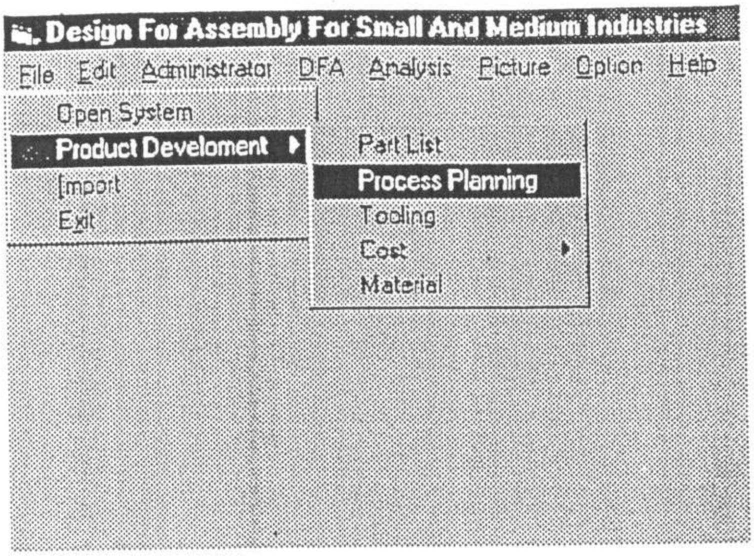


1. An existing DFA database can be opened or a new DFA database can be created by accessing from the 'DFA' menu.

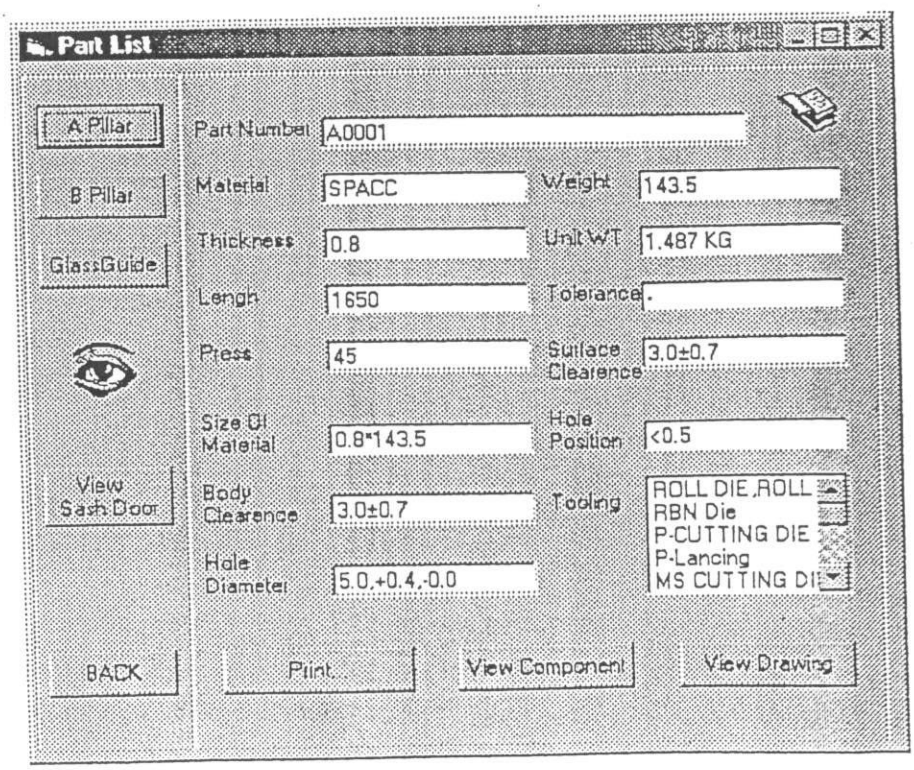


2. The content of 'Open database'.

Appendix E.1



3. Part list, process planning, tooling, cost and material can be opened from the 'Product development' menu.



4. The example of part list's interface.

Appendix E.1 (continued)

