The role and potential contribution of industrial design in developing agricultural machinery for Malaysia

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The Role and Potential Contribution of Industrial Design in Developing Agricultural Machinery for Malaysia

Mohd Nasir Hussain

BA in Art & Design (Industrial Design)
Universiti Teknologi MARA
Shah Alam, Selangor
Malaysia

MA in Industrial Design (Engineering)
Birmingham Polytechnic
England

A thesis submitted to the Loughborough University in partial fulfilment of the requirement for the degree of

DOCTOR OF PHILOSOPHY

Department of Mechanical and Manufacturing Engineering
Loughborough University
Loughborough, Leicestershire
LE11 3TU

February 2003

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DEDICATION

To my dearest wife Siti Zaleha Zainol,
son and daughter
Abdul Rasyid and Nadiah Nazirah
for their constant support, patience, understanding and love
DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application for any other degree or qualification of this or any other University or other institute of learning.
ACKNOWLEDGEMENTS

I would like to thank my supervisor Mr. Andy Taylor for his constant supervision, assistance, constructive criticism and encouragement. He also provided me with many excellent research facilities and guide me all the way through. Without his support the work would not have been completed so successfully.

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To colleagues in the department and within the Loughborough, Leicestershire, Cranfield, Liverpool, Manchester, Dundee and Southampton, I owe a great debt of gratitude for their moral support and helpful discussions.

Gratitude must also be extended to those individuals in industries and government agencies in Malaysia and also in the UK who have co-operated in the interviews and case studies.

I would like to express my considerable thanks to the Faculty of Mechanical Engineering, University of Technology Malaysia (UTM) and the Civil Service Department of Malaysia for providing study leave and financial support.

Finally, I would like to thank to my family in Malaysia for their moral support, encouragement, patience, understanding, sacrifices and prayers.
The Role and Potential Contribution of Industrial Design in Developing Agricultural Machinery for Malaysia

Mohd Nasir Hussain
Ph.D Thesis

Abstract

The aim of this research is to determine whether Industrial Design has an important role to play in the design and development of agricultural equipment, particularly in Malaysia. It is perhaps natural to think of agricultural machinery and equipment as being functional devices with issues such as task performance, robustness and reliability in all weathers being paramount. So is there really a role for the industrial designer? It is argued here that effective design of agricultural products cannot be achieved by considering only the functional requirements and technological aspects, since there are also many human issues to be taken into account. Effectiveness of new product development depends on interdisciplinary team working.

This research has been conducted utilising qualitative and quantitative survey methods consisting of interviews and postal questionnaires. The findings show the need for a broad approach to design and confirm that industrial design has an important contribution to make in Malaysian agricultural equipment industries. Introducing two design projects in this research has strengthened the research methodology. The purpose of these design projects is to implement the knowledge and skills of the researcher into agricultural machinery design activities as a means of gaining insight into the problems and processes fundamental to agricultural design. Design guidelines formulated from the research findings will provide Malaysian industrial designers with an approach for effective participation within agricultural design activities. These will help design teams to identify and consider the broad range of issues inherent in agricultural design projects, and hence to work more effectively.

Designing agricultural machinery requires an understanding not only of the tasks, crops and the working environment but also of the people who will buy and use the products. Malaysian agricultural machinery design activities have been left behind compared to some other countries. A push in this area could create major benefits because agricultural machinery design can provide significant advantages to the farmers and hence to the country.
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<td>2 Dimensional</td>
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<td>BS</td>
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<td>CAI</td>
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<td>CAID</td>
<td>Computer-aided Industrial Design</td>
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<td>Design for Manufacture and Assembly</td>
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<td>Engineering Designer</td>
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<td>European Economic Community</td>
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<td>HICOM</td>
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<td>International Conference on Engineering Design</td>
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<td>IEM</td>
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<td>IRPA</td>
<td>Intensification of Research in Priority Areas</td>
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<td>ITM</td>
<td>Institut Teknologi MARA</td>
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<tr>
<td>JCB</td>
<td>Joseph Cyril Bamford (trade name for J.C.Bamford Tractors and Excavators)</td>
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<td>MAMMDA</td>
<td>Malaysia Agricultural Machinery Manufacturers and Distributors Association.</td>
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<td>Political &amp; Economic Planning</td>
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<td>Society for Industrial Artists</td>
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<td>SIAD</td>
<td>Society for Industrial Artists and Designers</td>
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<td>SIRIM</td>
<td>Standard and Industrial Research Institute of Malaysia</td>
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<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
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<td>UK</td>
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<td>VE</td>
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CHAPTER ONE

Introduction

1.1 Introduction

Since independence 44 years ago, Malaysia has become a fast developing country. The government has implemented various development programmes; for example the 5 year Malaysia Plan. The objective of these programmes is to co-ordinate the social-economy of the multi-racial society in Malaysia. Malaysia has proven its ability to build a manufacturing industry by pulling together its resources and for the past 15 years has concentrated more of its resources in the manufacturing industries. These industries, involved in all fields in the private and public sectors, are able to use the creativity of industrial designers. This thesis is concerned with the ways in which industrial designers in Malaysia can best contribute in the field of agricultural equipment design.

This chapter provides an overview of the thesis which is divided into eight chapters, with the first chapter providing the background for the research. The second chapter is a literature study followed by chapter three describing the research methods used in this study which comprised interviews, postal questionnaires and case studies. Chapter four elaborates in detail the output from the interviews conducted in the UK and Malaysia. The following chapter discusses the outcome of the postal questionnaires. Chapter six illustrates two case studies, considering the design of a collecting device for oil palm loose fruits and another for collecting and transporting coagulated latex.

Chapter seven discusses the creation of design process guidelines for industrial designers to help them when involved in projects with other professionals especially mechanical engineers and agricultural engineers. Chapter eight concludes the findings from the chapters mentioned above, and provides recommendations and suggestions for future work.

It is intended that the outcome of this research will highlight the role and contribution of industrial design in the field of agricultural machinery and equipment design. In the longer term this will help to create more effective products, not only for Malaysian use but also for export for regional used as well as world markets.

1.2 Overview

The design and development of agricultural machinery and equipment in Malaysia is currently experiencing a number of pressures. These are:
A long-standing reliance on imported machinery and equipment and a consequent desire to develop a sophisticated home industry to supply a growing demand.

A realisation that in order to successfully produce and market appropriate agricultural machinery and equipment, design capability will need to be established at the centre of research, development and production activities.

Many plantations face tremendous problems in planting, clearing, picking and transporting in their everyday activities. The involvement of designers is necessary to consider these problems and create products or systems to improve the situation.

Older people are operating most of the plantations because youngsters prefer to work in the factories rather than on the plantations.

Usage of imported machinery is unsuitable for certain plantations and causes major damage to the land.

Currently a large number of agricultural machines and implements are imported from abroad and most of them are not specifically designed to suit Malaysia’s requirements. Modifications have to be made to adapt agricultural machinery to the situations and implementations that are practical in Malaysia’s environment.

Malaysia is a country rich in natural resources. As a developing country, Malaysia can be said to have made great improvements in its economic development. Within a short time, Malaysia has proven its ability to build a manufacturing industry to utilise its own natural products such as rubber, palm oil etc. Before these, most of the natural products were exported to countries such as Japan, Britain and European countries which in turn export the finished products back to Malaysia at higher prices. In order to improve its balance of trade, Malaysia has started manufacturing products which are necessary for its development.

Malaysia has now developed the manufacture of cars and motor-related industries but not in agricultural machinery and equipment. Currently, most of the agricultural equipment is imported from foreign countries such as the United Kingdom, United States of America, Japan and Europe. Most of the agricultural machinery and equipment is not specifically designed to suit the needs of Malaysia’s agricultural environment. To overcome this problem, research bodies such as MARDI (Malaysia Agriculture Research & Development Institute), PORIM (Palm Oil Research Institute of Malaysia), RRIM (Rubber Research Institute of Malaysia) have to undergo a process of design adaptation to fulfil this shortcoming.

Palm oil is one of Malaysia’s important exports beside petroleum, rubber, mining and timber. In recent years, the agriculture industry in Malaysia needed a lot of workers but it has been very difficult to fulfil the demand. Due to shortage of manpower, use of traditional methods, and the need to improve efficiency of operation, greater emphasis must be placed on
mechanisation and automation. At the moment, Malaysia still lags behind other developing countries in applying mechanisation into the agricultural sectors.

The rapid progress of industrialisation has received new and powerful impact in the nineties with the government's commitment to convert Malaysia into an industrialised nation by the year 2020. However agriculture will still contribute significantly towards the economy of this country.

The role and contribution of industrial design in agricultural industry can and should become one of the tools used to gain in upgrading the output and quality of agricultural goods. Design has the power to develop a product or brand. Products today not only need to be functional, but also have to be saleable.

Experience shows that design and development in agricultural industries do not make use of the skills and services of industrial designers. This study will attempt to find ways in which industrial designers can play their role, contribute expertise and become involved in the process of design in Malaysia's agricultural machinery industry.

Several agricultural industries have been identified as utilising adaptation technology as a means to improve their productivity. R&D institutions and the general public have not realised the potential for the skill and services of industrial designers to overcome such design problems in agricultural machinery.

1.3 Research Background

Industrial designers have not really played a part in Malaysian agricultural machinery design work and the projects have usually been carried out by mechanical engineers and agricultural engineers without industrial design background. Although industrial design has been established in Malaysia since the late 1960's, this agricultural machinery and equipment design activity has not foreseen the potential of industrial design to contribute in this area.

Therefore, this research will attempt to find out ways in which industrial design can contribute to the process of designing agricultural machinery to suit to the geographical, economical and social requirements of Malaysian agriculture. The researcher will also attempt to find out ways in which industrial design can become an accepted discipline in agricultural design projects. It is anticipated that the results of this research will increase the understanding of industrial design and its potential within Malaysian R&D institutions, universities and private sectors.
1.4 Justification for the Research

Over the past twenty years, Malaysia has grown rapidly and become a successful developing country. With a shift from an agricultural to an industrial base, Malaysia has the capability to produce her own cars, motorcycles and electronic parts and products and although she has become an industrialised country, agriculture is still a major part of the economy.

Several Malaysian Government Research and Development agencies have been set up to carry out research and try to develop suitable machinery and equipment that can be used by farmers. MARDI (Malaysia Agriculture Research & Development Institute), PORIM (Palm Oil Research Institute of Malaysia), RRIM (Rubber Research Institute of Malaysia), and UPM (University Putra of Malaysia), previously known as agricultural universities, are the government agencies that concentrate on agricultural activities in the country. There are also private organisations which support the government in speeding up agricultural development with their own association known as MAMMDA (Malaysia Agricultural Machinery Manufacturers and Distributors Association).

The government has identified two reasons why mechanisation is essential to agricultural sectors. The first is to upgrade every farmer's income and the second is to change the way of working in the plantations from manual to mechanised wherever possible. Several countries which are in similar stages of industrialisation are not addressing agricultural mechanisation. The problem of labour shortage is not a new issue in Malaysia in general and the plantation sector in particular. These factors have made farmers and plantation workers migrate to the industrial sectors. The nature of plantation work and the less comfortable rural environment in plantations have led to fewer Malaysians taking up employment in this sector which means that a large percentage left behind are elderly people and children.

Because of Governmental constraints caused by shortage of labour and increasing costs of production, R&D efforts have been directed at specific technologies to address these critical issues. In the short term foreign workers are recruited from neighbouring countries to meet the shortfall in labour.

1.5 Research Programme

The research programme for this study comprises four inter-related stages: literature study (stage 1), qualitative and quantitative survey (stage 2), case studies (stage 3) and proposed design guidelines (stage 4). The research was divided into two phases. The first phase was carried out within the UK and phase two was carried out in Malaysia. The organisation of the research programme is illustrated in Figure 1.1.
Stage one consists of identifying a research programme and as described in Figure 1.1 the researcher has laid out the programme in several stage and phases. A literature study is the focus of stage one where the research subjects relies on the literature from a number of design disciplines. The literature search includes the relationship between industrial and engineering design and other disciplines. Literature search was a process that continued throughout this research programme.

The literature study helped to identify several research aims and questions. The result of the literature survey is presented in chapter 2 and the research methodology is presented in chapter 3.

A qualitative survey based on interviews has been performed in stage 2. Open-ended interview questions were produced. Interviews were carried out in the UK and Malaysia. The results of a quantitative survey administered in Malaysia and the UK are presented in chapter 4. Chapter 5 discusses the results of the quantitative survey.

Part of stage 3 was conducted in Malaysia and involved interviews with Malaysian respondents, the circulation of postal questionnaires and observations for case studies. Engineers from PORIM and RRIM agreed to the researcher working on two of their current design projects with the intention of identifying the role and contribution of industrial designers. The results of these case studies are presented in chapter 6. Stage 3 also covers the analyses of all the data collected within the UK and Malaysia as well as the results of the case studies.

The results were then used to help produce design guidelines for Malaysian industrial designers. The design guidelines were evaluated by interviews with professional designers in the UK and the results are discussed in Chapter 7.
1.6 Importance of the Research

The development and design approach identified will be beneficial for agricultural machinery design, not only for Malaysia but also for other developing countries and third world countries. A significant contribution is expected in the area of reducing design modification and reconstruction, which will help to establish an indigenous Malaysian agricultural industry. The other important factors of the research are:

- To make more use of the role and contribution of Malaysian industrial designers in this area.
- To give some realisation to other disciplines of the importance of industrial designers to be as part of the design team.
- To have the equal opportunity in producing agricultural machinery and equipment and to promote Malaysian agricultural machinery and equipment successfully abroad same as others well known agricultural producers in the world.
- To help farmers in upgrading their incomes to afford to buy or have the equipment.
- To provide a magnificent method which can be used by Malaysian industrial designers when they wish to be involved in this design activity.

1.7 Aims and Objectives of the Research

There is a need for research which will inform the development and application of industrial design to agricultural machinery and equipment within the Malaysian economy. The ultimate purpose of this research is to provide industrial designers in Malaysia with methods or guidelines to assist them in designing machinery appropriate to Malaysian agriculture circumstances, and hence to help to establish an indigenous Malaysian agricultural design industry. A second purpose of the research is to understand the implementation of design processes in the UK and Malaysia and the interaction between industrial and engineering designers in a design team.

Specifically, the research aims were:

1. To study the design processes implemented by UK industrial designers and engineering designers in the field of agricultural machinery.
2. To study the role of Industrial design in the agricultural machinery industry.
3. To identify the type of design approach that is most suitable for use in agricultural machinery design.
4. To propose an appropriate methodology to help industrial designers to contribute in the design of agricultural machinery relevant to Malaysia circumstances.
The development and design approach identified will be beneficial for agricultural machinery design, not only for Malaysia but also for other third world countries.

1.8 Research Questions

This research will respond to a number of research questions, which have been identified to strengthen the research aims and objectives stated above. The research questions were divided into two sections, which are:

1.8.1 Main Research Question

- How can industrial designers contribute most effectively in agricultural machinery design in Malaysia?

1.8.2 Further Research Questions

- What are the differences in design processes used between industrial designers in the United Kingdom and Malaysia?
- What is the level of acceptance of industrial design by agricultural machinery producers and manufacturers in the United Kingdom and Malaysia?
- How might industrial designers become more involved in agricultural machinery design?
- What approaches are suitable for use in designing agricultural machinery?
- What are the difficulties industrial designers might face when involved in designing agricultural machinery?
- How important is involvement from industrial designers in designing agricultural machinery?
- How might design best be managed?

1.9 Research Method

This study involved the use of several research methods including literature survey, interviews, questionnaire surveys and case studies which are summarised as follows:

1.9.1 Literature Study

This research began with a literature survey to find relevant information aimed at broadening the understanding about the research area and to establish the viability of this research. An extensive literature survey was carried out throughout the research programme to accommodate the needs of the research.
1.9.2 Interview Survey

This method was carried out in the UK and in Malaysia. The same set of interview questions was used for the industrial designer and engineer/agricultural engineer. Interviews were carried out with industrial designers experienced in designing agricultural products as well as mechanical and agricultural engineers.

1.9.3 Questionnaire Survey

Questionnaire surveys were carried out with selected respondents from the UK and Malaysia. Results were analysed using statistical analysis package, SPSS for windows.

1.9.4 Case Studies

Case studies concentrated mainly on the researcher's own skills, knowledge and experience as an industrial designer. Before the design projects were carried out, the researcher made observations during a field visit in Malaysia to identify the problems and difficulties faced by the users in the plantations. Two case studies were carried out one involving a loose fruit collection device and another considering a coagulated latex collection and transportation device.

1.10 Proposed Design Process Guidelines

Design process guidelines were proposed based on the research findings to cover the stages from design needs up to a final design proposal. A novel aspect is the introduction of a scenario analysis stage after identifying design needs and also before the final design evaluation stage. The first scenario analysis identifies the whole environment of the situation and the problems occurring in current practice in the plantations. The second scenario analysis stage identifies the practicalities of using the proposed design in the actual situation.

These scenario analysis stages were introduced in the design process to make use of the capability and skills which industrial designers have within their discipline. The value of these 'scenario illustration and analysis' and 'virtual scenario evaluation' activities lies in helping the design team to obtain a clear picture of the problems in the plantations and how the proposed product design might merge with the actual environment before it is produced.

The significance of this scenario approach is to:
- make the early part of the design process understood very clearly by the team members
- make use of the skills that industrial designers have
- reduce the overall time taken during design activities.
The researcher has produced several charts to be used in identifying problems in agricultural design projects. The first chart represents the 'main task' where the problems are highlighted and from here it branches out into more detail. A list of questions related to the headings is then produced and at the same time a product design specification is also prepared. The designers produce a set of questions which are developed in parallel as the project continues.

Industrial designers will use the speciality that they have to produce preliminary concept ideas without having any unnecessary restrictions but the structured approach will help to avoid impractical designs arising due to too much freedom. Evaluation techniques are used in every design stage from preliminary concept ideas up to final design development stage. The proposed design process guideline is essentially for Malaysian industrial designers to enable them to work in stages and is intended to speed up the design project.

After evaluating these design guidelines more work needs to be done before it can be fully utilised by industrial designers. In the future it is the researcher's intention to develop a computer-based version to speed up the process.

1.11 Scope and Delimitations of the Research

1.11.1 Scope

1. From the literature search it was found out that there is a major incentive to involve industrial designers in agricultural machinery and equipment design projects. It also provides evidence that co-operation between industrial designers and engineers can produce successful agricultural design products. The literature search shows that the engineering design process can be implemented within the industrial design discipline with some modification to fulfil the necessity for industrial designers to have some formal method to follow during design projects.

2. The interview survey has provided sufficient information and has identified the importance of industrial designers be one of the members in the design team and the importance of gaining basic engineering knowledge to enable them understand the principle of designing agricultural machinery and equipment.

3. Postal questionnaire surveys have proven the importance of industrial designers in this area and the significant contribution to agricultural machinery and equipment design activity.
4. Case studies have shown that industrial designers can provide sufficient input to agricultural machinery and equipment design projects which could speed-up the process in achieving the end proposed design product.

5. The design process guidelines have provided a systematic way for industrial designers to perform design projects, especially in agricultural machinery and equipment which have been regarded up to now as engineering design projects.

6. Design process guidelines also provide a whole scenario of how the current practice is implemented, the problem occurring during working procedures and how new products may suit the environment, simplify the work process and minimise the problems to the users.

7. The evaluation method used in evaluating the design concept within the design process guideline has shown the effectiveness in identifying the outstanding preliminary design concept, design concept development and final design development.

1.1.2 Delimitations

The thesis is focussed on industrial design rather than engineering design. It does explore the relationship between industrial design and engineering design, but it does not attempt to provide a full picture of engineering design.

1. It is focussed on the needs of Malaysia and the circumstances and culture of Malaysian designers. The working practices of UK designers have been explored as part of the research, but the thesis is intended to be of most value to the people in Malaysia who are involved in creating and developing machinery and equipment for local agricultural needs. As the indigenous design capability increases it is expected that the results will be of benefit to other countries with similar agronomy.

2. The agricultural equipment to be designed in Malaysia will concentrate on low volume production because at the moment Malaysia is still in a developing stage and will change to high volume production when the products prove to be successful.

3. The thesis is not treated as an ergonomics exercise. It is acknowledged that ergonomics is very important in the design of agricultural equipment, but the thesis does not attempt to do the job of an ergonomist. The intention is to achieve an improved understanding of relevant design practices and to propose design guidelines which allow ergonomics, as well as many other considerations, to be effectively brought into the design process.
4. The use of computers in design has not been considered. Industrial designers and engineering designers now use computers for much of their work. Although the computer is an important tool, the working practices of industrial designers have not changed significantly.

1.12 Thesis Organisation

This thesis has been organised into eight chapters in which the first chapter contains research background, importance of the research, purpose of the research, aims, objectives and research questions which fulfil the purpose of this study. The second chapter presents the literature survey discussing agricultural mechanisation in both countries, the UK and Malaysia. It also reviews the nature of industrial design in the UK and Malaysia. This chapter also reviews the relationship between industrial design and engineering/agricultural engineering and the role of industrial design in the field of agricultural machinery within the Malaysian context.

Chapter three discusses the research methodology and research programme employed. The qualitative surveys, quantitative surveys and case studies have provided the basis for the design process guidelines. This chapter discusses how the interviews and postal questionnaire were conducted in the UK and in Malaysia. Two case studies are discussed in general to give an overall understanding to the reader of why the researcher chose to create a design for a product for the purpose of helping the users in the plantations. Chapter four discusses the findings from the interview surveys. The interview questions have been analysed by dividing into themes, to assess the relationship towards this research.

The UK and Malaysian quantitative survey in terms of postal questionnaires is discussed in chapter five. An overview is provided of the method used to analyse the data gained from postal questionnaires, which focused on frequency distribution and crosstabulation distribution to look at the relationship between two variables using the chi-square test. The UK and Malaysia results are discussed at the end of the chapter.

Chapter six covers case studies, which were conducted after observations made during three months in Malaysia. The researcher has chosen two types of case study after discussions with PORIM and RRIM engineers. The chosen design projects are based on collecting oil palm loose fruits and collecting and transporting coagulated latex. The researcher used the typical design process, which he has used for the past 15 years as a design lecturer and industrial designer in conducting the design projects. The findings from these design projects are discussed in this chapter.

Chapter seven discusses the proposed design process guidelines and how it may be implemented in real situations within the industrial design discipline. The problems,
difficulties and advantages of this design process guideline are discussed. The findings from
the interviews with professional designers towards the effectiveness of these design
guidelines are also discussed and the summary of this chapter focuses on the next steps to
be conducted in the future.

Finally, chapter eight concludes the findings of the research for each of the methodologies
used in this study and overall conclusions. This chapter also provided several
recommendations for future work especially in organising the design process guidelines in
manageable ways and the need to establish the procedure and technique in software form.
This research has brought about new insights on the role and contribution of industrial design
in the design of agricultural machinery and equipment.
CHAPTER TWO

Literature Study

2.1 Introduction

This chapter begins with an overview of design and the definitions given by a number of well established people involved in industrial design and engineering design. This is followed by a review of literature to gain an understanding of agricultural mechanisation in Malaysia and the UK.

The understanding and definition of industrial design and engineering design, and how it is practised is discussed including the fundamentals of both professions. It is also intended to establish the relationship between industrial design and engineering design and the importance of the relationship between these two professions.

The role of industrial design in the field of agricultural machinery is discussed to show that there are opportunities for industrial designers in agricultural machinery and equipment especially for Malaysia.

2.2 Overview of Design

Design is a broad field of making and planning disciplines and is essentially a practice of creation. Every design requires varying amounts of creativity, ranging from the aesthetic to the practical.

"Design! Good design, bad design, evolutionary design, and appropriate design. I have a problem with this word. Like a fundamental particle. Design comes in so many shapes, spins, colours and flavours that we discount its meaning. Is it a verb or is it a noun? What it means really does matter because we often make mistakes when we do something with a fundamental misconception of the nature of what it is we are trying to do." (Edge, 1997: 4)

Design, is a discipline, not science and it is not art. It has its own purposes, values, measures and procedures. These become evident through comparisons, but they have not been extensively investigated, formalised, codified or even thought much about in literature created for the field (Owen, 1998).
Design is a process, the making of a pattern for the progression from a state of needs and resources to one of needs and means to satisfy them (Lisborg, 1966). The word design means many things to everybody. It includes or contains the work of people from a wide range of disciplines such as industrial designers, design engineers, architects, graphic designers, environmental designers and all those industry and product-related disciplines. Design in an industrial context is not simply a matter of good looks; it is a translation process, translating the results of research, technology and innovation into a physical product (Williams, 1993).

There are a number of definitions of the word 'design', but the one that Howard Biddle (1994) finds most useful is 'design is the synthesis of technology and human needs into manufacturable products'. Kimber (1993) expressed that a basic definition of design can be obtained from any dictionary e.g. 'a design – a mental plan, intention; plan or representation of a thing by an outline; a draft or scheme to serve as a guide in subsequent practical work'. Hence to design is 'to evolve and prepare such plans or scheme'.

Design is considered to be one of the most significant of intelligent behaviours in humans (Oxman, 1996). Design and designing are important human skills, especially as good design is not easy. According to Morrison and Twyford (1994) design is:

- An ever-changing and evolving process based upon human achievement and technical prowess.
- Imaginative life made real.
- Predominantly a problem-solving activity.

Papanek (1983) believed all men are designers. Although professional designers might naturally be expected to have highly developed design abilities, it is also clear that non-designers also possess at least some aspects, or lower levels of design ability (Cross, 1990). All that we do, almost all the time, is design, for design is basic to all human activity. Design is the conscious effort to impose meaningful order. And the term meaningful replaces the semantically loaded noise of such expressions as 'beautiful', 'realistic', 'abstract', 'nice' (Papanek, 1983). Dormer (1993) expressed the notion that design was seen to have two separate but related functions: it could be used strategically by a corporation to help plan its manufacturing and shape its marketing; and it has a more obvious role in making individual products attractive to consumers. Morrison and Twyford (1994) said design is a field of study that has economical and industrial significance, with regard to its role in promoting flexible and creative attitudes towards industry.

By 1588 the word 'design' had the meaning 'purpose, aim, intention': by 1657 the meaning had become 'the thing aimed at'. By 1938 it had gained the composite meaning of aim plus thing aimed at. It has come to stand for a process – from the original conception through the
plan and the manufacture to the finished object. The idea of honesty is fundamental to good
design. A well designed object should not only serve its purpose well but should look as if it
were made for that purpose and no other. (Bertram, 1979)

Design must become an innovative, highly creative, cross-disciplinary tool responsive to the
true needs of men. It must be more research-oriented, and it must stop defiling the earth
itself with poorly designed objects and structures (Papanek, 1983). Telling people “design is
good for you” is not enough, however. To make a difference, you must be able to
demonstrate in practical terms how design specialists and non-specialists alike can work
together to produce a competitive product (Summers, 1997).

Design can be viewed as a discrete activity, as a total process or in terms of its tangible
outcome. It also can be viewed as a management function, a cultural phenomenon and as an
industry in its own right. It is a means of adding value and a vehicle for social or political
change. Design is defined differently in different countries (Cooper and Press, 1995).
Designing is not a new activity. All ascendant civilisations have used it. The essential shape,
form and structure of many artefacts, such as containers, tool, cloths and decorations, were
fixed ten, twenty or even one hundred generations ago (Dormer, 1993).

Pye (1964) believed that design is the thing which sharply distinguishes useful design from
such arts as painting and sculpture in that the practitioner of design has limits set upon his
freedom of choice. A painter can choose any imaginable shape. A designer cannot. If the
designer is designing a bread knife it must have a cutting edge and a handle; if he is
designing a car it must have wheels and a floor. These are the sort of limitation which arise,
as anyone can tell, from the ‘function’ of the thing being designed.

According to Ashford (1955) design is not something static which can be repeated like a
formula. It is essentially creative, something growing all the time, and the only person who
can produce it is the artist, the designer. Kimber (1993: 29) defined design as given by SEED
(Sharing Experience in Engineering Design):

“Design is seen as the total activity necessary to provide an artefact to meet
a market need, it commences with identification of the need and is not
complete until the resulting product is in use, providing an acceptable level of
performance. Design is seen as having the following characteristics: Central
to engineering, trans-disciplinary and highly complex, iterative and
interactive. It demands of its practitioners the following attributes: ability to
communicate, creative and analytical skills coupled with the ability to
integrate, use of judgement and management ability”
Evan et al., (1982) described design as the process by which they took a conceptual idea of his or her own, or of the clients, and created from it a desirable artefact or environment. Design described by Talbot (1982) is an activity which affects the interests of a variety of individuals, groups, organisations, communities, and even perhaps countries and civilisations. So the design has to serve the interested parties. Yeomans (1982) said design is supposed to begin with an analysis of the problem and include testing of the solution against the requirements of the brief. Cross (1982) mentioned he will overcome with something known as 'good design' which is expensive, difficult to obtain, usually not to the layperson's taste, inconsistent lifestyle and 'bad design' because they are self-evidently bad – they are uncomfortable, unsafe or injurious. Bill Hollins (1993) who was on the committee that compiled BS 7000 'Guide To Managing Product Design', does offer two definitions of design (in the context of product design). One as a verb "To generate information from which a required product can become a reality" and one as a noun "The set of instructions (e.g. specifications, drawings and schedules) necessary to construct a product". John Butcher (1988) defined design as the planning process for products or services that fully satisfy the aspirations of the customer.

A design is a man-made product or process that satisfies acknowledged and stated criteria. This definition states concisely that design may be either a product (artefact) or a process (method) that is the end-result of man's purposeful activity. Further, that the design activity is purposeful is made explicit by stating that the characteristics of the end result are prescribed by the initial starting criteria – such criteria having been acknowledged (accepted) and stated (recorded) at the outset by the designer (Gibson, 1993)).

Design is universal and it is broad in its terms. However it can be expressed in many ways according to the understanding of each individual designer. Booker expressed in his own terms that design is the creation of new things, new products, new concepts, etc. from the old. It is an iterative process for generating a plan which when put into action is intended to satisfy a stated need (Booker, 1993). Design is about the function, nature and appearance of "things". Furthermore, it is a creative activity concerned with problem solving and, in its broadest sense, communication. Design is certainly concerned with objects or products, but it is an activity (Cooper and Press, 1995). Geddes (1979) said design is not primarily a matter of drawing but is also a matter of thinking.

Russell (1997) believed design must be good because it is an essential part of a standard of quality. Good design always takes into account the technique of production, the material to be used, and the purpose for which the object is wanted. It is also not something that can be added to a product at a late stage in its planning or manufacture. It is fundamental. He believed that good design is not precious, arty or "highfalutin".
Design is a human activity, its study should not be concerned solely with processes involving the form, function and costs of artefacts, models, systems or image. Design is also a mixture of trends, tasks, aesthetic ideals, problem-solving and decision-making for use in many fields of knowledge that are historically, socially and culturally located (Morrison, 1994). Wooding (1966) in his paper mentioned Hinton believed that design is the highest form of engineering art.

Taylor and Ben (1993) categorise design as an evolutionary process where as they develop raises problems to be addressed which in turn to proposed solutions and hence to further evaluation. Evaluation and synthesis are therefore clearly interdependent and have a symbiotic relationship operating in a cyclic manner throughout design.

Bayley (1988) defined in his own words to avoid confusion about design by saying:

“Design is really not one subject, but many. Although the word has, in various forms, been in use since the 15th century, I would say that design is an essentially ‘modern’ phenomenon. When I say ‘modern’ I mean post 18th century. It is a process which has occurred since the manufacturing cycle got split up between maker, seller and user. Design combines engineering, material science, inventions, art, commerce, anthropology, ergonomic and social science.”

Hollins (1993) believed any definition of design should include the following:

- An indication of market need (market pull) or an idea (technical push) or other trigger that kicks off, what must be, a process.
- It should describe it’s multidisciplinary nature.
- It should state that it is an iterative process.
- It must mention that it’s purpose is to produce a product.
- It must state that it continues beyond the start of production preferably as far as the eventual disposal of the product. If the designer thinks that far ahead many future problems could be accounted for or eliminated.

Almost any definition of design is acceptable provided that the context is identified, and that it be validated by evidence in the real world. In other words, such a definition must rest on solid epistemological and metaphysical foundations. Gibson has come out with a definition in the context of product design: Design is a purposeful process that takes an initial specification forward into a product (Gibson, 1993)). Gordon Edge (1997) see design as ‘innovation’. He described this word as a continuum extending from the concept all the way to the market. A cultural continuum of design to contribute to the way a product operates, looks, feels, behaves, costs, is delivered and supported. Design is holistic and has relevance to many
elements of human and professional life. Design also is not merely about generating products and messages: it touches the lives of all people across the globe (Clark, 1994).

'Design is a human activity of long standing. Its appearance in the world marks the progression of life from a proto-human to a human state. Design happens whenever a person intentionally creates something, as each of us must do many times daily to meet life's needs. Humans respond to these needs intuitively, without reflection. It is also true that some of the highest, most keenly felt, human aspirations are expressed through design, an activity that is highly reflective... Design comes alive with insights and new possibilities when seen as a whole, in terms of its defining essence' (Willem, 1991: 136).

'Design is now recognised as a multi-layered discipline which should be built into all the marketing and promotional strategies of a business right from their inception. The good design of products, and a strong corporate identity, has quickly become a prerequisite to retailers for survival' (Conran, 1988). It is widely recognised in business and government that design is important, both to the success of individual firms and to the economy of every country as a whole (Sentence, 1997). Designing is the creation of what becomes real by the deconstruction of something else (Jones and Jacobs, 1998). Beyond the year 2000, Sheridan Tatsuno (1994) believed that there would be a major revolution in design. Design is not an added value, it is a value (Chan, 1994) After all some points that are certainly true about design as described by Fox (1993) are:

- It is creative.
- It is a multidiscipline process.
- It seems to need to be iterative.
- It is evolutionary.
- It serves human needs.

Design after all must be accepted by the public. Design – there's no end to it.

2.3 Agricultural Mechanisation – An Overview

Since independence in August 1957, Malaysia has developed successfully. At the early part of independence, the government focussed on developing the country as agricultural base because of the suitable land that can be planted with many type of commercial plants such as rubber, oil palm, coconut, pineapple, tea and other commercial crops.

The use of mechanisation in the plantation is to make work easier and speed up the activity. Fertiliser application, in-field fresh fruit bunches (FFB) collection and mainline transport is the
major mechanisation in field operations. Agricultural machinery design and manufacture takes place in foreign countries and Malaysia has to import both the technology and machinery in its mechanisation work due to the lack of expertise in agricultural machinery development. Technology is considered as appropriate when the skills and abilities of the people of the country are utilised as fully as possible and when the technology serves to upgrade and build-up these abilities and skills in a continuous learning process. Local machinery design and development would serve to upgrade and build-up the abilities and skills of presently available human resource in a continuous learning process.

Agricultural engineering has been introduced in most of the agricultural activities from land cultivation to the processing of agricultural products. It can be said that the progress has been achieved in the field of agricultural engineering but Malaysia is still behind from others developing countries in the mechanisation of the agricultural machinery and equipment. With the increasing numbers of agricultural engineers produced from local and foreign universities, the time has come where Malaysia should take a more positive and appropriate approach in its mechanisation efforts utilising domestic materials for the development of small and medium scale agricultural machinery and equipment. More efforts are urgently required to give encouragement to the agricultural machinery design development in this country.

The researcher under his groundwork study and observations made in Malaysia found out that industrial designers have to work or co-operate with agricultural engineers in developing agricultural designs in order to improve the agricultural machinery and equipment design activities. Industrial designers are good in making the products look good aesthetically as well as human-factors which could transform the products ease and comfort of use. Although engineers within R&D institutions and universities have carried out research and design projects, involvement of industrial designers seems to be neglected by them in looking at the process of designing agricultural machinery and equipment.

2.3.1 Agricultural Mechanisation In Malaysia

Agricultural mechanisation has become increasingly essential due to problems of inadequate labour during the traditional peak labour periods of land preparation, transplanting, harvesting and transportation. Mechanisation has been introduced in Malaysia for the past 40 years and has been confined to testing and adaptation of foreign-made agricultural machinery.

The government has to ensure that the importation of foreign technology and machinery in this country has to follow some sort of restriction to avoid a lot of modification and reconstruction which would save money in long run. The technical and economic issues
related to this matter that had been identified associated with agricultural mechanisation included:

- The need for relatively low ground pressure devices to avoid damaging soft soils.
- The need for adequate ground clearance.
- The need for adequate manoeuvrability.
- The need for durability and easy maintenance.
- The need for low capital cost and high annual utilisation.
- The need for local design and development to meet the region's specific requirements.

(Seng, 1980)

Research and development efforts by government agencies and by private industries have developed some mechanisation systems and work methods but they do not work perfectly. One way to overcome this problem is by introducing modern technology. Palm oil, rubber, and rice planting can be done in efficient ways by utilisation of modern mechanisation. Planting rice can be done twice a year to increase the production of the farmers.

Malaysian agriculture is a labour-intensive activity and many youngsters have moved to industries equipped with more facilities than they can get in the plantation. This is one of the factors that decreases the labour force in the agriculture industry in this country. In the oil palm industry, millions of Ringgit Malaysia (RM) are thrown away because of lack of labourers in this particular industry. Reports from labourers association show that, although the income they can get is less than they can get working in the plantation, they prefer working in urban industries which have a more comfortable environment compared to plantations.

Overcoming food deficiencies by increasing agricultural production could also increase the income for every farmer. These changes have to be supported by several inputs related to agriculture activities, for example introducing animal farm industries or using new seed for planting. Protecting animals and crops from viruses, using the right fertiliser and pesticide, managing the farm in a proper way, and also introducing efficient ways of harvesting the crops can change the scenario of agricultural industries.

The importance of introducing agricultural machinery in upgrading the way of increasing the production can speed-up the working process as well as give the opportunity to the farmers to do extra work. There are quite a number of advantages in using machines in their plantations. It is time the farmers have to improve their production by using the appropriate machinery to increase their income and have a better life.

Plantations, which produce more than once a year, for example rubber and oil palm, have a great demand for using mechanisation. These plantations are quite unique and although
several machines from abroad have gone through several modifications to suit the work process they still do not meet the criteria. There is no denying that the demand in these particular plantations needs urgent action at the present and in the future to improve the productivity of these industries. There are strong requests from these sectors asking the government to introduce special machinery and equipment which are designed specially for rubber and oil palm industry to overcome the problem of using modification machineries and also to solve the shortage of labour. The efforts in producing new machinery are on going by several R&D institutions and universities such as PORIM (Palm Oil Research Institute of Malaysia), RRIM (Rubber Research Institute of Malaysia), MARDI (Malaysian Agriculture Research Development Institute), UPM (University Putera of Malaysia), UTM (University Technology of Malaysia) and UKM (University Kebangsaan of Malaysia).

2.3.2 Agricultural Mechanisation in the UK

'From the primitive farm implements of antiquity to the sophisticated agricultural machines of today is a far cry. Their evolution has been sporadic rather than a smooth progression and not infrequently in the face of scepticism and opposition by farmers and farm workers. Much of it has been trial and error, but gradually the advance has been until today Britain's agriculture is the most highly mechanised in the world'. (Partridge, 1969: 1)

Agriculture plays a fundamental role in the social, economic and political development of nation states. Today Western Society is concerned with the role of agriculture not only the nation-state but also in the supranational organisation of the European Economic Community (EEC). (Kirt, 1979)

It is generally accepted that the UK has the best structured agricultural industry in Europe. The economic situation and the future supply of food for world population require the productivity of power and machinery to increase further. Demands by the private sectors in the industrialised countries are specifically essential. They demand special machinery with high performance, simple operation, automatic setting and equipment which can speed up the working process. In the UK, full-time farmers normally require medium to high performance machinery depending on the size of the farm they have. Usually tractors and agricultural equipment will be maintained on their farms. Part-time farmers usually will go for machinery which is easy to operate, robust and inexpensive. (Kutzbach, 2000)

The agricultural engineering industry in the UK had been founded towards the end of the eighteen century. The establishment of this development began between 1700 and 1750. (PEP, 1949) According to Partridge (1969) many types of light and heavy ploughs equipped with wheels and without were being used in Britain during the seventeenth century. There
were many types of plough in use with different parts of the country that depend to the type of terrain and nature of the soil. Partridge added that in the mid-seventeenth century, there was an attempt made by Walter Blith in producing the essentials of good plough design and construction. Blith came out with a recommendation for designing and constructing a plough for better use but no one added anything of significance to Blith’s theory for a century or more after his death.

During the growing season of the crop the farmers’ efforts were concentrated on controlling weed growth, the only methods available were hand pulling devices. The horse-hoe was developed in order to hoe between rows of growing crops and remove the weeds and the device is very simple but quite effective. It was entirely a new design and was introduced by a successful person known as Jethro Tull, who had his own long and successful farming career and his worked was published in his *Horse Hoeing Husbandry* in 1733. Tull was the great pioneer of clean farming. He may, in fact, be regarded as the father of modern row-crop cultivation. (PEP, 1949 and Partridge, 1969)

After some time during the eighteenth century the theory and debate regarding plough design took place to encourage improvements in agricultural machinery in the UK. In 1839 the Royal Agricultural Society of England was formed and began a series of tests and trials of new machines and intensified competition took place between designers with offers of medals and prizes for outstanding developments. Ploughing matches were also organised. Factories producing ploughs had been established in England and Scotland early in the nineteenth century. Since then many agricultural machines have been designed such as the reaping machine designed by Joseph Boyce in 1800 but not very successful, Patrick Bell then came out with a more effective reaper machine during autumn 1828 and was known as the inventor of the first effective reaping machine. By the close of the nineteenth century harvest work had become fully mechanised. Machines were available for reaping and binding the crop, threshing, dressing and bagging the grain, and for elevating or stacking the straw into ricks.

In the twentieth century the development of the tractor has changed the face both of agriculture and the agricultural machinery industry but the use of horse remained unchallenged until Fordson tractors were introduced in 1917. The demand for tractors became high during the thirties. More than 55,000 tractors were used in Great Britain in 1939 and by 1942 it gradually increased to 116,830 tractors of all types of usage. 173,370 were used in 1944 and in the middle of January 1948, 261,180 tractors were used in Great Britain. (PEP, 1949)

Fordson tractors became popular to the British’s farmer until by the late of 1946 the Ford Motor Co. became the highest manufacturer supplying about four-fifths of the total British production of four-wheel tractors. Since than several new names emerged such as the

During the early years of the motor tractor the farmer had to adapt to the changing of the new era in implementing with new machines and equipment. Many of the leading manufacturers who had previously made tractors tried to come out with equipment that was suited to their tractors. Because the demand was too high, they assigned sub-contractors to build the equipment for them. In the middle of 1947 and early 1948, quite a number of sub-contractors firms emerged to manufacture equipment which can be attached to the tractors to perform additional work on the farm.

Changes happened rapidly towards the end of the twentieth century where engineers, agricultural engineers and industrial designers as mentioned in section 2.8.2, have designed different types of machinery to suit different types of work task. Changes keep happening to improve the agricultural industry in the UK as described by Graham McConnell (1995) where he has stated that there will be four types of changes which influence agriculture in the UK over the next ten years which are:

- Government and EC policy
- A changing attitude towards things environmental
- Advances in technology
- The ability of the education system to prepare participants for the new order.

He added that there would be a greatly increased sophistication of cultivating, spraying and fertilising techniques which will be exciting fields of endeavour for the agricultural engineer by 2005. Farming will change and become worldlier and more sophisticated, and so will engineering and design in order to serve the new look in agricultural industry in the UK, and European countries (EU) as well as for the whole world. Engineers, especially agricultural engineers and designers, should look forward to an increasingly important and challenging role in this field.

2.4 Industrial Design

There has been a variety of thinking, understanding and know how about industrial design since the Industrial Revolution but after the First World War, based on massive capital investment and with the growth of mass-production, a new generation of industrial designers emerged (Heskett, 1980). Industrial design was first mentioned in 1913, but the first person to style himself as an industrial designer was Norman Bel Geddes, in 1927. (Middendorf, 1998) The concept of industrial design became generally accepted during the Great
Depression of the 1930's through the work of Raymond Loewy and a little later of Henry Dreyfuss.

Industrial designers came from various types of background, for example Henry Dreyfuss (1955), his background was the theatre, Walter Dorwin was a typographer, Sixten Sason trained originally as an artist in Paris, then as an engineer, Raymond Loewy as an engineer etc. 'The confusion about exactly what industrial design is is understandable. If you ask 50 people, you might get 50 different definitions for industrial design' (Blaich, 1988). That is why the term and meaning of industrial design are slightly different towards clarifying industrial design. However industrial design has been determined generally as a profession which is involved with design that can be produced in large numbers to satisfy needs.

Industrial design is concerned with the design of manufactured products. For less complicated products the industrial designer may take responsibility for the whole of the design, simply handing over to production engineers for the production of the product. For most products the industrial designer works with design engineers, having a relationship with mechanical engineers etc (Tovey, 1989). Kees Dorst (1993) has defined industrial design is the development of mass-produced products (durable) for the consumer market.

Holme (1934) defined industrial design by separating these two words because it must be clarified carefully to avoid suggesting something different from what they actually mean. Design from his point of view is the deliberate ordering or planning of shape, matter or activity for a given purpose and industry means the production of material things for the use and well-being of man. By the combination of these two words he defined industrial design as the conscious ordering and planning of the production of material things to this end.

It is called 'industrial' because of its concern with products manufactured by industrial processes, and has tended to have an emphasis on vocational effectiveness and practice (Tovey, 1997). Industrial design, as Loewy (1979) puts it, 'delivers the goods'. It is a serious profession which combines good taste, technical knowledge, and common sense. Dreyfuss (1955) derived from Gilbert Seldes that defined industrial design as the application of taste and logic to the products of machinery. He added industrial design is a means of making sure the machine creates attractive commodities that work better because they are designed to work better. It is coincidental, but equally important, that they sell better.

Black (1983) derived from Dr. Tomas Maldonado who formulated industrial design as a creative activity whose aim is to determine the formal qualities of objects produced by industry. These formal qualities are not only the external features but principally those structural relationships which convert a system into a coherent unity from the point of view of the producer and the user. Industrial design extends to embrace all the aspects of the human environment which are conditioned by industrial production. Flurscheim (1983) addressed in
his way industrial design, which embraces aesthetic, ergonomic and graphic techniques – or arts, for they can be considered as either – provides tools that can assist in the specification of what is needed by the market and in design for man/machine interface.

Bayley (1979) expressed his view that industrial design has currently become a European language. It is the name given to one of the most significant processes to have developed during the twentieth century. At one end it can be concerned with the engineering design. Lucie-Smith (1983) put it, in his own definition of industrial design, as the business of determining the form of objects which are to be made by machines, rather than produced by hand.

According to Liu Zhiliang, (1991) industrial design has to include the knowledge of different branches of science and technology such as mechanics, chemistry, biology, etc. but also history, geography, art, politics and law. This is because everything is interwoven one with another and if the interactions are not considered, industrial design will surely be colour blind and make mistakes in designing products. Of course it is impossible for anyone to have full understanding of so many branches of knowledge at the same time, therefore industrial design must carried out with good co-ordination by specialised designers who have good command of the knowledge of their own fields.

Industrial design still has, and will continue to have a tremendous impact on every individual and on the community as a whole. In fact, industrial design is of great importance for social and cultural development, and consequently for the quality of life in the future.

2.4.1 Background

Designers, like salesmen, need to have faith in the products that they are developing to ensure that they have full commitment to meet the demands of quality and reduced time to market.

Designing is a kind of positive activity of consciousness and an important form of consciousness. It has every feature of the consciousness form. However, it often confuses everyone because it is very close to production activity and material basis, and frequently appears and disappears in material movement (Industrial Design, 1992)

It is been stated by Oakley from Morrison and Twyford (1994) that the origins of industrial design are 'man is a social animal, distinguished by 'culture': by the ability to make tools and communicate ideas. Employment of tools appears to be his chief biological characteristic, for considered functionally they are detachable extensions of the forelimb'.
After the Industrial Revolution in the eighteenth and nineteenth century, the changes in manufacturing processes that took place have been gradually developed from the craft-based to mechanical based production technology. The first change was the textile industry. New machinery was brought into the society to bring together the workshop under one roof for greater control of the manufacturing process.

The growth of the iron industry created a new context of design which became a major factor in increasing the rate of its development. The availability of coal made attractive to manufacturers of all kinds especially ceramics business at that time. Wedgwood had set up his own ceramic factory and his aim was to convert into an elegant and important part of national commerce. Wedgwood’s ability changed the scenario from domestic production to the manufacturing process and he became among the first industrial designers. The business of Wedgwood plays an important role in the history of modern design because he gave rationalism itself a visible, material existence in the shapes his factory produced. Wedgwood provides a link between the second half of the eighteenth century and our own design revolution (Lucie, 1983).

Discussion of design in nineteenth century Britain was dominated by the tension created between a continuing and expanding demand for articles with a tradition of craft production, making them accessible to a greater proportion of the population (Dreyfuss, 1955).

During the nineteenth century the three major industrial powers, Britain, the United States of America and Germany, gradually saw the emergence of industrial designers. The first step towards this was the development of education for designers. Britain set up a school of design at Somerset House, London (Lucie, 1983) with the objective of training designers for industry. The best-known industrial designer from this school was Christopher Dresser, who created designs for mass production for companies (Mc.Dermott, 1992). Significantly, however, Dresser is associated solely with domestic items, not with the products of heavy industry (Lucie, 1983).

As a profession, industrial design was first introduced in the early 1900s by a group of German architects, designers, producers and merchants. This group known as the Werkbund, aimed to improve the technical and aesthetic values of the product for the end user. The efforts made by the Werkbund and the Bauhaus design school started a new era of designing for better quality in products. Due to these developments, industrial design has been recognised as a playing a major role in industrial development.

Industrial design has become a major means of building corporate images. Large corporations now use designers, especially industrial designers, in a systematic way, creating not only a product but also a whole range of related products. Industrial design is
also responsible for the ability of an organisation to sell not merely products but a corporate image.