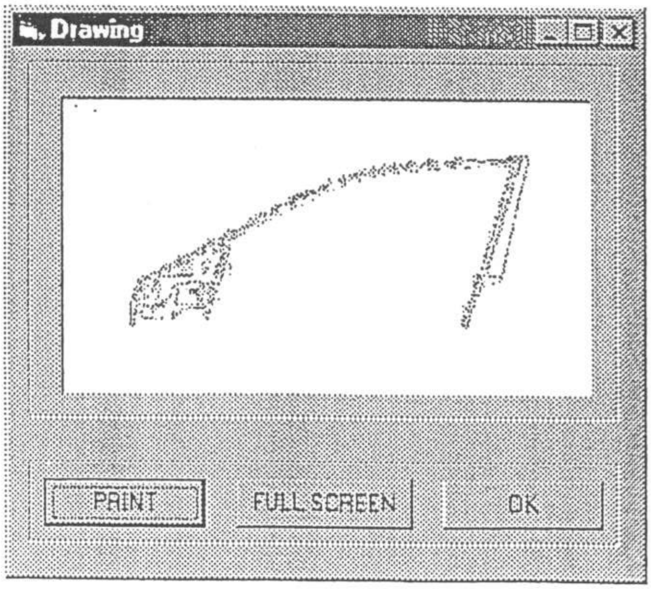
PartList Report About Sash Door For DFA

06/11/00

Code	Name	PartNum	Material	Thick	Weig	Lengh	Unit	Press	Toler	Mater	Surfa	Body	Positi	Diamet
APILLAR	Sash A	A0001	SPACC	0.8	143.5	1650	1.487	45	-	0.8*14	3.0±0.7	3.0±0.7	<0.5	5.0,+0.4
BPILLAR	Sash B	B0001	SSACC	0.8	174	650	0.710	45	-	0.8*6	3.0±0.7	7.1±0.7	<0.7	7.0,+0.4
CPILLAR	Sash C	C0001	SPCC-SD	1.0	55	677/2	0.146	45	-	1.0*5	3.0±0.7	3.0±0.7	<0.5	5.0,+0.4
REINF	Rinforcement	D0001	SGACC	1.0	480	274.7/2	0.518	45	-	1.0*4	3.0±0.5	3.0±0.2	<0.5	5.0,+0.4
GLASSGUIDE	Glass Guide	E001	SPCC-SD	1.4	-	-	-	45	-	-	3.0±0.5	3.0±0.5	-	-
BPILLAR INNER	B Inner	B0002	SPCC-SD	0.8	174	650	0.710	45	-	0.8*1	3.0±0.7	7.1±0.7	<0.7	7.0,+0.4
BPILLAR OUTTE	B Outter	B003	SPCC-SD	0.7	76	478	0.200	45	-	0.7*7	-	-	-	-