### 2.4.2 Industrial Designers' Ways of Working

The aesthetic value of a product depends upon its ability to evoke a positive response from the person looking at it. Middendorf (1998) states that the job of the industrial designer is to give the product the outward form that expresses unmistakably, and without the need for a salesman to speak, that the product has the qualities the potential customer wants. Industrial design helps a product to be immediately attractive to the potential buyer. This is an important attribute of a product.

Industrial designers design manufactured products. It can be as simple as candy box to the tank on a railroad car, styling - redoing or originating the 'skin' for a piece of equipment, consumer products for example hot water heaters, bicycles and also designs for the handicapped, etc. Industrial designers also work closely with other disciplines such as structural, mechanical and electrical engineers to come out with the products for transportation, industrial equipment, agricultural machinery and equipment, communications, etc.

When designers are asked to discuss their capabilities and express how they work, several types of work styles are mentioned. This convincing statement was from the architect Danys Lasdun:

> ‘Our job is to give the client, on time and cost, not what he wants, but what he never dreamed he wanted; and when he gets it he recognises it as something he wanted all the time’ (Quoted in Cross, 1990: 130)

Theories of the design process had been produced in different design disciplines and this had led to vastly different views of design (Lloyd and Scott, 1994). Industrial designers are men and women who set out to solve practical problems which arise out of life's situations. Design is not a process or activity which can show the sudden output in just a second but it is a process which takes weeks, months and years before the product can be successfully produced and used by the public. It also includes thinking processes, testing and examining until the designer and the manufacturer are satisfied with the product.

An important part of the process is research and investigation for the purpose of understanding the problems faced in depth. The designers do not have to jump to a conclusion suddenly and straight away come out with a solution to solve the problem. There is always a possibility that the designers will make inappropriate problem definitions that are inaccurate and lead to products which are not suitable for the customer needs. In design,
there is no guarantee of success. Research and investigation done by designers can help to identify the scope of the problem relating to the situation.

The process and the activities (Figure 2.1) (Hussain, 1987) show the overall sequence of the design process. Although there is a generic design process shown it is not as straightforward as it seems in Figure 2.1. The design process is very interactive and is constantly changing depending on the scope of work for each designer.

Pahl and Beitz (1984) believed every thing related to product design must come across as a problem-solving procedure where it will begin from problem identification, then it will be followed by a ‘confrontation’ of a problem with what is already known. From here the designers may need more detailed ‘information’ about the problem. Next comes the ‘definition’ where it can forecast more deeply into the solution to the nearest possible problem, then we come to ‘creation’ whereby the designer will come out with various ideas to
fulfil the needs. If there are many possible solution to the problem, these will be 'evaluated' and then followed by 'decision' on the basis of which the best variant is selected. The procedure is illustrated in Figure 2.2.

Although this is taken from an engineering design text it illustrates the importance of iteration in the design process, whatever the field.

This whole process starting from 'confrontation' to the 'decision' must be repeated as the problems are identified during the design process, or 'iteration' as Pugh emphasises in his description of the design process. To understand the design process in more detail, Pahl and Beitz (1984) illustrated in Figure 2.3 how the design process may be organised step by step. During the activities the problems are found and steps and repeated to find the mistakes are start again to try to clarify the problems. Problem identification occurs in every stage of the design process. Figure 2.3 again shows the importance of iteration in design.
Chapter Two

Task

- Clarify the task
- Elaborate the specification

Specification

- Identify essential problems
- Establish function structures
- Search for solution principles
- Combine and firm up into concept variants
- Evaluate against technical and economic criteria

Concept

- Develop preliminary layouts and form designs
- Select best preliminary layouts
- Refine and evaluate against technical

Preliminary layout

- Optimise and complete form designs
- Check for errors and cost effectiveness
- Prepare the preliminary parts list and production documents

Definitive layout

- Finalise details
- Complete detail drawings and production documents
- Check all documents

Documentation

Solution

Figure 2.3: Steps of the design process (Pahl and Beitz, 1984)
2.4.3 Industrial Design in the UK

The term 'industrial design' came into use in Britain in the nineteen-thirties, but not into general use until after the Second World War. Until the thirties the term 'industrial art' was in more general use, as in Britain's first professional association of designers, the Society for Industrial Artists (SIA) (now the SAID), which was founded in 1930 (Conron directory of Design, 1985). In 1944 the Board of Trade in Britain established a Council of Industrial Design (CID).

The education of industrial designers has been mostly the responsibility of art schools, particularly in the UK. The various changes in higher education in the UK in the last 25 years have resulted in the discipline at degree level being located almost exclusively in the new Universities. However, because of both its relative youth and its roots in the art school approach it has lacked any tradition of research. The principle objective has been that of educating industrial designers who could practice professionally (Tovey, 1997).

In the early twentieth century of Modern Movement, the founding of the Bauhaus and the evolution of modern materials and processes gave a revolutionary new delivery to the designer and suggested for the first time that there could be a true synthesis between art and industry.

It is a generally accepted fact that the economic future of the UK is closely related to its export trade (Leowy, 1979). It is recommended that consumer goods should bring with them every advantage of quality, low cost, and the visual appeal of modern design. In a report on Design and the Economy (Design council, 1990), products will be competing in world markets which can determine the commercial success or failure of a product. A number of strategies will have to be recognised and implemented across a range of disciplines. The strategies were identified and these are summarised below:

- Britain must produce goods that are not only competitive in price but are also competitive in terms of their appearance and reliability, quality of manufacture, materials and finish, as well as in their safety and ease of use and after-sales service. These 'non-price' factors are becoming increasingly important as the market demands more sophisticated products. JCB is an example of a UK company that has succeeded in this way.

- There is a need for greater market awareness, which involves keeping in touch with the customers during both the initial design and developmental stages of a product as well as after they have bought the product.

- There is a significant need to improve the management of the design process in industry and to ensure that design and innovation have the right climate in which they can flourish.
Design is clearly an activity that makes a valuable contribution to the British economy. The work of designers adds to the output of the economy and generates employment and profits. Well-designed products and services are valued by consumers and enhance the competitiveness of British industry (Sentence, 1997).

2.4.4 Industrial Design in Malaysia

In Malaysia during the nineteen-sixties, there was only one higher institution that ran design as a subject which is under the Institut Teknologi MARA (now University Technology of MARA, UiTM) situated in the state of Selangor. At the beginning the design department was known as The School of Applied Arts and Architecture. It was formed in 1967 but by 1972, the design department had separated from the school and formed their own school known as the School of Art and Design. The establishment was divided into four departments which are Department of Fine Art, Department of Three-Dimensional Design, Department of Textiles and Department of Graphics.

After several years running the courses, the Department of Three-Dimensional Design had developed into several departments to differentiate the courses being held into different disciplines. The departments created are the Department of Industrial Design, Department of Fine Metal and Department of Pottery. The School of Art and Design in Institut Teknologi MARA (now UiTM) for the time being has nine departments.

Malaysian industrialisation has received a new and strong pressure from the government's commitment to convert the nation into an industrialised country by the year 2020. The Ministry of Education of Malaysia found out that there would be a lack of expertise such as industrial designers if the government were only to rely on one institution to serve the country's needs. The government gave the opportunity to the private schools and also the university to create or set up a course related to industrial design. There are several private art schools throughout the country but most are situated at Kelang Valley. Most of them offer non-degree courses in various subjects such as Graphic Design, Interior Design, Fine Art, and Furniture Design. In the last five to ten years, the School of Art and Design under the Institut Teknologi MARA (now UiTM) is the only one offering professional courses in industrial design.

The establishment of the Heavy Industries Corporation of Malaysia Berhad (HICOM) which is one of the successful industries run by them has launched the Proton Saga (Malaysia's first own national car) and by now HICOM has already produced more than five models from its first production. Now Malaysia can be proud because most of the third world and developing countries use Malaysian cars. Five years previously Malaysia under the commitment of the government launched a new second national car known as Kancil and Rusa under another Multi-National Company. Kancil can be classified as a town car because of the size and the
capacity of not more than 1000 cc. Rusa was designed as a van and can be used either for leisure or business. There are several large manufacturing companies with full government backing as part of the country's industrial development thrust but they mostly concentrate on product assembly for export markets, and even tools and dies are imported from abroad.

Only recently, after raw material from this country became less profitable, the government and the manufacturers felt that there was a need for local design input to generate a Malaysian identity and penetrate local and outside markets. The local industrial designers must play their vital role to make radical progress and must not concentrate on aesthetics and styling only; they have to gain experience of areas such as production and marketing.

Recently, after industrial design was recognised as one of the important disciplines with a vital role in the economy, the private colleges and universities started to introduce industrial design courses and also industrial design subjects as part of the syllabus in engineering courses. Universiti Teknologi Malaysia (UTM) is the first university that teaches industrial design subjects to the mechanical engineering students as part of the subject in their curriculum. Universiti Malaysia Sabah (UMS), Universiti Sains Malaysia (USM), Universiti Putra Malaysia (UPM), Pasir Gudang Polytechnic and several private colleges are now offering industrial design courses but all of the institution perform industrial design as art based courses, as does the Institut Teknologi MARA (now UiTM).

Industrial designers at Universiti Teknologi Malaysia (UTM) after more than fifteen years serving mechanical engineering found that it is time for them to come out with a course which brings engineering, manufacturing and marketing subjects into the industrial design course. After all this while, industrial designers at UTM appreciate the importance of including other subjects so that industrial designers later on hopefully will become some of the finest designers that can design magnificent products which Malaysia can be proud of.

Malaysia's Industrial Designers who graduated from ITM (now UITM), private colleges and overseas have found employment either with the government, private sector or run their own business related to product design. They work as researchers, teachers, lecturers, design managers (own company), design consultants and designers. Most of the designers work in Malaysia's National Car manufacturing employed as car stylists and also as car interior designers.

There is no question that industrial designers are needed to contribute in developing product design for consumers or capital products such as agricultural machinery design. This is one of the design areas which is important for industrial designers to play their role in improving the human-machine relationship.


2.5 Engineering Design

Engineering is frequently viewed as a problem-solving discipline and it also requires a great deal of decision making (Middendorf, 1998). Engineering design can be applied to several different ends. One is the design of products such as consumer goods and appliances or highly complex products and the other is a complex engineering system such as an electric power generating station or a petrochemical plant. (Dieter, 2000)

Many attempts have been made to define engineering design. Asimow defined design as a purposeful activity directed towards the goal of fulfilling human needs, particularly those which can be met by the technology factors of the culture (Hubka and Eder, 1987). Fielden defined engineering design as the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform prespecified functions with the maximum economy and efficiency. Taylor (Hubka and Eder, 1987) put it as the process of applying various techniques and scientific principles for the purpose of defining a device, a process, or a system in sufficient detail to permit its physical realisation.

2.5.1 Background

Engineering design can be expressed in several aspects to achieve a good product design which:

- fulfils its functional purpose,
- is economical with respect to resources of promoters and users,
- embodies satisfactory answers to problems arising out of its very presence, such as strength, durability, obstruction, adaptation and extension.
- has lasting aesthetic qualities appropriate to users and beholders. (Lisborg, 1966)

According to Wooding (1966) there are two factors in engineering design:

- aspect of technology which is concerned with the scientific and mathematical principles on which the design depends.
- mechanical design of the machine itself as an aggregation of parts which can be manufactured economically and which, when made, will be efficient, trouble free, easy to operate and maintain, pleasant to look at and having an adequate length of life.
Engineering designers may create a magnificent functional product on paper but when it comes to be manufactured it must be produced at a practical cost and in a timescale to satisfy the customer. Production must be from available and advantageous materials, methods, processes, and equipment. It also must be competitive in quality, performance, appearance and service life. To be successful, the engineering designers must collaborate closely with those who specialise in these aspects of the overall problem (Niebel and Draper, 1974).

'Engineering has to be broken down into manageable packages - that is, manageable to both students and teaching staff', Pugh (1990) ... good understanding and learning in engineering courses which contain specific engineering information, techniques and technology is necessary'. Pugh added, 'to ensure the achievement of engineering competence, the major part of any engineering course will be necessarily taught (in a product sense) as partial design'. This is illustrated in Figure 2.4.

![Figure 2.4: Traditional partial design segmentation (Pugh, 1990)](image)

Pugh (1990) considers partial design shown in Figure 2.4 as a basis for any engineer. To achieve high optimisation in engineering, Pugh found that in parallel with partial design teaching, the structured approach to total design greatly enhances design performance.

'The structure and framework of total design should be of a form that automatically leads not only to integration, but to a natural feeling of integration within the participant, irrespective of discipline. Each contributor should be able to see how his partial contributions fit into the whole. Total
design should be taught and practised in a progressive manner, with enhanced information, knowledge and techniques leading to increased rigour in a total design sense, incorporating engineering rigour'.

'Total design may be construed as having a central core of activities, all of which are imperative for any design, irrespective of domain. Briefly, this core, the design core (Figure 2.5), consists of market (user need), product design specification, conceptual design, detail design, manufacture and sales. All design starts, or should start, with a need that, when satisfied, will fit into an existing market or create a market of its own. From the statement of the need – often called the brief – a product design specification (PDS) (Figure 2.6) must formulated – the specification of the product to be designed. Once this is established, it acts as the mantle or cloak that envelops all the subsequent stages in the design core'.

Figure 2.5: Design Core
Figure 2.6: The design core enveloped by the product design specification (PDS). (Pugh, 1990)
From Figure 2.6 we can see that there are iterations from the beginning until the end of the design core at any time or at any point in the design activity, but operating within the design core rigorously and systematically will minimise unnecessary iteration.

Pahl and Beitz (1984) approximately have the same approach as Pugh whereby engineers work systematically to reduce unnecessary problems occurring during the design activity. Pahl and Beitz also give a lot of examples such as Hansen, Rodenacker and Koller who defined their own design steps. Everybody seems to agree that design has to progress from the beginning until the end and if there are problems in between, the engineer has to come back to look at the problem to determine how the design might satisfy the specification.

Cross tried to integrate so called 'prescriptive' and 'descriptive' by coming out with a hybrid model which has the following features such as symmetrical relationship between problem and solution, and between sub-problems and sub-solution. Secondly, there is a hierarchical relationship between problem and sub-problems, and between solution and sub-solution. Finally, the activities can be worked out starting with 'clarifying objectives' and ending with 'improving details' (Figure 2.7).

Figure 2.7: Hybrid model (Cross, 1991)
Engineers play a vital role in the development of competitive products. They must have thorough knowledge of the principles of engineering science in order to analyse the problems properly and develop relevant solution concepts. In addition, they must have a satisfactory capability of engineering design. The challenge to the design engineer is to provide the users with what they want, rather than to persuade them to buy what the engineer thinks the users want (Holt, 1989).

2.5.2 Engineering Designers' Ways of Working

Dieter (2000) elaborated that engineering design must consider many factors to produce successful and meaningful products. He categorises these under:

- Functions with associated performance characteristics.
- Environment in which it must operate.
- Target product cost.
- Service life.
- Maintenance and logistics.
- Aesthetics.
- Expected quantity to be produced.
- Ergonomics.
- Quality and reliability.
- Safety and environmental concern.
- Provision for testing.

The work of engineers differs greatly from one field to another. These occupations cover a broad spectrum, and somewhere in the middle of the spectrum is the occupation of engineering design.

Designing an engineering product is different in many ways from designing other products and is often a matter of creating something for the very first time. Sometimes a design engineer also follows the trend of fashion and gives a product a new look more suitable to the current year. When a product has been changed or updated for a better performance or better look, other aspects of appearance are given careful consideration. The material might be changed for additional strength or to make it lighter and cheaper. Safety factors might be increased and other factors might be considered to make the latest products successful in every aspect of the design, manufacturing, marketing and sale.

The first thing that any engineering designer must do is to satisfy him or herself that if he or she succeeds in turning out a good design after all his or her work, it will sell in enough quantities at a sufficient price to be commercial success. That is the best definition of a
successful design according to Kennaway (1981). He added, to become commercially successful, a product must provide:

- fitness for purpose – in every sense;
- value for money – not just first cost, but throughout its life;
- appeal, with all the emotional and aesthetic aspects which are so hard to quantify.

In the early industrial period, most products evolved slowly with step-by-step improvements being tested in the field. As products became more complicated and the need for new products accelerated, it became necessary to develop techniques which would lead in a predictable manner to successful designs. Engineering method was developed to make the design process of a product meet the purpose of producing the product. Middendorf (1998) has identified the method into four categories which are:

- Establish a set of specifications.
- Develop a design concept.
- Use physical and mathematical models to test the design concept.
- Draw conclusions as to whether the design satisfied the specifications.

He added that if the design does not meet the specifications, the process is repeated, utilising the information gained in the first attempt. Although it is possible to return to the first step and to modify the specifications, it is more probable that the design concept will be changed or that the models will be improved. Performance after the second cycle is again compared to the specifications, and the process is repeated as necessary until the design is acceptable.

The engineering design process is a general problem solving process which can be applied to any number of classes of problem, not just engineering design. The design process as outlined will not produce any design solutions, it supports the designer by providing a framework or methodology. Without such a process there is a very real danger when facing a design problem. Cross (1989) has identified several design processes, which are:

- Three-stage model
- French model
- Archer model
- Pahl and Beitz model
- VDI 2221
- March model
- Hybrid model
- Pugh design core
The engineers will plan out the design process. Within each phase he or she will systematically check all of the steps. They will know that it is good idea to enter each phase by rechecking what the user wants. If the user's needs have changed, then the objectives may also be changed. All the steps are reviewed. The systematic approach of the design process in Figure 2.8 shows the steps that the engineers have to follow to make sure the project finishes on time. Agricultural engineers in PORIM (Palm Oil Research Institute of Malaysia) use this design process to fulfil the requirements stated by the users or by the research committees. The design process serves as guidelines for the activity to follow and as criteria for judging the degree of success when the final design is completed.

Figure 2.8: PORIM Design Process
If we compare the design process implemented by industrial designers under Figure 2.1 and the design process carried out by agricultural engineers, there are great differences from one another. In Figure 2.8 there is a very big loop between stages, which could create problems. It is not advisable to proceed with the next stage if the designers have a problem in the previous stage. Although there are quite a number of design processes that have proved successful they depend to some extent on what type of projects have been carried out by each designer. When designers find the system which they feel is appropriate for them then they will stick to that for the following projects.

We will observe how PORIM agricultural engineers led by Hitam et al., (Oct. 1999) carried out a design project for the SuperCrawler. It is a tracked machine designed for infield transportation of fresh fruit bunches from palm base to roadside platform particularly in difficult areas. This SuperCrawler was derived from the soil-drilling machine used in the construction industry. Modifications were made to the original machine to make it suitable as an infield transport vehicle. The project assignment given to them was to design a transport system that can perform the work task. They prepared their planning schedule to achieve their goal.

The main objective of developing this machine was to replace the manual collection either using wheelbarrow or by manual carrying. The objectives were as follows:

- Reduction in labour requirements.
- Reduction in cost of production.
- Increase in productivity per worker.
- Maximum fruit recovery.

Several design concepts had been produced in developing the machine. The focus was on methods of transporting that would be suitable to be operated under a wide range of field conditions. In addition the following features have also been considered:

- Low ground pressure.
- Suitability for operation in wet swampy or soggy conditions, and in steep slopes.
- Rut reduction
- Robust use in plantation.
- Minimal breakdown frequency.
- Simple operation.
- Ease of transportation of fresh fruit bunches from palm base to roadside.
- High payload.

The outstanding design concept was chosen and the team members started producing engineering design for prototyping. At the same time they also developed the technical
specification for the machine. Before a prototype can be built, all necessary components
must be purchased or made. When the prototype was ready, several functional tests were
carried out under various estate environments. From these tests, observations were made
and improvements were incorporated. Field trials were then carried out to assess its
performance in an actual field situation.

The aims of field trials are to assess the efficiency of the machine, to establish a system for
the machine, to evaluate the productivity of the machine, to monitor the robustness of the
machine and its components, and to carry out basic economic analysis. The field trials were
carried out on the coast of Peninsular Malaysia, where this machine is most suitable. From
these trials, it was found that the productivity ranged from 20 to 30 tonnes per day which is
equivalent to 20 manual workers.

In general, the SuperCrawler works well in areas which are soft and soggy because of low
ground pressure exerted by the tracks. The development of this machine as an infield
transportation vehicle met the objective required. The rutting problem, normally caused by a
wheeled vehicle is eliminated. The only disadvantage of using metal tracks was the rapid
wear of the undercarriage, especially the tracks.

The systematic working as described above is indeed timesaving, but not in the sense that
one may regard the design process as final piecework. It is not easy to define design activity
in a way which covers all the design process chosen. Matousek (1963) expressed that one
thing which is certain in design is that the main burden of the creative work done is
undoubtedly intellectual in nature, and it is intellectual activity of an extremely complex kind.

Designing can be treated as a process where the input is a problem and the output is the
solution. The design process above are a process which generates a solution with respect to
a problem. Love (1980) described to become a successful in engineering designs, the
engineers have to fulfil the following:

- Do plan to have low-cost iterations upstream in order to avoid high-cost unplanned
  iterations downstream.
- Do encourage your colleagues and subordinates to start design iterations when they
  should.
- Do develop your target specifications before searching for alternative design solution.

and do not do these:

- Do not rush pell-mell into the design process and try for a quick shot at the target.
- Do not scream too loudly when somebody rips up a design and starts all over. It won't
  hurt nearly as much as doing it later on.
• Do not wait till the last minute to issue your specifications.

These points were taken into account in developing the design guidelines proposed in Chapter 7. Although the design method is in itself a simple one, it is worth using in a formal manner because it saves so much time, so many errors. This is true for quite experienced engineers or designers. The important thing that the people need is a means of applying their imagination, their engineering judgement, and their knowledge of basics in science and mathematics, their ability to analyse, to the service of a real problem to arrive at a satisfactory solution. The engineer not only applies what he has from his experience but also what the sales department has told before something is commercial. Sometimes in his work he uses trial and error concepts to get a result. It is recommended that every designer continually studies the designs of the products around them.

As engineers they are empowered with the technical expertise to develop new and improved products and systems. At the same time an engineer must be increasingly aware of the impact of their actions on society and the environment in general and work conscientiously toward the best solution in view of all relevant factors. The number and breadth of these factors is too large for a single discipline and therefore teamwork is essential.

2.6 Relationship between Industrial Design and Engineering Design

The industrial designer is usually educated as an applied artist or architect as defined by Dieter (2000). This is a decidedly different culture from the education of the engineer. The two groups have roughly opposite styles:

• Engineers normally work from the inside out.
• Industrial designers work from the outside in.

Engineers are trained to think in terms of technical details and industrial designers usually start with a concept of a complete product as a customer would use it and work back into the details needed to make the concept work.

Gibbs and Flurscheim (1983) believe that industrial designers have to be involved throughout the design process.

'In practice the man/machine interface problems amenable to solution by industrial design procedures vary widely... The industrial design contribution can influence the design of major components... Industrial design capability should therefore be available locally in the design office, whether provided in-house or by external sources, throughout the design period, so that the
problems requiring attention can be identified and dealt with as they arise and before design is too far advanced'. (pp. 298-299)

Dieter believed that it is important to have industrial designers involved at the beginning of a project, for if they are called in after the details are worked out there may not be room to develop a proper concept. As engineers, industrial designers will follow a generally similar methodology. Dieter divided industrial designers into two general situations, which are:

- the industrial designer is part of the integrated product-development team from its inception and
- industrial designers are brought in during embodiment design (Figure 2.9) to provide styling and to ensure that human factors are given proper consideration.

Figure 2.9: French's model of the design process (Cross, 1989)
From these two situations, Dieter preferred the first situation and from this, industrial designers would have to consider the following factors during design project, which are:

- Determine the customer needs
- Product conceptualisation
- Preliminary refinement
- Final concept selection
- Control drawing — making of final concept which documented functionality, features, sizes, colours, surface finishes, and critical dimensions.

Flurscheim (1983) stressed that it should not be neglected that industrial designers can often contribute to the definition of what is needed, and their position within the engineering function should be such that their views are considered at the earliest stages, when the specification is still flexible.

‘Design is a highly integrated operation, and it follows that it is not practicable to isolate the industrial design requirements, or the requirements of any other technology, in a separate specification, because of their interdependence and the imbalance that would result’. (p. 290)

Everything we have around us — environments, clothes, furniture, machine, communications systems, even much of our food — has been designed. The quality of that design effort therefore profoundly affects our quality of life (Cross, 1990). Despite the different approaches there is considerable overlap between engineering design and industrial design, as they are both concerned with designing pieces of technology. Before the early nineteen seventies, engineering design and industrial design were often thought to have a similar design process; Archer presented a similar model of the design process in a 1962 conference on design methods (Jones, 1970). Unfortunately criticism of a shared view of the design process began in the early nineteen seventies. Roozenburg and Cross (1991) believe that there are good reasons for trying to get the type-models to converge. It is clear that both models have particular strengths, and particular weaknesses. A more developed, generalised model of the design process would integrate the strengths of both models, whilst avoiding their weaknesses.

Engineering designers who are equipped with engineering education will focus their skills to solve complex technical problems, whereas industrial designers use their knowledge to design the visual elements of new products (Cooper and Press, 1995).

Designing objects to be industrially manufactured is generally attributed to the profession of designers. According to Goldschmidt (1995) a designer must know a little bit about everything because design work requires varied knowledge and an outstanding capability for
mental integration and synthesis. Designers must be capable of handling any professional design challenge.

Teamwork in design is a relatively recent phenomenon, emanating from the scope and complexity of many design tasks and the need for multiple expertise and division of labour (Goldschmidt, 1995). Barlow (1988) has explained every product requires an appropriate balance of engineering and industrial design skill. Between these two disciplines, Barlow gives the example of the telephone (Figure 2.10) because this seems to him to be a product that requires roughly equal inputs from the industrial designer and the engineering designer. The engineering designers ensure that the electronic components are configured to perform their task appropriately, while the industrial designers give the products both visual appeal and effective ergonomic qualities. The design of an electronic component falls exclusively to engineering designers.

Industrial design is, of course, only one sort of design. It has much in common with architecture and design within engineering. Indeed the relationship between industrial design and mechanical and production engineering is similar to that enjoyed by architects with civil engineers. Within its art school traditional industrial design is regarded as a specialisation in three-dimensional design, like furniture or ceramic, and separate from say fashion and textiles or graphic design. Despite its roots it has a much stronger structural relationship with engineering design because they are both concerned with manufactured physical products (Tovey. 1997).

Pahl and Beitz (1984), derived from Dixon and Penny, place engineering design at the centre surrounded by other disciplines. This shows the relationship between the spectrum of disciplines and with industrial design in particular for quality teamwork to produce quality products. (Figure 2.11)
Cross (1989) derived from engineering designers and industrial designers such as Howe, Stevents, and Happold that design activities have common themes of which one is the importance of creativity and intuition in design. According to Edwards (1997)

'people involved in the design process are part of a multi-disciplined team, working both individually and collectively, trying to apply creative problem solving techniques – in order to translate customer requirements into a technical product. Each member has a position and an expected role within the team, and probably comes from different cultural and education backgrounds' (p. 14).

Design disciplines such as industrial design and engineering design are related and must interact with each other to produce good, excellent and magnificent products. It is very doubtful that a single designer has all the talent by him/herself to create magnificent products.

The combination of several disciplines involved in producing a product shows that there is a requirement from people of many disciplines, both engineering and non-engineering. Pugh believed that to design a product, there must be co-ordinated inputs from different specialisms. This can be observed in Figure 2.12 that shows strong involvement between the engineering designer, industrial designer and other disciplines. He claimed that a lack of co-ordination between different specialisms is often responsible for product failures, such as the Sinclair C5 three-wheeler electric car for personal transport introduced on to the British market in 1985. To him it is a good example of a failed product. Pugh (1990) was convinced that the design team should always include non-engineers.
Design is not always to do with mass-production, sometimes it is design to suit to certain need such as a hospital-bed. 1961, the Nuffield Trust in Britain provided funds for a research team, under L. Bruce Archer and Misha Black at the Royal College of Art, to investigate the design of non-surgical hospital equipment. A hospital-bed (Picture 2.1) was designed and it was represented by many disciplines to suit the needs and to ensure the comfort of patients and to facilitate nursing.
Industrial designers and engineering designers need to work closely. JCB's chairman, Sir Anthony Bamford strongly believed the interaction between engineering designers and industrial designers in his company has made a tremendous contribution in designing all types of machinery so that most of JCB's annual turnover currently comes from products that simply did not exist five years ago. One of JCB's design team, Ashley Leake, said 'if a product looks sensuous from the outside, then the people will assume that it's modern on the inside. At the same time, we need to project an identifiable family image, so that there is some kind of genetic look that both says "JCB" and identifies the brand with innovation' (Darwent, 1997).

A survey done by Carol Slappendel (1996) shows that larger manufacturing companies in New Zealand had employed industrial designers expertise compared to smaller companies which use significantly less industrial design. From here it shows that the importance of industrial designers working closely with engineering designers to generate increases in turnover of the companies.

As we know industrial design and engineering design have their own speciality in expressing how the end product is going to look, should the design be functional or aesthetic? This is one of the most complicated, least understandable, and mixed-up questions in design today. However a product must look fabulous, functional for its purpose and be accepted by the end users. Most products had to be created by a design team to make the outcome perfect. Although the team may have had a leader, in no case could any one person claim entire responsibility for the product because everybody worked as a team and they are all entitled to the credit.

Teamwork is of considerable importance in normal professional design activity, and is becoming of even greater importance in product design as it becomes a more integrated activity (Jonas, 1993). Team work is generally considered more fruitful compared to an individual's endeavour but within the design team there must be someone acting as a team leader to avoid conflict during design projects.

2.7 Role of Industrial Designers in the Field of Agricultural Machinery in Malaysia

2.7.1 Background

Malaysia gained her independence in 1957, and since then she can be said to have made great progress in economic development. This is because the involvement of both the government and private sectors is very widespread regarding the application of technology, not only in industry but also in agriculture.
Since the earliest days of agriculture, man has recognised that food can be produced more effectively if mechanical aids are employed (Marchant, 1991), and there is no doubt that the agricultural machinery design has mainly come from agricultural engineers. Since independence, industrial designers have not played any role at all in agricultural machinery problems and they have been handled by agricultural engineers. If the farmers or the users had any problem or difficulties in handling the machines, the agricultural engineers are the only ones to sort out the problem. Industrial designers only played their role late 1970s after several industrial designers came back from overseas and joined R&D institutions such as MARDI (Malaysia Agricultural Research & Development Institute), PORIM (Palm Oil Research Institute of Malaysia) and RRIM (Rubber Research Institute of Malaysia) appointed a research assistant working closely with agricultural engineers. Although there are industrial designers working in the agricultural design team, the contribution is still not widely exposed. Because of this, the projects regarding agricultural machinery are still being carried out only by agricultural engineers. Developed countries such as European countries, US and Japan have realised the importance of industrial designer's input and contribution in agricultural machinery design and other products.

### 2.7.2 Industrial Designers’ role in Agricultural Machinery

Since the late 1930s and 1940s we can see the involvement of industrial designers such as Henry Dreyfuss and Raymond Loewy. Dreyfuss (1986) is an early industrial designer who contributed his knowledge and skills in designing agricultural machinery when he designed for John Deere and Company. (Figure 2.13) 'From that mission began a remarkable marriage of rugged engineering and imaginative industrial design which has distinguished Deere from most of its competitors for almost 40 years. It's far-reaching use of designers from Dreyfuss' consultancy, especially since the mid-1950s'.

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Another industrial designer as mentioned earlier was Raymond Loewy. Loewy (Jodard, 1992) was asked by the International Harvester Farmall to come out with a better design for their tractor. Starting from here Loewy began redesigning the Farmall tractor (Picture 2.2), widening the front wheelbase to increase stability, improving the seating and controls, and improving visibility.
Chapter Two

Picture 2.2: The International Harvester Farmall tractor after it was redesigned by Raymond Loewy (1940)

Picture 2.3: The International Harvester Farmall tractor before it was redesigned (Loewy, 1979)

Picture 2.3 shows 'the International Harvester Farmall tractor before it was redesigned. Mud-clogged wheels become heavy and hard to clean. A fair number of farmers found it difficult to reach the high seat. Whoever designed it must have forgotten that some farmers are old, or paunchy, or arthritic. Industrial design means a concern for the broadest spectrum of humanity, not only for ideal forms. Farmall was also unstable, due to its three-wheel arrangement' (Loewy, 1979).
Two years later, in 1942, Loewy (Jodard, 1992) came out with a new redesign of the McCormick-Deering International Harvester tractor, known as the Caterpillar tractor (Picture 2.4), again improving the seating, and otherwise cleaning up the outlines of what had been a purely functional design. Loewy (1979) not only redesigned the tractor for that company but he was also involved in designing a company logo, and designing the packaging and labelling for a range of spare parts and accessories. Loewy's office also designed a modular system for International Harvester's service and sales centres, all of which promoted the International Harvester as an up to date, efficient company.

![Picture 2.4: The International Harvester tractor, known as the Caterpillar redesigned by Raymond Loewy in 1942 (Jodard, 1992)](image)

Picture 2.4 shows 'the International Harvester tractor. In its original version it was rather uncomfortable to operate, the exhausts were so short that the driver inhaled the fumes. Pipes were raised up, while creating a more comfortable seating and operating pattern. The sides were greatly simplified and smoothed out, which improved maintenance' (Loewy, 1979).

![Picture 2.5: The McCormick-Deering International Harvester tractor before it was redesigned (Loewy, 1979)](image)
Douglas Scott was one of Britain's industrial designers involved with agricultural machinery design when his company was appointed by one of the well known agricultural manufacturers, Peter Hamilton Equipment Ltd., to redesign one of their excavators. The Hy-Mac 480 was a jumble of bits tacked together which appeared to bear no relation to one another. Scott applied Loewy principles by removing a rough-and-ready looking piece of agricultural equipment into the kind of exciting machinery. (Picture 2.6) He gave the excavator a lower, broader look, which appeared more stable and efficient that it had been before.

![Picture 2.6: The Scott version boosted sales through a combination of greater stability, all-round visibility for the operator, easier access to the engine and control equipment, and good looks. (Glancey, 1988)](image)

Agriculture nearly always takes place in an unstructured environment. Because of this, machinery must work under a wide range of conditions. This makes an agricultural workplace very different from an industrial one. For example, on a car production line the positions of car bodies is known very accurately but for an agricultural environment, it's quite different. Many agricultural operations are characterised by a harsh environment, for example exposure to weather, corrosive chemicals, proximity to large animals and so on (Marchant, 1991).


'In the last fifty years the revolution in agriculture owed as much to industrial design as to plant breeders and chemists. Engineers and farmers in partnership have continuously reduced the burden of human labour while doubling the yield of crops for human or animal consumption'. (p. 97)
2.8 Summary

Design is being recognised as a critical factor for business success. The result is new interest in the quality of design available, and more fundamentally interest in how design can be improved. For developed and developing countries, high-quality design is the most cost-effective resource available to improve trade balance (Owen, 1998). Developed countries realise the importance that industrial design can contribute in agricultural machinery design and also in other capital products. It is quite different if we look at Malaysia, industrial designers are far away from being involved in this area. Malaysia is set to develop into an industrial country by 2020 and it must not put away the importance of agro-based industry because Malaysia will still produce agricultural products such as palm oil, rubber, timber, and other commercial crops. Industrial designers must be more serious in design and development activities which have to be integrated with multi-disciplinary knowledge into the design team to create successful agricultural machinery products.

The literature has described the importance of the relationship between industrial design and engineering design. The ratio of involvement between these two disciplines depends on what type of product is to be designed. The integration between industrial design and engineering design in the design processes is vital in order to achieve better, meaningful and interesting products. The literature also provided examples of the work of industrial designers in agricultural machinery, that shows there is a scope for industrial designers to use their capability and knowledge in designing agricultural machinery especially for Malaysia and her regions to avoid modification and adaptation of inappropriate machinery.

However, although the literature shows the need for industrial designers, engineers and other parties, including clients and customers, to work together it does not tell very much about how this can best be done. In particular there is little information on methods for helping collaboration between industrial designers and engineering designers.

Therefore there is a need for the industrial designer to become involved in agricultural machinery design because no research has been undertaken to integrate industrial design and agricultural engineering design in Malaysia. There is a gap existing with respect to industrial design in agricultural machinery design.
CHAPTER THREE

Research Design

3.1 Introduction

This chapter explains the methods used to carry out this research. The first section of this chapter draws out definitions of research methodology and continues with a description of the research methods used. These include combination of the methods as triangulation which combined interviews, case studies, observation and questionnaire surveys. Design guidelines emerged from the research carried out.

The following sections describe the programme conducted throughout the study. The research has undergone several investigations within the UK and Malaysia to identify ways of improving the involvement of industrial designers in agricultural activities.

Figure 1: Research Stages and Phases

Figure 1 gives an overview of the research programme. Section 1.8.2 has identified several research questions supporting the aims and objectives of this study. Research questions were used rather than hypotheses in this research programme. Identifying topics, which are worthy of enquiry and then formulating meaningful research questions are some of the most difficult parts of the research activity. Being clear about what research questions are being asked is essential.
Chapter Three

Research Design

This chapter also outlines the survey conducted during three months in Malaysia. The survey consists of interviews and discussions with engineers, industrial designers, lecturers and managers. The researcher has visited palm oil and rubber plantations to observe the activities carried out and subsequently conducted two design projects to better understand the potential contribution of industrial designers in this area.

The last section in this chapter describes the importance of design guidelines that need to be developed based on the understanding emerging from the qualitative and quantitative surveys and case studies. This chapter ends with a summary.

3.2 Background

Research methodology, according to Berry (1983), is 'not just about data collection and the rules of evidence, it is more about the nature of explanation and the means by which explanations are produced'. How knowledge is developed from these explanations depends upon the methodology used. Once the research problem has been formulated clearly enough to specify the types of information needed, the investigator must work out his research design.

Research is finding out something you don't know. It may be defined as the application of the scientific approach to study a problem. It is a way to acquire dependable and useful information. Another definition is simply controlled inquiry concerning a certain event or events, with the purpose of furthering and/or verifying knowledge. Research is also known as problem solving. Kailani (1997) and Ashari (1997) defined research as a process of gathering information, analysing and reporting. The importance of research is to create knowledge and information, to disseminate information and to assist in decision making. This research is a controlled inquiry to further knowledge about agricultural design in Malaysia and to assist in making decisions on the best way forward for industrial designers.

Research takes many forms and it incorporates many tools, methods and techniques with which we attempt to understand the world around us. (Anderson, 1990) According to Cohen and Manion (1985) research is a combination of both experience and reasoning and must be regarded as the most successful approach to the discovery of truth. They quote from Verma and Beard who defined research as best conceived as the process of arriving at dependable solutions to problems through the planned and systematic collection, analysis, and interpretation of data. The term research itself may take on a range of meanings.

Research is a word which seems to be used more and more these days and, of course, it is used to mean many different kinds of things. Generally, it is used simply to mean 'finding out'
something. (Allison, 1993: 5) The research which has been carried out would never be able to
tell precisely which is the right thing, but it puts us in a position where informed judgements
can be made which really means that we can decide by taking into account all the available
evidence.

A research method is an approach to examining a research question and it is also concerned
with the collection and analysis of data which allows us to arrive at conclusions which are
valid. They are based on evidence which has been collected during the research.

Research is a process which has utility only to the extent that the class of inquiry employed
as the research activity vehicle is capable of adding knowledge. It also stimulates progress,
helping society and man relate more efficiently and effectively to the problems that society
and man perpetuate and create. (McGrath, 1970) McGrath quoted from Griffiths and English
who specified: “Research is … a method of inquiry … a process by which one ascertains the
“truth” of the matter”.

3.3 Research Methods

The research is to establish whether it is possible to achieve something or to bring about a
change in something by adopting a given course of action. There are quite a number of
different problems in research so it is important to be clear about the nature of the problem
and the precise reason why the research is being carried out.

What is a research method? A research method is an approach to addressing a research
question or problem. Methodology can be in many approaches. Each research method
consists of a number of different stages, all of which are followed through systematically.
Research methods need data, though its precise nature varies from one approach to
another, as does the method by which it is processed. What you achieve as your product
depends both on the quality of the data and on the way in which it is processed. (Anderson,
1990)

Research methods are no more than the tools of the trade. There is an unfortunate tendency
to think that research begins and ends with research methodology. It is important to be
aware of the range of research methods available and to understand how they work,
appreciating their advantages and disadvantages. Such knowledge is, however, of little use
unless it can be applied to specific research problems. The essential thing is to be able to
select the method which is most likely to meet the objective of the research.
3.4 Research Methods Used in the Programme

In this research, descriptive methods consisting of qualitative and quantitative surveys together with case studies have been used. Interviews were conducted to find out about the overall design process and the participation and involvement of industrial designers in agricultural machinery design. This also included the level of awareness of industrial designers in designing agricultural machinery. Questionnaires have been designed carefully to provide additional data on the competence, background knowledge and skills that industrial designers must have. The data acquired needed to be clear, significant and ethical to the research carried out.

Triangulation is fundamentally the use of different points of view. Its makes use of combinations of methods, investigation or perspectives, thus facilitating richer and potentially more valid interpretations. Investigation from a variety of sources uses an appropriate combination of methods to gain accurate data and meaningful results. (Banister et al., 1994) One important way to strengthen a study is through triangulation, or the combination of methodologies in the study of the same phenomena or programmes. This can mean using several kinds of methods or data, including using both quantitative and qualitative approaches. Morse (1994:225) also mentioned that qualitative research might also incorporate quantitative methods into the design to answer particular questions.

Bryman (1988) derived triangulation from Webb et al. who suggested the researchers are likely to exhibit greater confidence in their findings when these are derived from more than one method of investigation. Their focus was largely on the need, as they perceived it, for more than one research instrument to be used in the measurement of the main variables in a study. The use of triangulation is recommended as the only way of getting round the potential bias that comes from relying on a single research approach.

3.4.1 Descriptive research

Descriptive research is a clear statement and is fundamental to all research. Descriptive research sets out to seek accurate and adequate descriptions of activities, objects, processes and persons. Descriptive research is important because we often do not know the state of the thing being described. The most commonly used instruments for descriptive research are reports, texts, questionnaires, scales and observation schedules.

Description may be quantitative or qualitative and it can be both. Quantitative description is based on counts or measurement which are generally reduced to statistical indicators such as frequencies, means, standard deviations and ranges. According to Bryman (1988)
quantitative research or method is associated with a number of different approaches to data collection and is typically taken to be exemplified by the social survey and by experimental investigations.

Qualitative data can be presented in writing, or through audio-tape, photographs or films. It tends to be associated with participant observation and unstructured, in-depth interviews. Qualitative methods tend to be more open than quantitative methods.

Descriptive research can be categorised into stages as follows:

- Examine the problematic situation.
- Define the problem and state hypotheses.
- List assumptions upon which the hypotheses and procedures are based.
- Select appropriate subjects and source materials.
- Select or construct techniques for gathering data.
- Establish categories for classifying data.
- Validate data gathering techniques.
- Make discriminating objective observations.
- Describe, analyse and interpret findings in clear and precise terms. (Allison, 1993:19)

There are many different forms of descriptive research and these fall into a number of main categories some of which have been used in this research. Before any categories are chosen, a survey has to be carried to determine which categories are suitable in this particular research. Whether the survey is large-scale or small-scale, the collection of information typically involves one or more of the following data-gathering techniques: structured or semi-structured interviews, self-completion or postal questionnaires, standardised tests of attainment or performance, and attitude scales. After frequent discussion with the supervisor and looking to the aims of this research, stages of descriptive research were determined which can be categorised as follows:

- Interviews
- Postal Questionnaires
- Case Studies

3.4.1.1 Qualitative method – Interview

There are a number of definitions of an interview, each tied to the particular form or type of interview. Everyone has an idea of what to expect from an interview. Interviewing is a means of gaining access to information of different kinds by asking questions in direct face-to-face interaction.
Research interviewing is a specialised kind of interviewing, its goal is to obtain accurate information from another person which may be useful in the research. Using this method was intended to fulfil three of the research objectives, which are a) to study the role of industrial design in the field of agricultural machinery, b) To identify the type of design approach that is most suitable for use in designing agricultural machinery, and c) to study the design processes implemented by industrial designers and engineering designers in the field of agricultural machinery.

'Questions and answers are the most basic currency of interviews as they are in a lot of everyday conversation and communication...interviews are generally understood as particular, formalised events which carry with them different and distinctive meanings in the ways their basic components - the questions and answers – are organised and interact'. (O'Sullivan et al., 1995: 3)

According to Kvale (1996), the structure of the research interview comes close to an everyday conversation, but as a professional interview it involves a specific approach and technique of questioning. It is conducted according to an interview guide that focuses on certain themes and that may include suggested questions.

O'Sullivan et al. (1995) specified four steps and stages in the interview survey as a whole as shown in Figure 3.1, which are:

![Figure 3.1: Interview survey process](image)

Qualitative research can be defined first in a simple, but quite loose, way. It is the interpretative study of a specified issue or problem in which the researcher is central to the sense that is made. Qualitative research is:

a. an attempt to capture the sense that lies within, and that structures what we say about what we do;
b. an exploration, elaboration and systematisation of the significance of an identified phenomenon;
c. the illuminative representation of the meaning of a delimited issue or problem. (Banister et al., 1994)

On the other hand Denzin and Lincoln (1994) quotes from Nelson who defined qualitative research as:

"...an interdisciplinary, trans-disciplinary, and sometimes counterdisciplinary field. It crosscuts the humanities and the social and physical sciences. Qualitative research is many things at the same time. It is multiparadigmatic in focus. Its practitioners are sensitive to the value of the multimethod approach. They are committed to the naturalistic perspective, and to the interpretive understanding of human experience. At the same time, the field is inherently political and shaped by multiple ethical and political positions."

Qualitative methods are first and foremost research methods. They are ways of finding out what people do, know, think, and feel by observing, interviewing, and analysing documents. Patton (1990) summarised qualitative methods into three kinds of data collection:

- in-depth, open-ended interviews
- direct observation
- written documents

The data from interviews consists of direct quotations from selected people involved. The data from observations consists of detailed descriptions of any activities required from research carried out and open-ended written responses to questionnaires and surveys. The data for qualitative analysis typically come from fieldwork. Extensive field notes are collected through these observations, interviews, and document reviews. (Patton, 1990)

Qualitative methods are not appropriate for every program evaluation or action research question and it is wise to understand when it may be particularly appropriate to use qualitative methods. Certain purposes, questions, problems, and situations are more consonant with qualitative methods than others. According to Hakim (1987) qualitative methods are concerned with individuals' own accounts of their attitudes, motivations and behaviour.

A great strength of qualitative methods is in the study of motivations and other connections between factors. Qualitative methods are extremely valuable for identifying patterns of
associations between factors on the ground, as compared with abstract correlations obtained from the analysis of large scale surveys and aggregate data.

Mason (1996) stated that qualitative methods should be:

- Systematically and rigorously conducted.
- Strategically conducted, yet flexible and contextual.
- Should involve critical self-scrutiny by the researcher, or active reflexivity.
- Should produce social explanations to intellectual puzzles.
- Should produce social explanations which are generalisable in some way, or which have a wider resonance.
- Should not be seen as a unified body of philosophy and practice, whose methods can simply be combined unproblematically.
- Should be conducted as an ethical practice, and with regard to its political context.

Research involving interviewing has to undergo careful planning and thoughtful preparations are essential such as preparing questions, piloting the questions, selections of respondents and time spent for each interview. Edwards and Talbot (1999) suggested that researchers have to devise several stages before interviews begin which are:

- write the research questions;
- brainstorm the questions;
- group the questions into themes;
- place the themes in order;
- drawing on the brainstorm, start to write the questions;
- put the interview in order and
- end the interview with positive question about future plans or a summary.

Qualitative methods utilising case studies and interviews will be conducted during the research. The interview is to find information about the overall design process and the participation and involvement of industrial designers in agricultural machinery design. This also includes what is the level of awareness of the potential contribution of industrial designers in designing agricultural machinery.

3.4.1.2 Quantitative method – Postal Questionnaire

Quantitative methods require the use of standardised measures so that the varying perspectives and experiences of people can be fitted into a limited number of predetermined response categories to which numbers are assigned. The quantitative approach assumes
that it is possible to measure the reactions of a great many people to a limited set of questions. This gives a broad, generalised set of findings.

Quantitative research depends on careful instrument construction to be sure that the instrument measures what it is supposed to measure. The instrument must then be administered in an appropriate, standardised manner according to prescribed procedures. Although qualitative and quantitative methods involve different strengths and weaknesses, both data can be collected in the same study. (Patton, 1990)

Briefly, the researcher would like to identify the major difference between these two approaches; the samples for quantitative methods are large, sometimes it can be hundreds or more but for qualitative methods, the samples are small, typically less than 100. The interview length for qualitative research is long, sometimes more than an hour depending on the respondents' answers.

The quantitative method requires questionnaires in which the questions follow a set format and is the same for each respondent. On the other hand, the qualitative method follows respondents' reactions to various stimuli within a framework of a general set of questions. Analysis under the quantitative method usually uses statistical analysis packages.

One other thing which is important is the content of the covering letter. It is essential that a covering letter is attached with the questionnaire. Kumar (1999) suggested that these points should be in the covering letter which briefly:

- introduces ourselves and the institution we are representing;
- describes the main objectives of the study;
- explains the relevance of the study;
- conveys any general instructions;
- assures respondents of the anonymity of the information provided by them;
- provides a contact number in case they have any questions;
- gives a return address for the questionnaire and a deadline if possible for its return;
- thanks them for their participation in the study.

The covering letter used is attached with the postal questionnaires in Appendix I.

3.4.1.3 Triangulation

Creswell (1994) mentioned in his book that Denzin used the term triangulation which he borrowed from navigation and military strategy to argue for the combination of methodologies
in the study of the same phenomenon. Patton (1990) has quoted from Denzin who has identified four basic types of triangulation:

1. Data triangulation – the use of a variety of data sources in a study.
2. Investigator triangulation – the use of several different researchers or evaluators.
3. Theory triangulation – the use of multiple perspectives to interpret a single set of data
4. Methodological triangulation – the use of multiple methods to study a single problem or programme.