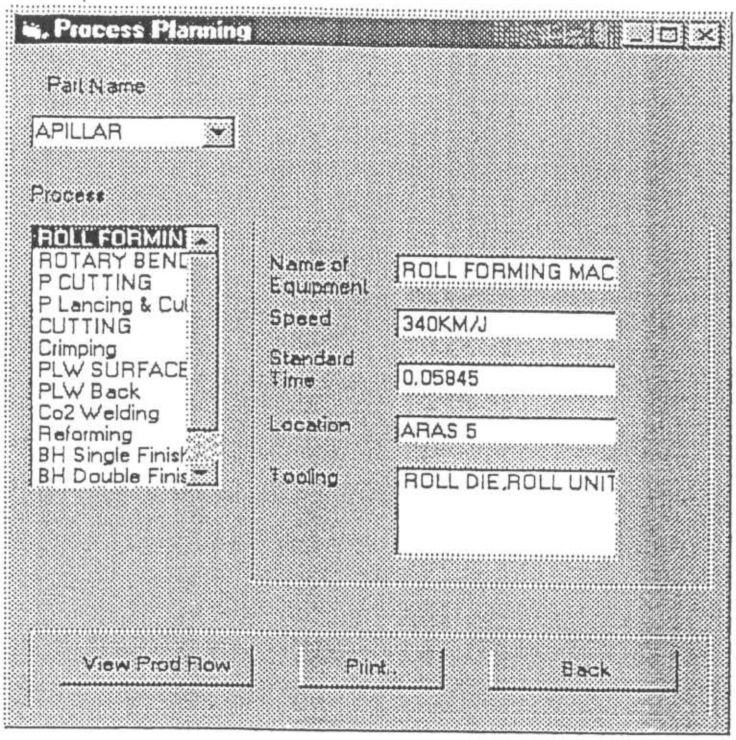
1 of 1 Close 29/10 02:30 Total:7 100%

5. The other interface for part list exists for printing.

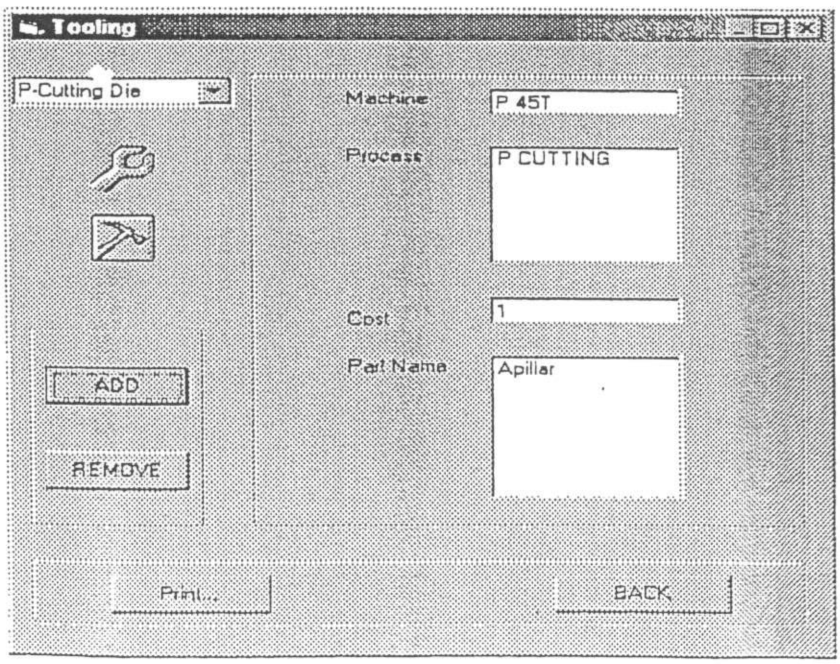


6. Interface for the 'Drawing'.

Appendix E.1 (continued)

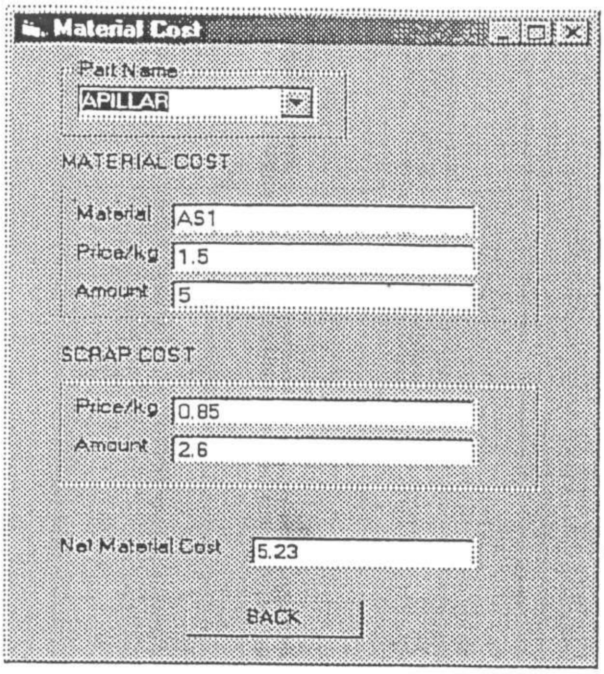


7. Interface for 'Process planning.'

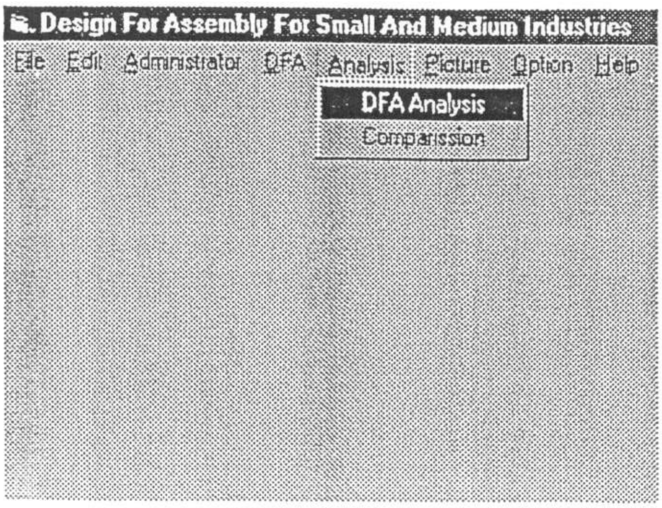


8. Interface for 'Tooling'.

Appendix E.1 (continued)



9. Interface for 'Material cost'.



10. The linkage for DFA analysis could be seen in DFA analysis menu.

PAPER THAT HAVE BEEN PUBLISHED AND WILL BE PUBLISHED

Rozlina Md Sirat, Masine Md Tap and Awaluddin Mohamed Shaharoun (2000) " A Survey Report on Implementation of Design For Assembly (DFA) in Malaysian Manufacturing Industries" *Jurnal Mekanikal*. **Jilid 1. Bil 9**. p. 60-73

Awaluddin Mohamed Shaharoun, Masine Md tap, Rozlina Md Sirat (2002) "An IDEF0 Based Framework for Implementing Design For Assembly (DFA) In Small And Medium Sized Enterprises (SMEs)- A Case Study." 2nd World Engineering Congress, Sarawak, Malaysia. 22-25th July.140-144

Rozlina Md Sirat, Awaluddin Mohammed Shaharoun, Masine Md Tap (2003) "Implementation Of Design For Assembly (DFA)- Between Theory And Practical" *to be presented and published in 19th International Conference on CAD/CAM, Robotics and Factories of The Future (22-24th July, 2003)*