From the above, point 4 has been selected to be used in this research because it is appropriate for integrating the findings from the interviews, postal questionnaires and case studies. These will be discussed in the following chapters.

Quantitative and qualitative methods are most frequently united in order to fill some gaps in the researcher’s knowledge of a group, organisation or whatever, because the gaps cannot be readily filled by a reliance on participant observation or unstructured interviewing alone. Such gaps may occur for a variety of reasons, such as the inaccessibility either of particular people or of particular situations. (Bryman, 1988:137)

3.4.1.4 Case Studies

Case studies are probably the most flexible of all research designs. (Hakim, 1987) At the simplest level they provide descriptive accounts of one or more cases. When used in an intellectually rigorous manner to achieve experimental isolation of selected social factors, they offer the strengths of experimental research within natural settings.

According to Robson (1993) case studies are not necessarily studies of individuals. They can be done on a group, on an institution, on a programme and on many other things. A case study, however, is defined solely in terms of its concentration on the specific case, in its context.

Case studies take as their subject one or more selected examples of communities, social groups, organisations, events, life histories, families, work teams, roles or relationships. The study is to determine between the descriptive report on an illustrative example and the rigorous test. Case studies can be divided into various methods but in this case only two methods were considered which are evaluation and action research (Moore, 1983).

In this research, it was decided to focus deeply into two of the design activity problems faced by PORIM and RRIM. These organisation’s engineers felt that they need to give these areas
priority to come out with a product to give the farmers, especially small and medium farmers, to maximise their income and speed up the work process without too much complexity especially to the elderly users and children. Instead of looking at the general problems facing these two organisations, the researcher felt that with the industrial design experience and skill he has, he would like to take the challenge of creating product proposals for both projects. These projects are:

a. Loose oil palm fruits collecting devices
b. Coagulated rubber collection and transportation.

The two projects carried out were considered to be the best way to raise questions which may have been overlooked in generating the interview and questionnaire surveys. Surveys depend on questions chosen and developed by the researcher and therefore will inevitably be influenced by the author's own viewpoint, no matter how objective he tries to be. Carrying out design projects introduces an external perspective and provides a means of relating the research directly to the field of study within the Malaysian cultural setting.

The detail of the projects is discussed and illustrated in Chapter 6.

3.5 Data Analysis

Closed questions and multiple choice questionnaires are recognised as the common types of questionnaires. The main advantages of this type are that they are easy to complete and easy to analyse.

There are a few statistical packages available. With the advent of modern computer technology and software, it is easier for researchers to analyse data and report the results.

Among the best-known programs are MINITAB, SAS, SPSS and Statgraphics. Such packages have the facilities for data tabulation, descriptive statistics, cross-tabulations, test for differences between groups, data plotting procedures, correlation analysis, plus a variety of non-parametric test and multivariate statistics; taking more variables at a time. (Diamantopoulos and Schlegelmilch, 1997)

In this research, data collected from the survey was analysed using the computer program SPSS for Windows. SPSS was initially developed in 1965 at Stanford University in California. (Howitt and Cramer, 1997)
Samples are made up of individuals. The individuals in a particular sample may be anything which share some common attribute or characteristic such as job function or number of years experience in a job or profession. So, in looking at the members of a sample, we ask how they 'vary' among themselves on one or more of such characteristics. Because of the variation among individuals, such characteristics are called 'variables'. (Rowntree, 1991)

It is helpful to label the variables and things are made clearer if each of the different categories of the variable is placed in order. Variables can have a label of up to eight characters. (Table 3.1) If the characters have longer version, it can be typed in a different column which will only be displayed in the output. The full list of the variables can be found in Appendix II.

| a1number   | - No. of Employees     |
| a2orga_a   | - Design Department    |
| a2orga_b   | - Research, Dev. Dept. |
| a2orga_c   | - Others design related|
| a3jobfun   | - Job function         |
| a4experi   | - No. years experience |
| a5total    | - Total experience     |
| b1design   | - Involved in designing|
| b2led_1    | - Directed from company|
| b2led_2    | - Research, Dev. Project|
| b2led_3    | - Consultancy work     |
| b2led_4    | - Others               |
| b3depro    | - Agri. Mach. Design project|
| b4last5    | - Design last 5 years  |
| b5invol1   | - Agricultural engineers|
| b5invol2   | - Mechanical engineers |
| b5invol3   | - Production engineers |
| b5invol4   | - Electrical engineers |
| b5invol5   | - Industrial designers |
| b5invol6   | - Marketing people     |
| b5invol7   | - Ergonomists          |
| b5invol8   | - Others profession    |

Table 3.1: The UK and Malaysian Variables

3.6 The Qualitative Survey
3.6.1 Interview

Interview surveys require a schedule which needs to be designed in much the same way as a posted questionnaire. The interview survey, which is becoming increasingly popular, is an
in-depth interview survey where a relatively small selected number of people are questioned to obtain information on the subject chosen. The interview is a flexible and adaptable way of finding things out.

The interview technique is a widely used method of gathering data from people who are willing to provide information in a face-to-face situation. The great advantage of the interview is that the interviewer is able to explain the purpose of the study and can ensure that the subject fully understands what is required. The interview can be used in different ways depending upon the research and whether it enables the researcher to gather the information he is seeking.

It is necessary to plan the interview if it is to be effective. The researcher must have a clear idea of the information he needs, and he must prepare questions which will elicit that information. The success of interview depends on the skill and sensitivity shown by the interviewer.

The interview is a specific form of conversation. According to Kvale (1996) an interview is literally an ‘inter view’, an interchange of views between two persons conversing about a theme of mutual interest. Kvale also asserts that there are six qualities in an interview. The quality of the interview is decisive for the quality of the analysis, verification and reporting of the interviews. The six qualities are:

- The extent of spontaneous, rich, specific and relevant answers from the interviewee.
- The shorter the interviewer’s questions and the longer the subjects’ answer the better.
- The degree to which the interviewer follows up and clarifies the meanings of the relevant aspects of the answers.
- The ideal interview is to a large extent interpreted throughout the interview.
- The interviewer attempts to verify his or her interpretations of the subject’s answers in the course of the interview.
- The interview is “self-communicating” – it is a story contained in itself that hardly requires much extra descriptions and explanations.

The purpose of interviewing is to find out what is in and on someone else’s mind and not to put things in someone’s mind. Interviewing is to access the perspective of the people being interviewed and to find out from them those things we cannot directly observe. It is also to allow us to enter into the other person’s perspective. It is possible for the person being interviewed to bring the interviewer into his or her world.
There are three basic approaches to collect qualitative data through open-ended interviews. The three choices are these:

- The informal conversational interview – it relies entirely on the spontaneous generation of questions in the natural flow of an interaction.
- The general interview guide approach – involves outlining a set of issues that are to be explored with each respondent before interviewing begins.
- The standardised open-ended interview – consists of a set of questions carefully worded and arranged with the intention of taking each respondent through the same sequence and asking each respondent the same questions with essentially the same words.

These three approaches to the design of the interview differ in the extent to which interview questions are determined and standardised before the interview occurs (Patton, 1990). The researcher used the third approach in this study.

An interview can be conducted in different ways depending on the nature of the subjects. Two types of interviews are ‘normative’ and ‘elite’ (Anderson, 1990). Normative interviews are used in mass surveys to find the views from large numbers of people with straightforward questions in oral form. Elite interviews concentrate on a small number of elite individuals to gain their experience or knowledge about the subject being discussed.

Before an actual interview begins with selected respondents and to finalise a set of open-ended interview questions, it is necessary to carry out a pilot test, that is, to do some preliminary testing and practising before beginning the proper interview (Appendix III).

3.6.1.1 Construction of the Interview Questions

To design interview questions is one of the most crucial and critical stages in the research design beside postal questionnaire formulation. This type of survey may be a structured interview survey or, if the interview respondents are relatively small in number, a semi-structured procedure can be used. In this research, both methods have been used depending on the answers given by the respondents. If the researcher felt that an answer given was appropriate, then the following question would be asked, if not the question was rephrased to make sure that the respondents provided relevant information.

Open-ended questions were used in this programme because the researcher wanted the respondents to express themselves freely on the questions asked.
Drafted interview questions were discussed with colleagues and after several meetings a set of 24 questions had been identified (Appendix IV). With these questions pilot tests were carried out.

Evaluation of the questions and further discussion were carried out to enhance the quality and ensure that the answers given were appropriate to the topic of the research. The number of questions was reduced from 24 to 18 (Appendix V). A pilot test for the second round was carried out but this time the researcher had forwarded the questions to his colleague through e-mail in Malaysia. They gave some advice on improving the questions to assist in categorising under different themes.

Discussions led to final questions categorised into six sections and the number had been increased to 35 questions altogether (Appendix III). These questions were then also used in interviewing respondents in Malaysia.

3.6.1.2 Interview Pilot Test

The pilot test is important to ensure that the wording will be understood. Pilot test interviews were carried out with 6 selected representative designers within Loughborough University including two industrial designers and three engineers. The researcher tried the same questions with a professional industrial designer who had been involved with designing agricultural equipment and also with a professional engineer who has experience in designing agricultural equipment.

The importance of the pilot test is to give the researcher practise in working with the particular procedures, the goal being to minimise interview error once the real interview starts. The other point is to test out any uncertain aspects of the interview. Such testing may often be necessary because the reactions from respondents can be difficult to predict. It is also sometimes necessary to make sure that the interview questions are being tested at the desired level.

Pilot tests can save a lot of problems in identifying the interview questions. The pilot test allows the researcher to focus on particular areas that may have been unclear previously. It also allows researchers to develop and consolidate harmony with respondents as well as establishing effective communication (Janesick, 1998)
3.6.1.2.1 Recording the Data

Before conducting an interview, we should decide how our interviews will be recorded. Three possible options are note taking, tape recording or a combination of the two. No matter what style of interviewing is used, and no matter how carefully one words interview questions, it all comes to naught if the interviewer fails to capture the actual words of the person being interviewed (Patton, 1990). The raw data of interviews are the actual quotations spoken by interviewees. The purpose of each interview is to record as fully and fairly as possible that particular interviewee’s perspective.

Tape recording was used in this research. By using a tape recorder, the interviewer can then concentrate on the topic and the dynamics of the interview. Tape recorders do not “tune out” conversations, change what has been said because of interpretation, or record words more slowly than they are spoken. In addition to increasing the accuracy of data collection, the use of a tape recorder permits the interviewer to be more attentive to the interviewee. Most evaluation interviews are arranged in such a way that tape recorders are appropriate if properly explained to the interviewee:

“I’d like to tape record what you have to say so that I don’t miss any of it. I don’t want to take the chance of relying on my notes and thereby miss something that you say or inadvertently change your words somehow. So, if you don’t mind, I’d very much like to use the recorder.” (Patton, 1990)

The use of tape recording does not eliminate the need for taking notes. Notes can be taken to consist primarily of key phrases and list of major points. When it is not possible to use a tape recorder, notes must become much more complete and comprehensive. In this research, the researcher managed to use a tape recorder for all the respondents in Malaysia and in the UK after asking permission.

3.6.1.2.2 Transcripts of Interviews

After an interview, the first thing to be done is to check the tape. If a malfunction occurred, the interviewer should immediately make extensive notes of everything that can be remembered. The period after an interview is a critical time to guarantee that the material or data obtained will be useful, reliable and valid.

Transcribing involves translating from an oral language, with its own set of rules, to a written language with another set of rules. Transcripts are not copies or representations of some
original reality, they are interpretative constructions that are useful tools for given purposes. The objective of transcription is to transform the oral to the written mode.' (Kvale, 1996)

Patton (1990) mentioned that the raw material or data of interviews are quotations. Unfortunately, transcribing is enormously expensive. Despite these costs, full transcriptions are the most desirable material or data to obtain. Transcripts can be enormously useful in data analysis and later in replications or independent analyses of the data.

There are no standard modes of presenting the results of interviews. Kvale (1996) elaborates even though there are no standard forms for presenting interviews, there are several options available. The usual mode of presenting interviews findings is in the form of quotations. The interview quotes give the reader an impression of the interaction of the interview conversation and exemplify the material used for the researcher's analysis.

3.6.1.2.3 Interview Analysis

Whichever method of questioning is chosen, the researcher has to decide what to ask. In this research, the questions were guided by the requirement of the research objective, other similar research approaches available, and the researcher's own understanding of the subject matter. The results will be analysed by content analysis under different categories or themes which have been identified in relation to the purpose of the investigation.

Different kinds of questions are required to obtain different kinds of information to interpret the meaning of the question given. The themes have to be identified before analysing takes place to ensure that the information accumulated from respondents is relevant to the research conducted. Analysing interview themes also involved clarifying the purpose of the study, which are:

- To provide Malaysian industrial designers with methods or guidelines to assist them in designing agricultural machinery and equipment;
- understanding the implementation of design processes and the interaction between industrial designers and engineers performances in a design team to accomplish agricultural design projects.

A number of themes have been identified that will be used for thematic analysis and which are elaborated in more detail in section 4.3.
3.6.1.3 Identifying UK Respondents

Interviewees for the UK respondents were selected from Loughborough University lecturers based in the Department of Design and Technology specialising in industrial design, and the School of Mechanical and Manufacturing Engineering specialising in engineering design. Also several professional designers were identified from companies involved in agricultural machinery and equipment design, and in designing capital products (Appendix VI).

In this study, the researcher has categorised the sample of population divided into two, which are industrial designers and agricultural engineers. The sample for the UK industrial designers and agricultural engineers respondents were based on Internet searching under company reports for which the activities related to manufacture, design, and sale of agricultural machinery and equipment. The search on the directory of design consultants was to identify industrial designers who are mainly involved in engineering design, but to find designers involved in agricultural design activities is now very difficult. Seven respondents were identified from the UK.

3.6.2 Postal Questionnaire

Questionnaire surveys are the most commonly used research method. Questionnaires are extremely flexible and can be used to gather information on almost any topic from large or small numbers of selected people. It is not easy to design a really good questionnaire and even well designed ones do not always manage to produce a high rate of response. Moore (1983) divided questionnaires into:

a. Closed questions where respondents are asked a question and required to answer by choosing between a number of alternatives. Sometimes the question is in a form of multiple choice. Closed questionnaires can only really be used to obtain fairly straightforward information.

b. Open questions produce quite detailed answers to complex problems. It is effective when used with a small group of people who are used to expressing themselves in writing. In nearly all cases it is worth ending a closed questionnaire with an open question to obtain the respondents' general opinion on the subject.

Postal questionnaires can be a powerful tool both in policy formulation and in evaluation if they are used appropriately. Sudman et al., (1984) divided this type of survey into eight major characteristics to determine whether postal questionnaires can be mailed successfully, these are:
their length,
the salience of their topic to potential respondents,
the need to ask open-ended questions,
the need to probe answers,
the need for branching,
possible order effects,
the desirability or undesirability of allowing recipients to consult records or other people,
and
the recipient's need to absorb information.

Certain of these characteristics clearly point to use by postal questionnaires and others argue for the use of interview methods. The length of the questionnaire must be shorter than interview questions but there is no answer to how short the questions have to be.

McNeill (1990) also defined postal questionnaire as divided into the two categories of 'closed' and 'open' questions. 'Closed' questions can be as simple as putting YES/NO/DON'T KNOW alternatives to choose from, or there may be a list of possible answers from which at least one or more answers must be ticked. The advantage of this method is that the results can be presented in the form of statistics and tables. 'Open' questions, depend on how the respondents would like the answer to look because the questions are normally asking their opinions. Such questions are more asked in the interview situation rather than in a postal questionnaire. Open questions make it possible for respondents to write what they feel but it is difficult for the researcher to organise the answers into categories in order to analyse them.

A questionnaire has a similar purpose to the interview except that it is usually in printed form and may be completed without the presence of the researcher. All questionnaires are structured. Questionnaires are particularly useful when needing to procure responses from large samples as they can be sent out by post. (Allison, 1993) According to Neuman (1991) there are two basic principles for good postal questionnaire: avoid confusion, and keep the respondent’s perspective in mind because good survey research will give valid and reliable measures, and help respondents feel that they understand the questions and their answer are meaningful.

3.6.2.1 Construction of Questionnaires

The common types of postal questionnaire use closed questions because it is relatively easy for respondents to choose between a number of alternatives.
Closed questions can be organised in several ways such as 'fill-in-the-blank', 'multiple choice', 'comment on', 'list', 'likert scales', and 'rank'. In this research the question's design will focus on 'likert scale' and 'multiple choice' types. Although there is a 'fill-in-the-blank' type in the questionnaire it is not essential.

The postal questionnaire can be found in Appendix 1.

3.6.2.2 Pilot Testing the Questionnaire

Before the final questions emerge, a pilot test has to be conducted. The respondents identified for piloting the questionnaires included lecturers from Loughborough University, professional designers from companies, and also engineers and industrial designers from Malaysia. E-mail has become one of the sources to get in touch with several respondents to become involved with the survey.

Pilot testing the questionnaire is essential to obtain comments from at least a small group of the intended respondents. The pilot test will identify the wording of the questions and it may indicate unanticipated answers. The pilot testing permits overall reactions including comments on the length of the questionnaire.

There are two types of respondents involved, industrial designers and engineering designers, and a questionnaire had been designed to allow both disciplines to answer the same questions. The questionnaire has been distributed by handling personally, posting and using e-mail.

The final postal questionnaires both for the UK and Malaysia respondents were similar in every section.

3.6.2.2.1 Processing the Data

After receiving the data, processing consisted of putting answers into categories, adding up totals, and expressing the data in statistical terms. Nowadays, computers have an essential role in processing the data obtained from any type of research. In this programme, the data obtained will be analysed using SPSS for Windows which has been elaborated in section 3.5 and the results will be discussed in more detail in Chapter 5.
3.6.2.3 The UK Survey

220 sets of questionnaires were circulated to companies involved with agricultural machinery design and industrial designers. From this amount, 22 questionnaires were returned because the addresses did not exist anymore and some of the companies had been closed. Also some did not have specialist people in this area who could complete the questionnaires.

198 are counted as the total questionnaires circulated. A total of sixty-three out of one hundred and ninety eight responded to the questionnaire (Table 3.2).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total circulation</th>
<th>responded</th>
<th>Response %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial designers</td>
<td>25</td>
<td>10</td>
<td>40%</td>
</tr>
<tr>
<td>Engineering designers</td>
<td>173</td>
<td>53</td>
<td>30.6%</td>
</tr>
</tbody>
</table>

Table 3.2: The UK questionnaire response rate

According to Miller (1991) response rates to mail questionnaires are typically low, usually not exceeding fifty percent and for Kumar (1996), obtaining a fifty percent response rate is considered successful because sometimes it may be as low as twenty percent. McNeill (1990) mentioned that the response rate for the postal questionnaire is usually around 30 to 40 percent lower than in face-to-face research (interview), in which we can hope to achieve up to 70 or even 80 percent response. Belson (1986) described that it is common to have response rates of the order of 30 percent or less. It is very hard to get engineers or designers to respond to postal questionnaires as mentioned by Wright (discussed at Mech. Dept., Loughborough University, 1999)

3.7 Malaysian Survey

The researcher went back to Malaysia for three months starting September 1999 until the end of November 1999 for data collection.

3.7.1 Contacting Malaysian Respondents

The researcher had contacted the respondents before returning to Malaysia. He has acknowledged most of the respondents the time schedule he has decided to see them and finalised the appointment with them after he arrived in Malaysia. Most of the respondent's names had been found through Internet searches. The respondents represented agricultural
Chapter Three

Research Design

R&D institutions such as PORIM, RRIM, MARDI, FRIM, government agencies such as SIRIM, universities such as UPM, UTM, UiTM, and companies (Appendix VII).

Twenty five respondents were interviewed in Malaysia.

3.7.2 Malaysian Postal Questionnaires

Before going back to Malaysia, the questionnaires were prepared for respondents identified before-hand. The questionnaires were posted on the second day in Malaysia to the respondents which covered East and West Malaysia.

3.7.2.1 Identifying Malaysian Respondents

Industrial designers in Malaysia don’t have any specific society. Most of the industrial designers have become members of MINDS (Malaysian Invention and Design Society) and this provided a source of respondents names and addresses. The researcher also contacted his previous college, department of industrial design under School of Art and Design where normally graduated students leave their addresses for future correspondence. Although there are not so many Malaysian industrial designers, the researcher feels that the amount that he managed to collect is sufficient.

Respondents for agricultural engineers and design engineers were identified from the Agricultural R&D institutions, government agencies and universities mentioned in section 3.7.1. Several names and addresses were obtained from early correspondence with one of the companies which designs and manufactures agricultural machinery and equipment - Howard Alatpertanian (Agricultural Appliance) Co. Ltd. The number of agricultural engineers and design engineers respondents were not as many as industrial designers but it is appropriate for the survey. The researcher had been told earlier that he would not be able to find many engineers who have knowledge and experience of agricultural equipment design activities. Somehow the researcher managed to compile 170 names of Malaysian respondents.

3.7.2.2 Malaysian Survey

For the Malaysian samples, 170 set of questionnaires were circulated. 110 questionnaires for the industrial designers and 60 questionnaire for agricultural engineering designers throughout west (peninsular) Malaysia and east (Sabah and Sarawak) Malaysia.
A total of seventy-four (74) out of one hundred and ten (110) industrial designers and forty (40) out of sixty (60) agricultural engineering designers responded to the questionnaire (Table 3.3).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total circulation</th>
<th>responded</th>
<th>Response %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial designers</td>
<td>110</td>
<td>74</td>
<td>67.2%</td>
</tr>
<tr>
<td>agricultural engineering designers</td>
<td>60</td>
<td>40</td>
<td>66.7%</td>
</tr>
</tbody>
</table>

Table 3.3: Malaysian questionnaire response rate

3.7.3 Malaysian Case studies

Having determined the scope and nature of the study, case studies have been chosen to become one of the requirements in this study. The researcher discussed with the designers and engineers involved in this particular subject to make sure that the design projects carried out would benefit the users and nation generally.

Discussions helped to work out how to make the design project work effectively within the research. The first task of the researcher was to gather all the information related to the subject matter which will be discussed in detail in Chapter 6. Then the researcher had to observe the existing practise in normal circumstances. Particular care had to be taken to ensure that the information gathered was substantial. This totally depended on the information and support from individual's co-operation.

For many years, agricultural engineers and design engineers have worked very hard to come out with new products or systems to be used in the plantations. A variety of designed products have been used, and a number of lessons have been learned. It is still an urgent matter to get the right products, and the development to solve these problems remains to be carried out. So far, despite many efforts, it has not really provided products or systems that can be used in a cost-effective manner.

Two suitable projects were identified, the first related to the palm oil industry which has neglected the importance to the users of collecting loose oil palm fruits. This problem has usually been monitored by PORIM. The researcher convinced the design centre that he should be involved in producing a design proposal for the purpose of improving the working procedure in the plantation. The second design project which was conducted by RRIM is a transport method whereby the users can easily collect and transport coagulated rubber from plantation to collection points or straight to the processing plants. At the moment, users will use whatever appliances they can to make the work process easy for them. The researcher
has taken these projects as a challenge to show that there is a great possibility that industrial designers can play a role and contribute their knowledge, skill and experiences in designing agricultural machinery and equipment.

The term 'observation', and in particular 'participant observation', is usually used to refer to methods of generating data which involve the researcher immersing himself in a research setting and systematically observing dimensions of that setting, interactions, relationships, actions, events and so on, within it (Mason 1996).

As stated earlier the culture of Malaysian agricultural practice is central to this research. The case studies offered an opportunity to make observations on the design process when the researcher was working on real-life Malaysian problems. The design work was carried out based on information gained from the interviews and from plantations in Malaysia. It was believed that this approach would be more meaningful than obtaining information from case studies in the UK.

3.8 Developing Design Guidelines

The fourth aim of the research is to propose guidelines to assist industrial designers in Malaysia. The purpose of having the design guideline is to ask designers, especially industrial designers, to make use of some sort of procedure to help to minimise the time consumed normally by designers during design projects and to improve the chances of a successful outcome. The design guideline is the procedure for performing design activities by individuals or institutions and companies. It specifies a general design process to be followed, but it is not intended to constrain the creative processes.

According to Stoll (1999), product design is a process. It begins with the recognition of the need and ends with manufactured product which is accepted by the users. The design process can be divided into several phases in which information about the design is developed (Figure 3.2).

![Figure 3.2: Phases of the product realisation process (Stoll, 1999)](image)

The formal design process is the heart of the design guideline. The design process will be discussed and elaborated in more detail in Chapter 7.
According to Stoll (1999) the actual process depends on the individual or the company and the type of products involved. The design guidelines usually include more than the formal design process as mentioned in Figure 3.2, it might include checklists for conducting each phase of the project, preparing design reviews, and guiding team member contributions.

The research will help to identify the stages of the design process which need most support, and will propose ways of providing this to the team.

Design guidelines can be simple or very complicated. In this case the design guidelines should be as simple as possible and as convenient as it could be for the industrial designers who are going to be involved in agricultural machinery and equipment design activities in Malaysia and the regions.

3.9 Summary

Much of the literature has discussed and described how industrial design and engineering design should be integrated in the design processes to achieve better design and successful products. Malaysia needs a system or approach in designing agricultural machinery and equipment to solve problems in agricultural activities.

There were several successful prototypes designed by Malaysia's R&D institutions, universities and private companies. Some of them have succeeded but many need further development to meet the demands of the users. The researcher feels optimistic that by incorporating industrial design knowledge and skill within multi-disciplinary approaches in agricultural machinery and equipment design the overall design will be improved.

The researcher decided to use descriptive research methods which utilise qualitative and quantitative approaches. The qualitative research utilises interviews and case studies, whereas the quantitative research is based on questionnaires. Interviews have been conducted with seven respondents from the UK and twenty-five from Malaysia.

The quantitative surveys have involved Malaysia and the UK. A number of questionnaires have been circulated. They will reveal findings between two different countries, nevertheless, the findings certainly will highlight the role and potential contribution of industrial designers in this area between these two countries which are discussed in the following chapters.

Case studies conducted as design projects are related to the second and fourth aim and objective of this research: i.e., to study the role of industrial design in the agricultural machinery industry and to develop approaches and techniques for designing agricultural
machinery appropriate to Malaysia's circumstances. Case studies help in exploring the contributions, the stages of the design process which most need support, and the skills and knowledge industrial designers will need to get involved in agricultural machinery design.

Design projects carried out will assist the researcher to create design guidelines, which will help Malaysian industrial designers to work effectively with agricultural engineers. It is anticipated that the involvement of these professionals will make major changes in producing agricultural machinery and equipment in the future.
CHAPTER FOUR

The UK and Malaysian Qualitative Survey (Interview)

4.1 Introduction

This chapter describes the qualitative survey consisting of semi-structured interviews. The survey was divided into two phases:

a. interviews with industrial designers and agricultural or mechanical engineers within the UK
b. interviews with industrial designers, agricultural engineers and mechanical engineers in Malaysia.

The interviews with the UK representatives were carried out after preliminary interview questionnaires had been constructed and the interviews had been piloted with selected people in the university and outside. The aim of the first interview was to develop appropriate questions following a literature search related to this type of survey. Modification and changes were determined from the pilot interview and the final version used for further investigation. The interview questions are listed in Appendix IV and Appendix V.

The interviews with Malaysian respondents were carried out during three months in Malaysia. The respondents had been identified beforehand and interview schedules had been fixed before the researcher started his three months work in Malaysia. Interviews were held with the agricultural engineers (academicians and staff researchers), Heads and researchers of the R&D institutions, Head designer and Managers from a private company and industrial designers (academicians and staff researchers). The interviews included persons directly involved in the research, design and development of agricultural machinery and implements.

This chapter has been organised into several sections. Section 4.2 deals with the type of analysis of the interview findings and sample sizes. Section 4.3 establishes the themes, and section 4.4 and 4.5 discuss the UK findings and Malaysian findings under these themes. A summary of this chapter is presented in the last section, 4.6.
4.2 Analysis of Interviews

Open-ended questions used in the semi-structured interviews required analysis. To do this the responses have been categorised under different themes. Hall et al (1996) suggest that research involving interviews, questionnaires and observations may be analysed under some form of 'content analysis', in which the various responses to the questions are grouped into a logical and orderly set of different categories.

Many authors discuss content analysis. Mostyn (1985) said that content analysis is the 'diagnostic tool' of qualitative researchers, which they use when faced with making sense of a mass of open-ended material. According to Neuman (1991), content analysis is a technique for gathering and analysing the content of text. The content refers to words, themes, or any message that can be communicated. The text is anything written or spoken that serves as a medium for communication.

Edwards and Talbot (1999) described content analysis as asking specific questions, derived from the focus of the research questions. According to McNeill (1990) content analysis is a method of analysing the contents of documents, interview transcripts or other non-statistical material in such a way that it is possible to make statistical comparisons between them. According to Kvale (1996), qualitative and quantitative approaches interact with each other. In more open approaches to interview texts, both methods, qualitative and quantitative, intermingle.

The relative emphasis will depend on the type of phenomena investigated and the purpose of the investigation. Content analysis (Minichiello et al, 1990) can focus on several elements such as words, concepts, sentences and themes of the interview transcript or written document. Eventually the purpose of the content analysis is to identify specific characteristics of communications systematically and objectively in order to convert the raw material into meaningful data. (Mostyn, 1985)

The interview answers have to be written out so that the answers to that question can be viewed together. If the same words appear in different responses, the answer will fall under the same category or theme. There will be different types of categories and themes to identify respondents' answers toward the questions given.

Once the categories and the themes have been applied to all the interview questions, David Hall et al (1996) advised the researcher to review the questions to see if:
Chapter Four

a. it makes good sense (face validity)
b. it is comprehensive (covers all responses)
c. it discriminates between responses.

Written text that is ready for analysis can be in the form of interview transcripts, observational jottings, or published material and documentary evidence. Content analysis starts by asking specific questions. These questions are usually derived from the research questions established before the interviews take place. Content analysis is based on the assumption that analysis of language in use can reveal meanings (Edwards and Talbot, 1999).

The most commonly used form of content analysis involves the researcher in accumulating the data to find themes and patterns or categories of evidence. For example, most of the respondents said that industrial designers have a role in agricultural machinery and equipment design, and therefore the category or themes of response could be labelled under 'role of industrial designers in agricultural machinery design'. Thematic content analysis was used in this research and is discussed in the following section.

4.2.1 Defining the Sample

The first thing to do before interviews can proceed is to identify suitable respondents from the group of interest. The important thing in sampling is to generalise a sample population and pick a suitable sample. The number of possible respondents for this research is small. If it were possible to question them all this would be called the 'target population' (Hall et al 1996, Anderson 1990, Lynn 1996, Neuman 1991). There are more people in the target population we can contact, but because the sampling for this purpose is not large then sampling is chosen as a form of selection. Hakim (1987) categorises this sample, which is a selection of people who are expected to offer some information with regard to the research need, as 'focused sampling'. Hall et al (1996) quote from Rose who explains the logic of sampling by contrasting three overlapping entities: a) the working general universe, b) the working universe, and c) the sample. In this case the researcher chose the sample from the small number of respondents on the basis of the people we have information on.

There are many ways to define the target population. One common method is the use of lists. The target population is defined as all those on the list. Several respondents were identified who have experience in designing agricultural machinery and equipment. Although some are not specialists in this area they do have the knowledge and capability in designing capital products as well as consumer products. Some of them have worked in design companies and then moved to the university, becoming lecturers teaching design and related subjects.
Chapter Four

The UK and Malaysian Qualitative Survey (Interview)

For the Malaysian sample the researcher had been advised to identify respondents in relevant R&D institutions, universities and private companies, which conducted design activities related to agricultural machinery and equipment.

4.2.2 Sample Size and Method of Analysis

An important question is that of sample size. How many people are needed in order to be able to generalise about the target population? There is no definite answer, for the correct sample size depends upon the purpose of the research. Cohen and Manion (1985) state that a sample size of 30 is thought by many to be the minimum number of cases if the researcher plans to use some form of statistical analysis on the data acquired.

One of the many sampling methods available is 'snowball sampling' (Cohen and Manion 1985, Hall et al 1996, Lynn 1996, Kumar 1999, McNeill 1990, Neuman 1991). The researcher identifies a small number of respondents in the organisations and the required information is collected from them. They are then asked to identify other appropriate people in their organisation, and the people pointed out by them become a part of the sample. This process is continued until the required number has been reached. This technique is useful because a researcher may know little about the respondents he wishes to study. The researcher is thus directed to other members of the group.

For the UK respondents, several were identified from universities and companies. The 'snowball sampling' method was implemented when respondents suggested other respondents for their participation in the interview survey. Several respondents who were willing to take part in this survey agreed to be interviewed when returning their postal questionnaires. The number of respondents from the UK was 10, and 26 Malaysian respondents.

4.3 The Interview Themes

There are many different forms of interview questions requiring different types of answers and individual questions vary according to the research. The interview themes were identified to reflect the aims and objectives of the research and the research questions. The many factors that industrial designers have to consider are discussed in the following sections.

The themes were identified as follows:
- Industrial designers' contribution to agricultural design in Malaysia
- Involvement of ID in agricultural machinery design - Role
• Level of involvement of ID in the design process stages
• Multi-disciplinary working in agricultural machinery design
• Importance of design methods in the design process
• Methods usually used in designing
• The crucial stages in designing
• Design element priority in agricultural machinery design
• Skills required by industrial designers
• Drawing capability for designers
• Communication in design
• Involvement of users or clients in design projects
• Involvement of marketing in designing
• The significance of verbal and visual communication in design
• The importance of prototyping in design
• The importance of physical modes in design activities
• The significant differences between 2D and 3D communication in design
• The future in designing agricultural equipment in Malaysia

4.3.1 Industrial designers' contribution to agricultural design in Malaysia

General points arising from the interviews are discussed here. All interviewees observed that the cultural conditions in Malaysia as an emerging industrial country would be central to the research and the way in which design is viewed. The beginning of the new millennium is a special occasion for future development. Efforts need to be made to improve some important aspects of agricultural activities, especially with new systems and devices which can provide a comfortable working environment and speed up the working processes. As mentioned previously most of the farmers now are elderly or, women and children. It is a totally different situation if compared with the UK farmers, who normally are equipped with the technology, modern machinery and equipment that helps them to do the job in a comfortable manner.

Many industrial designers came from backgrounds associated with different kinds of commercial art, exhibition and display and from there they were assigned projects by other companies to design products. In the 1990s, a new generation of industrial designer emerged. In Malaysia, although it has been established since the 1970s, most of the people still do not know what industrial design means and what contribution it can make to improve the quality of life in society (Bajuri, 1999). There are people who still have the wrong impression of industrial design; they think that it can only produce impracticable sophisticated images.
This misconception of industrial design in Malaysian society is understandable, since not much explanation had been given until the early 1970s when Malaysian industrial designers who graduated from UiTM (formally known as ITM) and overseas, found employment either with government agencies or in the private sector. At the early stage they were employed as researchers, teachers, furniture designers, graphic designers and interior designers. After Malaysia started to produce its own cars then many industrial designers were employed in car styling as well as car designers, working closely with other professionals in the government car manufacturing industry.

In agricultural industry, the first industrial designer was involved in 1975 after he graduated from UiTM and joined MARDI as a Research Assistant to work with their agricultural engineers. That was the first industrial design debut in agricultural equipment design in Malaysia. Unfortunately he left MARDI after his post-graduate course and joined a university as a lecturer. Subsequently no further industrial designers have been involved directly with agricultural agencies. Hence the importance and potential contribution of industrial designers in creating agricultural products are still not widely known to Malaysians and, because of this, many research and design projects were carried out without the involvement of industrial designers.

Developed countries such as Britain, the United States, Europe and Japan have long realised the importance and contribution of industrial design in the field of agricultural machines and other capital products.

Industrial designers have to make agricultural equipment look nicer, it must perform faster without damaging the crops, it must be quicker so that the farmer can concentrate on other activities which can generate more income. Agricultural machinery has to be economical, operator friendly and most importantly it must be cheaper. The machinery must be easy to maintain and last longer without any maintenance because farmers now expect 100% reliability from the machinery they buy. (Kilgour, 1999)

Paul Clapham (1999) stressed that if industrial designers wish to contribute to agricultural machinery and equipment design, they have to put themselves into a position where they understand thoroughly the crop’s characteristics and how to handle it. Agriculture is a very challenging activity and every single crop must be treated differently; if not whatever you design for will turn into destruction. Industrial designers also have to equip themselves with knowledge to allow them to understand the suitable materials for the crops, plantation, soil and users.
Industrial designers need to be knowledgeable not only about products, but about agricultural activities as a whole. They must not only focus on making the end product look good, even though the buyer’s first impression is the exterior of the product, but they have to make sure that the quality of the product is excellent in terms of satisfying the users and owners if the agricultural industry in Malaysia is to be successful.

4.3.1.1 Findings of the UK survey

In the UK industrial designers have been established for quite some time, since history has shown the capability of industrial designers to produce magnificent agricultural products. For example, JCB has developed machinery with the help of their industrial designers. They believe that the era will come where there will be healthy competition among the companies to produce beautiful and functional machinery.

4.3.1.2 Findings of the Malaysian survey

As described in section 4.3.1 industrial designers have not applied their knowledge, experience and skill in this industry since the early 1970s. It has become clear that it is time for Malaysia to take a step ahead after some industries have shown that Malaysia can penetrate the world market with cars and motorcycles. As a first step Malaysian industrial designers have roles to play in these industries to change the scenario of producing agricultural machinery and equipment for local use to regional use.

4.3.2 Involvement of ID in agricultural machinery design – Role

There is no doubt that agricultural engineers have established the change and the introduction of agricultural machinery. Agricultural machinery and related machines, as mentioned in the previous chapter, were imported directly from abroad and most of the machinery is not designed to suit Malaysian agricultural environment. Most of the machinery has to undergo several modifications and adjustments to allow it to work. In the early 1960s, modification of machinery became a common practice by agricultural engineers in Malaysian agricultural machinery design.

As has been mentioned, one of the established industrial designers who became involved in and contributed his skills to agricultural machinery design was Henry Dreyfuss. Dreyfuss paid careful attention to the impact of products on the users. Dreyfuss made it clear that industrial designers should be concerned not only with appearance, but also with function.
The contribution from industrial designers did not only concentrate on the beauty of the end product. Agricultural machines have to be capable of performing in the plantations and it is important for industrial designers not only to concentrate on the exterior of the product but to consider other aspects in order to achieve acceptable, competitive and successful products (Clapham, 1999, interview). Cost effectiveness is an essential aspect of all product development, without it there will be no product that can be commercially successful. The quality and cost are both to improve effectiveness through the industrial design contribution to performance and quality, and also to reduce the actual costs of production and operation.

Bajuri (1999, interview) stressed that the role of industrial designers contributing towards agricultural machinery design has to be the aesthetics of the product. Industrial designers have to focus on aesthetics and ergonomics as well as function. Although function is more related to engineering, industrial designers have their own perspective on the function of the products. Kilgour (1999, interview) also stressed the product appearance as people buy things based on the shape and general feeling of the product, not only the technical aspects of the machine.

Industrial designers have to work like those in other industries such as truck, and other automotive related industries where agricultural machinery has to look right in a sense of making the product more competitive (Leake, 1999, interview). Swain (1998, interview) believed that industrial designers have to play their role from the start of the project. This is to make sure that the project works perfectly because it is wrong to design a product and then ask industrial designers to take part at the end of the process just to make the product look good. It is essential for industrial designers to convey their contribution from the very start to the end of the project.

There are companies and organisations, which employ industrial designers to work with other professionals to produce excellent and satisfactory products. There are good examples of how industrial designers work together with other disciplines as we can see from what is happening to agricultural machinery and equipment products that have been produced by European countries, Britain, United States and Japan. Ahmad (1999, interview) absolutely believed that industrial designers have a role in agricultural machinery design. This was supported by Kasim (1999, interview) that if we think about producing agricultural machinery and equipment for the purpose of exporting then it is totally essential for industrial designers to put their contribution in this area.

As mentioned earlier, there are no more industrial designers involved directly with agricultural machinery. Most of the engineers in UPM (University Putra Malaysia) urged the involvement of industrial designers in this activity. For design factors such as safety, commercial value
and aesthetic value it is important to involve industrial designers if the government wants to see our agricultural machinery and equipment exported, not only for our market but also for world market. We can come out with a new tractor that can be used on soft soil. The existing tractor is too heavy, too big and too expensive for small and medium farmers.

Industrial designers it seems must involve themselves in the robust activities which have been neglected by most industrial designers because the factors that have be taken into design consideration are very huge. MARDI agricultural engineers have a different point of view related to the involvement of industrial designers in this area. They have neglected the importance of industrial designers in agricultural machinery design. They think it is wise for industrial designers to be involved at the last stage concentrating on how to commercialise the product.

"Industrial designers will come in only at the last stage of the design process for commercial purposes". (Seng, 1999, interview)

18 Malaysian respondents would like to see industrial designers having some knowledge of engineering so that their way of thinking during design projects will be the same, and thus avoid a lot of confusion between both disciplines. They agreed that industrial designers have a role but they have to show their capability to overcome some problem areas left by engineers especially in ergonomics, aesthetics and commercial value. It was said that 'we tend to leave aside these factors because we are trained to make the product work but not how to make the product saleable'. (Seng, 1999, interview)

"I believe and am confident that industrial designers have a role to play in this area especially in commercialising the product world wide and reducing the cost so that the users can afford to buy the machinery". (Othman, 1999, interview)

There are not as many Malaysian industrial designers as engineers and they are not as well recognised as engineers. It is well known that industrial designers know how to make the product look fantastic without looking at the functionality of the product. Although the number of industrial designers is small their impact is going to be very high if their skill and knowledge is used correctly. They have to create some sort of society, for example engineers have their own society which is IEM (Institute Engineering of Malaysia) as well as architects who have IAM (Institute Architect of Malaysia).

"I think this discipline is not well established. If they can set up an institute the same as Institute Engineering of Malaysia (IEM), I think many people will
open their eyes and will employ more designers in their company. May be 
one day we will become like Japan and some European countries, which can 
be proud of their products'. (Sharif Hassan, 1999, interview)

By this effort, the government will realise the importance of industrial design contribution 
towards improving products for globalisation, not only for consumer products but also capital 
products.

4.3.2.1 Findings of the UK survey

Industrial designers have a role and are becoming more and more important nowadays in 
aricultural machinery. They have knowledge, experience and skill to make something look 
good and feel more comfortable. By increasing their knowledge, they can ensure a product is 
economical, functions correctly and is maintainable. Industrial designers working in the 
companies are not artists, they design things for commercial gain and they make money for 
companies.

4.3.2.2 Findings of the Malaysian survey

There is a big role for industrial designers in this area because the product has to be 
marketed and must have a value on it. Much agricultural machinery and equipment, which 
we can see in the market that has been produced by agricultural manufacture, seems a little 
anomalous, similar to the prototypes carried out by R&D organisations and universities and 
not yet in production. The product is a result of straightforward application of science, 
mathematics and engineer and the same goes for the fabrication companies. Aesthetic 
value, ergonomics and other design elements that industrial designers know about have 
been left behind.

4.3.3 Level of involvement of ID in the design process stages

From the interview survey two types of view come across from the respondents, referring to 
the point raised by Dieter (refer to Figure 2.9), which are that industrial designers often have 
to come in when the design project is nearly finished. The other view is that industrial 
designers must be involved from the early stage of the design project as described by Hitam 
(1999, interview):

'Once an industrial designer is involved in conceptual stage then he has to 
follow through until the commercial stage... When you put the prototype into
test, you may change certain aspects, industrial designers have to look to make sure the change would not make any problem for the mechanism'.

Kilgour (1999, interview) stressed that design is not an easy task and it has to consider every aspect of design consideration. Designing agricultural machinery is the most challenging activity compared to other design activities. Everything has to be considered from the very beginning if the product is going to have a nice stylish shape. The total design will influence the cost, the manufacture, material and other design consideration to get the design perfect. All the aspects mentioned are important in designing and it has to be carried out from the beginning of the project. Leake (1999, interview) also urged that industrial designers have to get involved from the concept all the way through.

All the respondents from the UK believed that industrial designers have to be involved from the beginning. Also most of the respondents from Malaysia agreed that industrial designers have to be included from the earliest stages of design projects. This was said even though the majority of respondents are not involved themselves with other disciplines during design projects. Respondents from the UK were usually involved with other disciplines on most of the projects assigned to them because for them team effort is important in producing a successful end product, which can be marketed.

4.3.3.1 Findings of the UK survey

Both industrial designers and engineers agreed that industrial designers have to be involved from the beginning of the project, to consider all aspects of the design process from identified design need straight to production line. It is definitely wrong to design a product half way through and then engage another person to complete the work task. It is not right either for engineers or industrial designers to lead the project without interacting with each other because every aspect of the design characteristics has to be evaluated by both disciplines to produce excellent products.

4.3.3.2 Findings of the Malaysian survey

There are two categories of consideration within Malaysian respondents regarding the level of involvement of industrial designers in agricultural equipment design process stages. The respondents with no attachment with other disciplines believe that industrial designers can become involved at the end part of the design process to beautify the products. It is totally different when interviewing respondents who have experience of working with other disciplines. They would like to see industrial designers involved from the beginning of the projects because it is hard to ask somebody to start working in part of the process without
knowing what was going on before that. They have to work closely to produce acceptable and functional products.

4.3.4 Multi-disciplinary working in agricultural machinery design

Agricultural activities cover a very wide area in Malaysia. It is very unusual to find a company, institution or organisation that can produce satisfactory agricultural machinery products which satisfy the users. To solve this problem the companies need to develop the products by team efforts. If the company does not have the capability in certain areas, such as material selection, they should ask other which could provide them with sufficient input to make the project successful and occasionally they may ask the individual to participate full time in that particular project. It is so important to include different disciplines working as a team in producing agricultural machinery and equipment.

According to Evans (1998, interview), it is difficult for one person to cover everything in a design project because it is impossible for him or her to acquire all the knowledge related to design activities such as materials, ergonomics, production, safety etc. He is optimistic that the various disciplines have to integrate with each other to create a successful design product by the end of the day.

Garner (1998, interview) mentioned that if companies wanted their product to meet the user expectations, they have to involve more people with different knowledge and experiences at all stages in design project to guarantee that their product can be marketed and also can compete with other similar products. In designing agricultural machinery products every designer involved must understand various characteristics of the crops, also the type of soil and many others factors that the designers have to consider.

Multi-disciplinary involvement within a design team is essential where the project is very complex. Also for designing machinery which does not yet exist, for example harvesting oil palm fruits as in chapter 6, there may only be a few designers involved but they will need to refer to other specialists for further information. Leake (1999, interview) described that the disciplines normally involved in agricultural machinery and equipment design included structural engineers, mechanical engineers, industrial designers, production designers, manufacturing designers, purchasing people as well as marketing people. Designing agricultural products must be that way otherwise it will be very inefficient and costly to produce a product.

In the field of agricultural equipment multi-disciplinary project teams are the most productive compared to a limited number of disciplines in a design team. The different types of
professional have to provide their input all the way through from identifying the need to marketing the products. Swain (1998, interview) agreed with Leake; the productivity of the project will be more successful if the number of people involved in the project consists of several disciplines that can convey meaningful input to the team.

In designing a product, the choice of disciplines in a design team will depend on the type of design. Although it is essential to involve multi-disciplinary people, the time frame and the constraints that will occur during the project have to be considered. According to Hitarn (1999, interview), we have to make sure that the personnel in the design team are the right people who can deliver the work at the end of the day within a time frame agreed by all parties. If the project involves a bridge, for example, it has to involve the people from the mechanical sector and civil sector because the application is for the purpose of the road environment. For the agricultural sector, the best people are those with expertise in agricultural activities because it consists of many characteristics, from crops to production of the end product. Very wide areas have to be considered.

In general, all the respondents agreed that multi-disciplinary disciplines involved in design project are essential depending on the size of the project. If the project is small, it is enough to involve selected people in the team but if the project is massive such as agricultural machinery, it is necessary to involve several disciplines. Nowadays, big companies employ designers with different backgrounds. It was observed that the products produced by JCB and Smallfry in the UK were much better than the products produced by Malaysian companies such as Howard Alat Pertanian which have one or two designers.

The only problem raised by several respondents in involving multi-disciplines in a design team was the commitment of each individual if the project is managed by one institution or a department and required other disciplines from other places. The full-time team members should be committed but the others only when they are asked for their expert views to solve a problem. This is because it is quite difficult to involve sufficient people who are willing to spend their time and interest in the project because they often have other important things to do when they are asked to get involved. Multi-disciplinary teams will be more successful when the teams are in the same companies or same institution which have the same interest in pursuing the project.

4.3.4.1 Findings of the UK survey

It is essential to involve multi-disciplinary people in agricultural machinery and equipment design. It is not a one-man show. No matter how big the projects and how small the companies, to produce products, multi-disciplinary teams have to be involved.
4.3.4.2 Findings of the Malaysian survey

Multi-disciplinary involvement in agricultural machinery and equipment design is essential but at present Malaysia does not include many professional people in a design team. Malaysia still in the process of developing agricultural machinery and equipment activities. Several prototypes have been developed but there are many factors, which have to be considered before it can be introduced to farmers.

4.3.5 Importance of design methods in the design process

Design methods are procedures, techniques, and tools that help guide and facilitate design by making the design activities more organised and systematic. Below are the most common design methods used by designers today.

- QFD (Quality Function Deployment)
- Concurrent Engineering
- DFMA (Design for Manufacture and Assembly)
- FMEA (Failure Mode and Effect Analysis)
- Hierarchical Tree Structures
- Morphological Chart

Many design methods are available and an individual may choose whether to use them or make some modification to suit to them. All respondents from the UK mentioned that design methods are essential to everybody in pursuing a design project. They do not use specific design methods during a design project. The persons who had created their own design methods were Leake at JCB and May-Russell at SmallFry and they were quite confident that the methods they used in their work have shown some improvement in their way of handling design projects. Leake is the only industrial designer in the company and worked with quite large numbers of engineers to produce agricultural machinery products.

Design methods had usually been created by each company where the designers worked. The designers will follow the design method to make sure that the project assigned to them will come out with successful products. Some designers will have their own method acquired through their education and will try to merge these with methods from the company. It is quite different if we compare it to methods used in academia. They will use whichever method is suitable for the project (Garner 1998, interview).
‘You need a method... you can't put everything into your brain and solve it...
I would say that I would not like to follow one person's procedure or another person's procedure, pick out the best idea, developed it for my own method’.
(Kilgour, 1999, interview)

Design methods are very important. It does not matter whatever design method he or she used, the importance thing is that they have something to hold on. Designers have to tackle the main things at the beginning of design task before they can proceed with further design work.

The importance of the design method in the design process is crucial in the initial stage. Designers can set up their own design method to carry out the actual performance or requirement or in some instances the customer will offer their method but this can be avoided unless the designer is not sure that he or she can deliver what the customer wants. According to Tuan Muda (1999, interview) he feels that it is unnecessary to use one type of design method at one time. Design methods can be used in different ways according to the design project stages. He does not depend on one type of design method because he usually looks at the design phase and design structure first then he will co-operate with the method used. The idea of not focusing only on one method was supported by Ahmad (1999, interview) who mentioned that designers have to know which method is suitable to them to finish the project as quickly as possible with excellent design products. With the experiences that they have it is possible for them to come out with their own design methods or approaches which make their design project organised in a proper manner.

According to Majid (1999, interview) design methods are important in the design process. The design process is the whole idea of designing whatever products we want to produce. In the design process there must be a method used by individual or groups of designers in pursuing their product to the best. He believed design methods could make the design process become hard or easy depending on the method chosen by the designers. Hamzah (1999, interview) expressed his view by saying that the design method is the methodology used to produce the ideas. Actually there are lots of methods used but it depends on the nature of the product to be designed and at the same time it has to be inline with the customer's need. The design method has to be adjusted accordingly to the type of design project carried out.

The design method is very important because if the design process is carried out without design method then it lacks direction. At the end of the process, there must be a clear definition of what kind of product is required and for what purpose.
4.3.5.1 Findings of the UK survey

Designing agricultural machinery and equipment must have a system of project control. Methods were considered essential by all interviewees, but individual designers and companies tend to have their own approach and ways of working. Whatever design method is used depends on type of assignment given, and methods are often modified to suit a particular project or situation.

4.3.5.2 Findings of the Malaysian survey

Design methods are vital in every design activity especially in agricultural machinery design. Having a design method does not mean that designers are forced to follow every step, it is used to direct designers in the right path to success. Designers can switch from one design method to another depending on the nature of the projects.

4.3.6 Methods usually used in designing

There are many design methods nowadays to help overcome the difficulties of modern design problems. The method can be used at any stage in the design process from the beginning of the project, to identify the problem, to the end of the project. As mentioned, all the respondents agreed on the importance of having a design method for managing the design activities. Nevertheless when they were asked which design method they used in design project, no one is committed to any of the design methods available.

'At the moment we worked to a specification from the customer and we adapted our standard towards what the customer required. We control the design specification. Because time is very crucial and also pressure from the market, we have to work in the time frame that we have'. (Clapham, 1999, interview)

Most of the respondents from the UK do not have a specific design method that they use. They will use whatever methods they think can speed-up their design project and can optimise some of the requirements, cost, performance etc. Leake (1999, interview) usually starts his project by producing visuals from the existing machine. From here he may produce a full size mock-up depending on the type of project. Modification and changes occur all the way through and if the project is not very costly then a working prototype will be produced to examine the functionality, durability, reliability, safety and aesthetics. He will try to improve
his design method if he feels something has to be done at the beginning of the design activities to shorten the time taken. May-Russell (1999, interview) says that SmallFry have their own design methods and techniques for effective design which have been developed over a number of years though it is highly confidential. They 'bring together a broad range of considerations covering costs and manufacturability together with user based issues of perceived quality and customer benefits in ways which allow maximisation of the profitability of the final design'.

Most of the respondents from Malaysia mainly used 'a problem-solving methodology' mentioned by Dieter as described above. When they get a new assignment, first they will identify the problem and come out with some alternative proposals for improvement. All the information gathered helps them to identify the best solution, generating alternative solutions with minimum disadvantages to the machine. Prototypes are built to evaluate the machine. Evaluation of the prototype is carried out extensively especially in the field to gather all the information needed for better understanding to improve the product. From there the development of the machine continues to create a better version.

Designers from SIRIM, used several methods but the most used was CE to reduce the time frame between concept and model making or concept to prototyping. During the manufacturing stage they usually work together with their client. It is quite obvious design methods are used by industrial designers and engineers in this R&D institution. Kasim (1999, interview) mentioned that. They try to impose QFD but it is still under trial to see whether the time taken during a design project can be reduced dramatically. Industrial designers, Sulaiman (1999, interview) used 'value engineering' design methods to improve the product after identifying the weaknesses but the important thing in this method is that all the disciplines have to be in the design committee to identify the requirement from the clients.

Industrial designers from UiTM have a different point of view on design methods. They use the usual industrial design method (Figure 4.1) which is:

![Figure 4.1: UiTM design methods](image-url)
Every stage of the design method will be evaluated and if problems arise during design then iteration will happen to look back at what has been missed before the next step can be carried out. The method mentioned is just a basis and if the project encounters difficulties then the design method will be more complicated to suit to the project. The important thing that the designers have to be aware of is to make sure that the methods employed ensure that the design activities work faster and finished on time. Industrial designers at UiTM and at UTM are quite different in adapting design methods in their work because of the nature of the environment in which they work.

4.3.6.1 Findings of the UK survey

Industrial designers and engineering designers in the UK did not describe exactly the methods they usually use during design project. Leake from JCB and May-Russell from SmallFry use systematic methods. Unfortunately neither of them were prepared to share with the researcher the detail of their methods. There are new approaches which have proved to work well but are confidential.

4.3.6.2 Findings of the Malaysian survey

Malaysian designers can be classified into two categories. Firstly industrial designers working among other disciplines who tend to impose engineering methods in their work. Secondly designers who spend most of their time working among their ID colleagues. These normally used what they called basic industrial design as shown in Figure 4.1.

4.3.7 The crucial stages in designing

Design activities most probably will come to a problem where most of the time taken is wasted at this particular stage. It can happen in any stage during the design process from identification of the problem to marketing the products. That is why the importance of having a design method is to manage the activity in a successful manner. The stages have to be monitored carefully and precisely to avoid any unnecessary incident happening during design activities, which will drag out the design project to take more time to finish it. In designing, problems will arise, the point is whether it is a major problem or just a minor one. If it is a major one and the designers notice from the beginning then it would not be such a disaster but if the designers ignore it or miscalculate certain area and later the problem will arise at the end of the project, then it will create a major disaster.

As mentioned, the crucial stages in designing can be from the beginning to the end of the project. Clapham (1999, interview) mentioned that the main problem which he usually
encountered in designing was to get sufficient information and on the assembly line where the worked is carried out in a limited quantity and mistakes have to be avoided. Ashley (1999, interview) who has direct involvement with designing agricultural machinery stressed that the manufacturing capability is the most challenging area in producing agricultural machinery where every single part in each section has to identify accurately during assembly of those parts within the production line.

According to Kilgour (1999, interview) the designer has to be familiar with type of soil, and type of crops where the machine is going to be used.

You have to know a lot about soil in order to design the equipment to work on soil. You also have to know quite a lot about the crops and their characteristics in order to make the machine work.

Different types of product have different degrees of risk. A 'new-to-the-world' design will clearly carry more risk than an incremental design. Development of a brand new product is scary. (May-Russell, 1999, interview)

The effectiveness of the product, cost effectiveness, test effectiveness, reliability can cause a lot of problems during designing agricultural machinery and equipment. All these have to be put together in order to minimise the risk during design activities. In order to minimise the crucial stages during design project carried out, the designers have to tackle the actual problem by understanding the whole process of the design activities.

The major thing that I discovered during my design project is to construct the 'prime mover' (combination most of the work task could be operated within one machine). These are unavailable in the market so I have to start from nothing... After searching locally and globally, there isn't a 'prime mover' available. Designing a ‘prime mover’ is a crucial stage for me. (Yahya, 1999, interview)

Ahmad (1999, interview) supported what has been mentioned by Clapham that lack of information will cause a lot of problems in conveying the design project. The difficulties in designing agricultural equipment are that the designers have to collect the information in the field from the users because this type of information is not compiled or stored by anyone.

According to Hitam (1999, interview) from his experiences sometimes, when building up the prototype for field testing and other evaluation processes, the cost will rise up to 3 times more expensive than the commercial value was supposed to be. Materials become the most
crucial stage in pursuing a design project (Noor 1999, Interview). The materials have been
decided for certain parts of the machinery but during fabrication the chosen material could
not be found in the country and had to be ordered from abroad. This situation has taken a lot
of time to get the exact material and the cost is quite expensive. The problem arises because
Malaysia does not have complete component or material catalogues for designers’ use.

The crucial stages in designing agricultural machinery and equipment are different from one
respondent to another and may be from the start of the design project to the end. It depends
on how designers interpreted their problem.

4.3.7.1 Findings of the UK survey

Respondents from the UK have put into several categories the crucial stage in designing
agricultural machinery and equipment product, which are:

a. Understanding the functionality of each part on the machine and how reliable was the
machinery.
b. Getting information on all aspects of the design project.
c. Understanding soil and crop characteristics before engaging with the design project.
d. In designing agricultural machinery, understanding how the product is going to be
manufactured and the ability of the production line.

4.3.7.2 Findings of the Malaysian survey

The biggest problem in agricultural engineering design is the range of conditions that have to
be considered. Malaysia has different types of land and it differs between one state to
another although it is not quite obvious. Weather changes dramatically and this creates
disaster to the machine when performing the work task. This is the criterion that makes it
very hard to design good machine. The crucial stages in designing agricultural machinery
varied from one respondent to another. However all agreed that the early stages of
understanding the work environment and the user requirements are crucial.

4.3.8 Design element priority in agricultural machinery design

One of the important design elements in the design process is human factors. A successful
design must satisfy many requirements other than functionality, appearance, and cost.
Human factors is one of the important requirements in design. Human factors is a study of
the interactions between people, products and systems they use and the environment.
Human factors expertise can be found in industrial designers and engineers which both of
these professions focus on different usage. Industrial designers concentrate on the comfortable use of the product and engineers emphasise the design of a production system for productivity and freedom from accidents.

The other design element in agricultural activity is how to make sure that the product is saleable. To guarantee the products saleability is very hard for the designers. It only can happen when a product can satisfy the need of the users. To convince users whether the product is good or bad design, we can characterise a product under good design and bad design. A product which has good design will be considered if it fulfils these criteria which are:

- Works all the time.
- Meets all technical requirements
- Meets cost requirements
- Requires little or no maintenance
- Is safe
- Creates no ethical dilemma (Bajuri, Hitam, Kamaruzaman, Kasim and San, 1999, interview).

A product can be categorised as a bad design when it does not meet the above requirements and it:

- Works initially, but stops working after a short time
- Meets only some technical requirements
- Costs more than existing product
- Requires frequent maintenance
- Poses a hazard to the user
- Fulfils a need that is questionable

The buyers will judge the worthiness of the products based on the considerations mentioned above.

Design elements are various and one of the priority given in designing agricultural machinery was power transmission where the machine has to undergo aggressive environments wet, cold, hot, dry and a wide range of other conditions which have to be satisfied. There are no specific design elements that can be considered as a major priority in designing agricultural machinery. This is more or less the same as what we can observe from section 4.3.9 where there are no specific stages identified as the most crucial stage in designing agricultural machinery.
4.3.8.1 Findings of the UK survey

Generally when designing agricultural machinery and equipment, we cannot identify which element has to have priority because each element has its own speciality and every design element has to be treated fairly in order to produce excellent products.

4.3.8.2 Findings of the Malaysian survey

Malaysian industrial designers, agricultural engineers and engineers do not limit themselves in establishing certain design elements as a priority in designing agricultural machinery. Design elements will be listed before any design activities take place. All those listed will become their guideline but without constraining the designers, the Malaysian designers do not put any design element as having the greatest the highest priority because everything has to be incorporated while working on the design projects.

4.3.9 Skills required by Industrial Designers

Industrial designers must have technical knowledge because they cannot get involved straightaway in the project such as agricultural machinery design. They have to know the function and also know what are the characteristics of the materials used. Industrial designers obviously cannot focus on appearance without understanding the functionality of each of the components on the machine.

Industrial designers must equip themselves with engineering background. Industrial designers with a good engineering background can appreciate the methods of manufacturing, production, assembly and maintenance as well as operating the machinery.

'...good basic education in engineering and good basic education in management and economics are essential to have the best solution in design practice...You can think of best idea by looking around and without having good basic knowledge, you wouldn't be able to interact with other engineers in a consistent manner'. (Kilgour, 1999, interview)

'I think as far as agricultural machinery design is concerned, industrial designers have to focus on the aesthetic and human factors aspects. They should be very skilled in that, they should more sensitive toward aesthetics'. (Hamzah, 1999, interview)
Chapter Four

Every Malaysian industrial designer should know how the engineering principles work. Without these skills a lot of debate and argument will be created among designers because one will tend to say that their idea is the best. Industrial designers can fix themselves anywhere and can work within other disciplines as long as they have the skill, the knowledge and the intelligence to work in this area.

4.3.9.1 Findings of the UK survey

Industrial designers who would like to be involved in agricultural machinery and equipment design have to have basic engineering and good basics in management and economics. They have to equip themselves in understanding method of manufacturing to keep the cost down, various skills during production stage, assembly stage and maintenance capability. The skills required so that industrial designer can interact within different disciplines in design team.

4.3.9.2 Findings of the Malaysian survey

Every agricultural engineer and engineer suggested that industrial designers who want to get involved in agricultural machinery design activities must have or must equip themselves with basic engineering knowledge. Without this knowledge it is hard for them to get along with the engineers and the success of the project will be questionable. Industrial designers are urged to strengthen the skills that they have, especially aesthetics and human factors in order to be involved in this area.

4.3.10 Drawing capability for designers

Drawings are the most helpful form of communication. Drawings are very good at conveying an understanding of what the product has to look like and it is essential to the designers and manufacturers who have to produce the end products. Drawing is a way of showing our design to other people, giving clear information of how the actual product is supposed to look at the end of the day. Drawings also help designers to visualise certain ideas quite clearly. Designers need to have drawing capability no matter whether he or she is an industrial designer, engineer or agricultural engineer.

There are no excuses for industrial designers not to be good in drawing because they are trained to have that skill. Drawings contain document functionality, features, sizes, colour, surface finishes, and critical dimensions. This drawing is not a detail drawing such as production drawing suitable for manufacture of the components but it is a drawing which gives a total view of the actual product and it is a reference for other designers.
Designers need to have the skill to draw because they cannot design without having this skill. Although there are methods and procedures in producing drawings using computers, designers still have to acquire drawing skills. There will be a great problem for designers without having this skill in terms of expressing their ideas on paper or on the computer screen to let other people see what come from his or her mind. Drawing is essential because designers have to draw to design.

‘Drawing capability for designers is important although the skill of drawing is becoming less and less because they moved to the advantages of using computers... there are certain skills which can’t be done by simulation through computer. So those are the advantage of doing sketches manually nothing could beat the satisfaction of doing sketches manually’. (Bajuri, 1999, interview)

It is useful to every designer because they can visualise what they think and come out with several concept ideas. From there it can proceed on developing to fulfil the needs of their management or of their clients. Engineers should have drawing capability to communicate easily because sometimes it is difficult to communicate verbally, drawing is much better than words. Drawing skill is important because ideas have to be transferred from imagination to paper, it is quite difficult for designers to generate ideas and come out with successful product without it.

‘Designers must have this drawing capability. To become a designer, first he or she must be good in sketching, second must have creativity, and understand the present technology for example CAD drawing and so on’. (Yahya, 1999, interview)

The importance of having this skill is that the designers can have a very meaningful discussion amongst themselves, without this it is quite impossible for them to comment and suggest improvements on the design.

‘I think it is quite crucial. If you have good skill then you will be able to draw something, which you actually have in your mind. If you can convert whatever in your mind onto paper or computer, that is excellent. What ever is in their mind is only a temporary image, if they can capture that temporary image onto something then that will allow him or her to modify even better’. (San, 1999, interview)
Every designer must know basic drawing so that they can interpret very clearly and precisely the information that they want others to understand from their drawing. We can see the importance of having drawing skill for each designer to assist discussion among designers, management, with clients and other disciplines involved in the project team to give ideas for further development to achieve successful and satisfactory end products. Communication of a design begins with the drawing and good layouts need to be drawn to enable further development to gain success.

4.3.10.1 Findings of the UK survey

This skill is essential for all designers. Without this skill it is quite impossible for designers to communicate efficiently with whomever they interact. It is quite difficult to make everybody understand what is being explained to them on certain aspects or ideas without any sketches or drawings in front of them.

4.3.10.2 Findings of the Malaysian survey

Every respondent agreed that drawing capability is essential for every designer especially for agricultural engineers and engineers. Some designers do not have good drawing skills and it is very difficult for them to describe the image that they have in their minds on paper, and it is quite difficult to explain and communicate with others in conveying their ideas. It is time for engineers to take a step ahead by absorbing this skill to enhance future design in producing competitive agricultural machinery and equipment.

4.3.11 Communication in Design

May-Russell, (1999, interview) stressed that communication is very important in any design activities because designers and other disciplines must be able to communicate at all levels in the organisation.

'Good communication is absolutely vital... it is very difficult to communicate with financial people, management people etc. unless you have good communication skill'. (Kilgour, 1999, interview)

Communication skill is a must for each designer especially industrial designers and agricultural engineers. These two disciplines have to learn to communicate with each other if they work in the same design team. As we know these disciplines are totally different and they have to understand the language to allow the project to run smoothly. Although Malaysian industrial designers are totally new if they want to be involved in agricultural
machinery design then they have to equip themselves with all the requirement needed and one of the requirements is communication.

Communication is not only between industrial designers and agricultural engineers but also with other disciplines or professionals. Communication is very global. Communication with marketing, production engineers, and financing people is the main factor that makes a product successful. If you have good idea and financial people don't understand the idea given, the project will not be supported and it will collapse. The ability to communicate in financial language and the ability to communicate with the marketing people is very important. Industrial designers cannot just design, they have to be inter-disciplinary people.

4.3.11.1 Findings of the UK survey

Communication is vital in design activities and most importantly with clients. Our clients put their money into the project. Designers must be able to speak to people at all levels, without good communication it is hard for everybody to do their job.

4.3.11.2 Findings of the Malaysian survey

Good communication by designers is vital. Without it projects have been seen to become a disaster to certain people. A designer may have excellent ideas and be confident that the products will be saleable but if he can't communicate efficiently with marketing, financiers or entrepreneur, he will be frustrated. Communication by designers has to be considered important to produce successful design work.

4.3.12 Involvement of users or clients in design projects

Users' visual perceptions of the quality of a product are based entirely on surface information (May-Russell, 1999, interview). Therefore surface quality is of principal importance. It is difficult to differentiate between customer's needs, musts and wants. Satisfying users is the most important factor. Users may be different from one another in terms of their expectations of the product. On some occasions the users know what they want, then the designer has to accept their ideas, if the designers think that the user's ideas are not appropriate then he has to convince the users to consider his ideas.

Involvement from the customers is quite essential and can be categorised into two:

a. customers who financed the design project
b. customers who are the potential buyer for the product
In category 'a', designers should consider the customer all the time because he is paying for the design work and should be involved from the start. By right he has to be involved. Those in category 'b' are the customers that somehow or another are going to use or buy our product. These customers are sometimes important to us during design. We can involve them by asking them to try our product during field tests on the prototype. We can get information from the market survey on the products which they feel are necessary for them to speed-up their work and help to avoid injury while carrying out the work tasks in the plantation. There are several ways the customers or users can take part in the design activities.

'If you worked on accepted project with your customer, as soon as you get input from them, obviously the basic specification does need fleshing out, you do need detail discussions with the customer... You do need to talk as early as possible because that effects the initial scheme'. (Clapham, 1999, interview)

Our users are important to all designers, companies and organisations. The 'customers always right' but how far they should contribute in the design project depends on the situation as mentioned above.

Customers may be involved in design projects occasionally or they can participate for the whole project. It is wise to involve them in some stages, for example if we want their decision in choosing which concept they prefer. They may also be involved during development stages because if they are going to produce the product, they have appropriate production experience. Users commitment during the prototype stage can be valuable when they can observe themselves and it may be necessary to ask them to test it in the laboratory or in the field. Their inputs are essential at this stage because they can comment and give meaningful feedback for further modification before proceeding to production.

'I think it is very important to involve your client but you should not involve them from the beginning because people might steal your idea and go to different people. It is important to associate yourselves with the client but I think there must be some secret issues which you keep to yourselves because clients are very unpredictable'. (Bajuri, 1999, interview)

It is quite different if we look at R&D institutions and universities, which have designed agricultural equipment. They are aware that something has to be done to overcome certain problems in the agricultural industries. They requested a grant from the government to carry
out investigations and produce a solution, for example producing a working prototype. The grant is known as Intensification of Research in Priority Areas (IRPA) scheme.

'At PORIM we have an advisory committee program. If we want to carry out a design project, we have to get approval from this committee because they will decide whether this project is suitable for industry or not... To get an idea for a design project, sometimes it comes from the estate management, from the manufacturer, and sometimes from us'. (Yusof, 1999, interview)

Users or clients can contribute their ideas at the beginning of the project by giving all the input related to the project. As mentioned earlier it is different dependent on whether the client is the one who is going to produce the product or the one who is going to use it. We can involve them in stages during design projects but not at all times because they may disturb our thinking in producing and solving the design problem. Clients usually know what they want the machine to do. Normally they want it simple, cheap but must be comfortable.

4.3.12.1 Findings of the UK survey

In projects financed by clients it is necessary to involve them in the project. What is the limitation of their involvement depends on their knowledge about the projects. Designers have to involve them as soon as possible because information is essential to success. If the project is based on management decision then involvement from users depend on stages of the design process.

4.3.12.2 Findings of the Malaysian survey

Contribution and involvement of users or clients in design projects can be classified into two stages. Firstly if the client is our potential investor, the involvement has to be straight from the beginning of the project because he knows what he wants from us. In the second case the designers should decide which stage to involve them, normally testing the prototype because they are the ones who will use the machinery.

4.3.13 Involvement of marketing in designing

Marketing people have direct contact with customers and users. They normally organised market surveys to predict whether the product can be successful, and how customers perceive the new product in the market. What is the expected product the customers would like if the product were going to be marketed? Marketing people know who they are aiming for and what are the reasonable quantities to be produced within a year and when should the
product be ready to be launched into the market. Marketing people are essential to be involved in the design team, particularly if the products are for global markets. In the UK’s agricultural machinery industries, marketing departments play a vital role in the design team because many of the products are marketed globally.

It is essential that the designers know which way the market is going in order to plan for new products. Designers need to have a close relationship with the marketing department to know the situation out there. It is quite convenient when designers work in a big company which have marketing department. The information gathered from the users is essential to the designers if they are to produce what the market would like.

'Good marketing will start early....European countries and Japan are doing that, they invested million of dollars to make just marketing. Another thing they do marketing when everything has finished is advertise the product'. (Bajuri, 1999, interview)

Involvement from marketing people can be categorised into two different situations in agricultural machinery and equipment industries, which are:

a. The UK context where it is feasible because most of the products are internationally marketed.

b. The Malaysian context, which is still developing for their own need to fulfil the small and medium scale farmer’s requirement.
4.3.13.1 Findings of the UK survey

We have to know how the product is going to penetrate the markets, and people in touch with this situation are from marketing. They know who to aim for using the product and how many quantities in a year the company can sell. Marketing people talk with users and they sometimes know what users want to be on the machinery that is going to be designed.

4.3.13.2 Findings of the Malaysian survey

Marketing people become involved when there is no information relating to the project. Usually big companies which have a big investment will assign marketing people to the design team. They would like to know whether the product could make any profit for the company. Malaysia doesn't export machinery globally because at the moment agricultural
machinery is still in the development stage, although there are several small machines produced by private manufacturers for local market.

4.3.14 The significance of verbal and visual communication in design

According to Hamzah (1999, interview) he thinks that both verbal and visual communication are important in their own ways. Industrial designers are good at presenting ideas visually so drawing is very important. After being in the design profession for quite some time, he realises that computer aids are now becoming essential for industrial designers but manual skill in drawing is still important when we talked about producing fast sketches to communicate with others, especially those not in the design office. He absolutely believed that verbal and visual communication are equally important.

Several engineers who often communicate with farmers believed that verbal communication is the important type of interaction. They usually go into the plantation and discuss a lot with farmers to hear the problems they are facing in everyday life while carrying out the work task. The engineers recorded and evaluated it, to help to come out with several alternatives and to choose the outstanding design to build a prototype for field-testing. Their experiences when the farmers were shown a sketch and model of the product that will help them later in the plantation showed that they couldn't appreciate them because they couldn't feel and would like to test a machine in the real environment.

Verbal and visual communication were regarded as equally important in design activities. The effectiveness depends on how they are interpreted. Designers have to explain their design concept or design proposal so both, visual and verbal have to complement each other to make everybody in the design team understand and allow everybody to contribute for the sake of further development. Nowadays, the world is becoming smaller, now computers enable interaction throughout the world. Designers can communicate with other designers on the other side of the world to gain information, through either visual or verbal communication.

4.3.14.1 Findings of the UK survey

Designers from the UK stressed that visual communication in design is more significant compared to verbal communication. It is important in terms of getting ideas from the people we are interacting with. Nowadays computers play a vital role in getting ideas and make communication more convenient.
4.3.14.2 Findings of the Malaysian survey

Industrial designers and agricultural designers described that both verbal and visual communication are equally important. It is vital for designers to communicate within themselves and also with management people to get their approval to proceed with a project. In Malaysia environment because the designing of agricultural machinery is carried out as a research activity then approval from top management people is vital. Verbal and visual communication has to be excellent to convince them of the value of the project.

4.3.15 The Importance of prototyping in design

The designer’s responsibility is to produce the prototype from which all the units to be offered to the users or consumers. A prototype normally will be built after approaching detail design stages with the purpose of test and evaluation before it can be produced. It is also to reduce the risk incurred in putting it into full production.

Building, testing and modifying a prototype is expensive but it is essential in designing agricultural products. Leake (1999, personal communication) mentioned that it is good practice to build-up several numbers of mock-ups and models for different aspects of the design to see whether the system works as we expected. When we are confident in every mechanism that we have tested then we can build a full-scale prototype for deeper evaluation.

The prototype on some occasions can also be used as a pattern for production tooling to manufacture the part by any medium of production methods. Prototypes are almost essential when the problems to be resolved are ergonomic, understanding the methods of building the actual product, and can decide what are the appropriate materials used. It is valuable to the designers, users and those responsible for manufacturing processes in deciding what has to be done and what has to be changed.

‘Prototypes are absolutely essential for agricultural machinery design activities because there are so many variables you can’t predict, for example soil condition, crops and animals... You have to test it to verify certain aspects by doing field test...Lots of farm industries don’t have prototypes, they make a plough, they test it and that also becomes a final version and they start doing production. That test was the original one and it will be sold’. (Kilgour, 1999, interview)
Doing a field test is the most effective way to collect data and find any faults on the prototype. Usually there will be minor modification to be carried out to perfect the machine. Designers cannot entirely predict what will happen in the actual environment. As mentioned, agricultural activities occur in a very rough and complex environment.

Without prototypes, it is impossible for designers to see all the problems which may occur. There will be changing or modification while testing is going on until it comes to a stage where everybody is satisfied. Prototyping was considered essential by the designers but in reality it depends on the companies whether it is done or not.

4.3.15.1 Findings of the UK survey

Designing agricultural machinery is considered to be very tough work with a lot of parameters to be considered because the machinery is designed to suit rough conditions. The machinery has to be tough. To get perfect machinery lots of experiments have to be carried out and this is best done using prototypes. Testing can be done to see the weakness before it goes to production but in practice the prototype is often sold as the first product and is not available for extended trials.

4.3.15.2 Findings of the Malaysian survey

Malaysian agricultural engineers are at the stage of trying their first products. Prototypes play a major role in producing the information needed to overcome the unpredictable problems occurring during design projects. Mechanisms have to be tested to see the overall movement on the machinery, but more than this prototyping is proving a rich source of information to the designers for future development to success.

4.3.16 The Importance of physical models in design activities

Physical modelling techniques offer valuable support to the design process because of the wide range of information they provide in a single entity, compared with a number of drawings or sketches. Physical models are an important part of the development and can be used to do many important things within design process such as study the ergonomics, proportion, colour etc. and can be adjusted for better modification of the product. Models can be used for better communication within designers in design team and also with their clients.

Physical model shows that it can be derived from conceptual sketches, development ideas and right through to the prototype stage. The increasing complexity, completeness, and cost become major issues if building up the model progress from proof of concept to prototype.
Designers can produce physical model for whichever stages they feel necessary for them to see the form and test the mechanism that can be done within their expectation. Usually a physical model will be less than a full size model or static model.

The making of models has been approached in many R&D institutions and also big companies with a lot of investment on each of the products they wanted to produce. Designers use models for thinking, communication, predicting, controlling, and training. A model is used as an aid to visualising and thinking about the problem.

Physical models were agreed to be important in conducting design activities. The faster we can produce the model the faster the designers have ideas to progress the work task. Although making a model takes some time, especially if the models have to be accurate, the outcome in generating ideas are worth it to the designers. There are also disadvantages of a physical model:

'A physical model is difficult to make, it's expensive, takes some time to build, and is difficult to change ... If your client would like to have some changes on the design and would like to see how it looks on the model then you have to ask for excuses to produce another model, it is not good for business'. (Kilgour, 1999, interview)

Physical models, although essential for certain aspects, also have limitations. A physical model couldn't be changed because it is rigid, unlike on the computer where you can change things instantly as required and it can be rotated 360°. There was no argument about the importance of models for certain designers. Other designers said that they preferred to work on the computer before deciding to produce a physical model. Using a computer at early stages can speed up their design activities and producing a physical model would allow them to evaluate certain aspects which couldn't be solved through the computer.

4.3.16.1 Findings of the UK survey

Physical models can give lots of ideas for designers to proceed with further development. Constructing a physical model can help a lot but of course this method requires a lot of time. However it is worthwhile to avoid a lot of time spent at the prototype stage to see all the problems.
4.3.16.2 Findings of the Malaysian survey

There are differences in the use of physical models in design activities. The ones who had been taught during their studies that physical models help a lot in developing ideas will make this their way in design activities. The others were not interested because they believed it made their work more complicated and building a mock-up or scale model will take a lot of their time. Several engineers preferred using computer modelling before producing a physical model for future evaluation that cannot be generated by computer.

4.3.17 The significant differences between 2D and 3D communication in design

Three-dimensional representations are important in communication if the design concept is quite complicated. Two-dimensional formats can include sketches, photographs, maps or engineering drawings. Communication using 2D and 3D material is valuable especially when discussion takes place during conceptual design. Some people in the design team such as marketing people, users as well as management people can’t imagine how the machine or equipment will look if designers do not show it to them in a form of 2D or 3D material.

Designs for agricultural equipment often consist of a lot of moving parts and if we compare 2D and 3D drawing during communication in design, 3D can make more sense than 2D.

‘...because we used to design working machines with a lot of moving mechanisms, that made 3D the best solution. I did a lot of 3D drawing compared to 2D, mock-ups and scale models to look at the mechanism aspect and movement devices’. (Yusof, 1999, interview)

3D drawing is quite magnificent if it can be produced at the early stage during conceptual sketches because definitely you can see from three angles, although it is in a form of 2 dimensional drawing. People understand 3D drawings more easily. If we talked about 3D physical models then we have to refer back to the discussion in section 4.3.16.

‘...in this modern situation, computer simulation is the way forward. You can design in 3D, you can render it as what you want it to be, you can make it look very realistic. You can make changes to it whenever you like’. (Kilgour, 1999, interview)

The designers can visualise 3D images in their head very easily compared to 2D drawing. Many people as described earlier don’t have the capability to visualise in 3D because they are not trained as designers are. Sometimes industrial designers do not understand a
drawing when it is shown to them in the form of complicated engineering drawing. By having 3D drawings, they really can work together in a team, otherwise the engineers have to struggle explaining what the drawing is all about. It is an advantage if designers can use 3D drawing computer software, to show to others what they want the product to look like.

Whatever methods designers use in conveying their ideas, the important thing is with whom they are dealing. If the interaction is between engineers, agricultural engineers and industrial designers, there will be less difficulty in terms of communication because each discipline should understand each other. Industrial designers already make themselves familiar with methods and processes which the engineers usually use in design projects. Communication with other disciplines has to be considered by observing or investigating the people that designers have to face, and sometimes designers have to prepare all sorts of visual aids to make them understand what the discussion is all about.

4.3.17.1 Findings of the UK survey

2D and 3D material are relatively important. In terms of drawing, 3D drawing will give more impact to the viewers. 3D drawing is more understandable and quite a number of people favour it. Communication using 3D material, especially using a physical model, is more meaningful because everybody can feel, touch and rotate it although it is quite expensive but not for a big company because it is one type of investment.

4.3.17.2 Findings of the Malaysian survey

It does depend on the occasion. If communication is within the design team, 2D is sufficient to start with and to develop the ideas. Eventually most respondents would agree that 3D is superior to 2D in terms of better understanding and better communication with different disciplines whether in the design team or not. It is quite different if we talked about 3D drawing and 3D physical model because each has its own specialities, advantages and disadvantages.

4.3.18 The future in designing agricultural equipment in Malaysia

The future of industrial designers involved in designing agricultural machinery especially in the UK is already established. We can see the industrial designer's handiwork in agricultural machinery produced by JCB. Leake (1999, interview) is optimistic that industrial designers' role in this industry will be on a par with the truck industry. There is no argument on involvement of industrial designers in other fields such as motor industries and other consumer products industries. This type of design activity is very robust work which is why
only a few industrial designers work in this industry. He also believed that the increase in employing industrial designers in agricultural machinery industries would expand and improve gradually.

Industrial designers and engineers in the UK agreed with Leake that the future of industrial designers is becoming important in these industries. Although small companies will not be able to employ industrial designers, there will be a place for industrial designers to engage in these activities through consultancy or their own design companies as has been done by SmallFry. They have different disciplines of designers in the company ready to take the challenge and produce design proposals and prototypes to fulfil the requirement of their clients (May-Russell, 1999, interview)

Unanimously all of the interviewees stressed that industrial designers have to equip themselves with basic engineering knowledge to be able to communicate with engineers in the same language. They have to make themselves excellent in the skills they already have such as good visualisation, human factors, and aesthetics. Form, shape, colour, balance, structure and texture were said to be among the many elements that could be incorporated with the input of agricultural engineers to take the challenge. It was agreed that good cooperation between these discipline could make the UK agricultural equipment industries become one of the biggest exporters.

From the interviews conducted with Malaysian respondents, it was established that in order for industrial designers to get involved in agricultural equipment design, they have to prepare themselves for this environment which is uncomfortable compared to other design activities. They have to be exposed to current machinery and equipment design as other consumer product designers do. When assigned a design project, they can usually have the entire related product in their hand to evaluate the advantages and disadvantages of those products.

Malaysia is in the process of taking up the challenge to become one of the countries that can produce agricultural machinery and equipment for local use as well as within the regions. Malaysia has a number of special plantations, which can be found in several countries such as oil palm trees, rubber, cocoa and paddy. These countries are looking at what Malaysia has designed for these crops. Malaysia has produced its own cars and motorcycles, it is now for Malaysia to take the opportunity to produce agricultural machinery and equipment products.
4.3.18.1 Findings of the UK survey

Industrial designers in Malaysia have to take all the challenges that have been experienced by industrial designers in the UK, especially obtaining basic knowledge of engineering and understanding the environment where the machinery would perform the work task. It is not a very simple task compared to other design activities where designers spend a lot of time in their design office. In agriculture, designers have to communicate with a lot of people to gain information and to understand the limitations that occur during use, manufacturing and on the production line.

4.3.18.2 Findings of the Malaysian survey

The government has to focus on this industry and try to make it one of the industries that can generate income for the country. Since the 1970s, Malaysia has produced quite a number of industrial designers, though their capability is not fully utilised. They can get involved in agricultural machinery and equipment designs activities if there are spaces for them although they have to push themselves toward this. UTM has made a drastic move in introducing basic engineering and management knowledge to their industrial design students to take the challenge of allowing them to work closely with engineers and so have better communication with other disciplines for future success in every design aspect.

4.4 The UK and Malaysian Qualitative Findings

From the qualitative studies, it was established that the involvement of industrial designers in the agricultural design process needs to be from the earliest stages because it is quite difficult to ask designers to become involved after half way through. Problems would occur because evaluation at each stage in the design process should incorporate all the disciplines involved from the beginning. That is why both disciplines have to have a good relationship and a good understanding and one cannot claim that their ideas are better than the others.

It is understood that engineering designers' work is more structured than that of industrial designers. A need for a more structured approach has been identified and therefore the researcher has produced a design guideline for industrial designers to be able to follow the design process systematically as discussed in Chapter 7.

Industrial designers would be required to gain appropriate skills especially engineering knowledge if they would like to be involved in this activity, especially Malaysian industrial designers because they are not as well exposed to engineering as the UK's industrial
designers. They have to have basic engineering knowledge to enable them to have good interaction and have the same way of thinking during design activities.

The power and importance of visual communication was stressed frequently in the interviews. It has been stated that industrial designers have good drawing skills. Using 2D drawing and 3D material has proven the effectiveness in good communication within designers and other disciplines. The findings have shown the similarities between both countries about the preference of involving clients and marketing people in the design projects, and use of visual media is essential for communicating with these parties.

It was made clear that it must be assumed that many of the people outside the design team cannot read engineering drawings or understand technical issues in any depth, so the form in which the design information exists at any stage is crucial to communication. Industrial designers have highly developed skills in communicating design ideas and proposals; hand renderings are a fast and powerful form of visual communication, and CAD output is useful, especially 3-dimensional modelling. Both countries also agreed that physical models are essential because they provide a lot of information to proceed with further development.

Similarities were identified on the importance of prototyping in agricultural design from both countries, from both engineers and industrial designers' points of view. Production volumes are relatively low for many agricultural products, and therefore proprietary components and subsystems are used, e.g. bearings, wheels, motors, hydraulics etc. Large investment is not usual. This means that available technology must be used and long development programmes are seldom possible. Prototypes are often sold once they are seen to work. Therefore the conceptual design phase is crucially important, and successful design depends as much on imagination and ingenuity as on technology.

The findings from these two countries discussed in this chapter have shown evidence that industrial designers have a role and potential contribution in designing agricultural equipment, especially for the Malaysian context.

4.5 Summary

Designing agricultural machinery and equipment is a complex design activity and very high effort is needed from the designers to come out with a product which can perform the work in a very sophisticated condition. A wide range of design criteria have to be considered to
achieve the requirements that allow the machinery to adapt to the type of conditions which are unpredictable, especially in Malaysia.

The qualitative survey, was focused on interviews. The UK interviews were held with agricultural engineers, mechanical engineers and industrial designers who are involved directly with agricultural machinery design. The respondents from Malaysia consist of agricultural engineers, mechanical engineers, and industrial designers, who have some experience designing agricultural machinery and equipment. The interviews have fulfilled three of the aims and objectives of this research which are to:

- study the design process implemented in the field of agricultural machinery,
- study the role of industrial design in the agricultural machinery industry, and
- identify the type of design approach most suitable for agricultural machinery.

The results from the interviews also helped to answer some of the questions which have been designed to strengthen the research aims and objectives. These are to determine:

- the differences in design processes used between the UK and Malaysian designers.
- the level of acceptance of industrial design in this area.
- factors influencing agricultural machinery design.
- approaches suitable for use in designing agricultural machinery.
- how might design best be managed.

The interview results were analysed using 'content analysis' methods, which used themes as a means to identify the outcome from the respondent’s points of view. The results have been divided into two which are the UK findings and the Malaysian findings. Chapter 6 will also verify the first three aims and objectives of the research to assess the role and potential contribution of industrial designers in the field of agricultural machinery.

Based on the overall findings from interview survey, it can be concluded that industrial designers could play a significant role and contribute their knowledge, skills and capability in designing agricultural machinery and equipment for Malaysia and for similar countries.
CHAPTER FIVE

The UK and Malaysian Quantitative Survey (Questionnaire)

5.1 Introduction

This chapter reports the quantitative findings of a survey carried out in the UK and Malaysia. They are discussed and analysed based on the stipulated aims and objectives to address the main research question in 1.8.1 and further research questions in 1.8.2. The findings from both countries will then be used to support the development of design guidelines for Malaysia.

This chapter has been divided into the following sections. Section 5.3 illustrates the nature of the quantitative survey consisting of postal questionnaires distributed in the UK and Malaysia. It also discusses the analysis package used and describes the method of analysing the data, concentrating on frequencies, descriptive analyses and a crosstabulation procedures to establish differences and similarities between UK and Malaysian industrial designers and engineering designers.

Section 5.4 provides detailed analyses of the results of the study. Survey results for UK industrial designers and engineering designers are discussed separately. A crosstabulation procedure was used to identify the relationship and differences between these two groups. Section 5.5 discusses the results from Malaysia. Results from the following analyses are discussed including frequencies descriptive distribution, crosstabulation and chi-square analysis.

Further detailed discussion of the UK and Malaysian surveys are found in section 5.6 and 5.7. Section 5.8 discusses the major findings emerging from the quantitative survey. The postal questionnaire is attached in Appendix 1.

5.2 Overview

The questionnaire is widely recognised as a standard method of collecting information. There are several ways of administering a questionnaire. Kumar (1999) divided it into three ways, which are:

a. The mailed questionnaire
b. Collective administration
c. Administration in a public place
Method 'a' has been used in this research. Respondents from the UK have been identified via the Internet under company homepages based on their activities and involvement in the manufacture, design and sale of agricultural equipment. It was difficult to find industrial designers with experience in this field. Companies were contacted by phone to identify whether their designers were involved in agricultural machinery design projects before the questionnaires were mailed. Altogether 198 questionnaires were mailed within the UK. 25 of these were sent to industrial designers and 10 were returned (40%). From the remaining 173 which were sent to engineers, 53 were returned (30.6%).

Malaysian respondents were divided into two categories, industrial designers and engineering designers. 110 sets of questionnaires were mailed to all the respondents and 74 of them responded, which makes 67.2%. Several respondents who did not return the questionnaires said that they did not have any experience regarding agricultural machinery design. The agricultural and design engineers' names were retrieved from agricultural R&D institutions, government agencies and universities. The researcher managed to gather 60 names and out of that, 40 questionnaires were received, a response rate of 66.7%.

The questionnaire used closed questions and the scale types used were 'likert scale' and 'multiple choice'. Neuman (1991) mentioned that likert scales need a minimum of two categories: 'agree' and 'disagree', though it is usually better to use four or more categories. A researcher can combine or collapse categories after the data has been collected.

Having gone through the literature study and several investigations the researcher decided to combine categories and numerical scale into one single question to simplify the method for better evaluation during the analysis stage (Figure 5.1). (It should be noted that although the PDS is not a design method but a fundamental part of the design process it is included with methods for this survey to determine the extent to which it is used by the different groups of respondents).

Multiple choice questions gives some flexibility to the respondents. The respondents do not have to determine which are appropriate to them but they have the opportunity to indicate that relevance to the questions. It is wise to produce this type of questionnaires in terms of
choices rather than present a blank to be filled in. Distinct choices make analysis easier than writing in sentences.

5.3 Statistical Procedures Used

Rowntree (1991) stated that statistics can be used in at least four different senses. First it can indicate very broadly a whole subject or discipline, and everything that gets studied or practised in its name. Secondly the term may refer to the methods used to collect or process or interpret quantitative data. Thirdly, the term may be applied to collections of data gathered by those methods. Fourthly, it may refer to certain specially calculated figures that somehow characterise such a collection of data. The researcher focused on the second part, mentioned above. Statistics as a set of methods of inquiry where ways of manipulating and summarising numbers that represent data from a research programme are discussed.

According to Kumar (1999) the role of statistics in research is sometimes exaggerated. Statistics has a role only when we have collected the required information. If the data is very large it is difficult to understand, so it is important for the data to be summarised. There are some simple statistical measures such as percentages and means which reduce the volume of data, making it easier to understand. Statistics play a vital role in understanding the relationship between variables.

Before any analysis takes place, the researcher has to understand which statistical procedures to use which in turn is dependent on how the variables are categorised. Before any attempt to analyse data, the researcher should start thinking about data coding (Neuman 1991 and Diamantopoulos et al. 1997). Coding is important, in that mistakes made are difficult to correct at a later stage.

The researcher has differentiated categories to describe the difference from one variable to another as shown in Table 3.1 in Chapter 3. Puri (1996) defines a variable as an observable quantity or attribute that varies from one member of the population being studied to another. A variable name is given to each of the variables in the data set so that the computer can reference them during analysis. There are three types of scale of measurement for variables, which according to Neuman (1991) and Hall et al. (1996) are: nominal scale, ordinal scale and interval scale.

A nominal scale serves only as a label for identification or classification. The ordinal scale relates to questions which offer the respondents a choice of categories which have a relationship to each other for example strongly agree, agree, neither agree nor disagree, disagree and strongly disagree.
According to Siegel (1956) the interval scale has all the characteristics of an ordinal scale and when in addition the distances between any two numbers on the scale are of known size, then a measurement considerably stronger than ordinality has been achieved. There is a further type of measurement known as 'ratio scale'. This type of scale measures actual figures and has a true zero point as its origin.

The researcher used nominal and ordinal scales. Frequencies and Crosstabulation procedures would be appropriate for further data analyses in this study. The statistical analysis package used for this research was SPSS (Statistical Package for the Social Sciences) for Windows. SPSS is a suite of programs covering a wide range of analyses. They include frequency distributions, univariate and multivariate analysis of variance, loglinear models, correlation analysis, regression analysis, factor analysis, cluster analysis, reliability analysis but the researcher will be focusing on frequency distribution and crosstabulation procedures. The computer package is useful, both for performing the necessary calculations and for representing the data in various forms.

5.3.1 Frequencies

Data description is the first step in any data analysis. Descriptive analysis provides a useful initial examination of the data. According to Diamantopoulos et al. (1997) the purpose of descriptive analysis is to:

- Provide preliminary insights as to the nature of the responses obtained.
- Help detect errors in the coding process.
- Provide a means for presenting the data through the use of tables and graphs.
- Provide summary measures of typical or average responses.
- Provide an early opportunity for checking whether the distributional assumptions of subsequent statistical tests are likely to be satisfied.

Descriptive analyses describe numerical data. These can be categorised by the number of variables, which have been identified prior to analysis. The easiest way to describe the numerical data of one variable is by a frequency distribution. This simply shows in absolute (i.e. simple counts) or relative (i.e. percentage) terms how often the different values of the variable are actually encountered in one's sample. According to Neuman (1991) this frequency distribution can be used with nominal, ordinal, interval as well as ratio scales. Information can be summarised on the variable chosen with a raw count (i.e. absolute frequency) or relative frequency distribution. It also can be presented in graphic form such as a histogram, bar chart, and pie chart.

In a frequency distribution the median is the value that divides the area into two equal parts. The mean and the median are frequently close together but if there are extreme values in the
observations, the mean will be more influenced by these values than the median. The positions of the mean, median, and mode are indicated in Figure 5.2.

<table>
<thead>
<tr>
<th>3</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid numbers is 13</td>
<td>Median</td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The mean is 6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The median is 5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.2: Central tendency of mean and median

5.3.2 Crosstabulation

Crosstabulation analyses two variables, to determine if there is a relationship between them. When we need to look at the relationship between two variables that have a small number of values or categories, we should use a crosstabulation, which contains counts of the number of various combinations of values of two variables. For example, we can count how many industrial designers and agricultural engineers usually use a PDS in their design work (Table 5.1).

<table>
<thead>
<tr>
<th>Industrial Designers and Engineering Designers Job Function</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Designers</td>
<td></td>
</tr>
<tr>
<td>PDS</td>
<td>Never</td>
</tr>
<tr>
<td>Quite</td>
<td>11</td>
</tr>
<tr>
<td>Useful</td>
<td>11</td>
</tr>
<tr>
<td>Expected</td>
<td>14</td>
</tr>
<tr>
<td>Always</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
</tr>
</tbody>
</table>

Table 5.1: Crosstabulation of ID and ED job function by PDS

Crosstabulation is a table with a cell for every combination of values of two or more variables. The table shows the number of cases with each specific combination of values as a row and column.

According to Neuman (1991) the level of statistical significance which is usually 0.05, 0.01 or 0.001 is a relationship appearing in the sample when there is none in the population. If the results are significant at the 0.05 level, this means the following:

- Results like these are due to chance factors only 5 in 100 times.
- There is a 95 % chance that the sample results are not due to chance factors alone, but reflect the population accurately.
5.4 The UK Data

In the UK quantitative survey, the researcher has categorised the two groups of respondents as industrial designers (ID) with experience of designing agricultural equipment and engineering designers (ED) comprising design managers, agricultural engineers, engineering designers, design directors and researchers.

5.4.1 Statistical Analyses

The same questionnaire was answered by industrial designers and engineering designers. The number of responses from industrial designers is not large but it is considered satisfactory because the information given and the personnel involved are considered adequate for the survey.

Analysis of the UK data will be categorised into three different sections. The first two sections discuss the frequencies both for ID and ED and the third section will combine the two disciplines to identify any relationships existing between these two categories of respondents. These data combinations were subjected to crosstabulation.

The questionnaire is shown in Appendix 1 and a full list of the UK and Malaysian variables can be found in Appendix II.

5.4.1.1 Frequencies

Based on the frequency output from the ID group and ED group we will be able to see whether the results have provided significant information which fulfil the aims of the investigation.

5.4.1.1.1 Results of the UK ID Frequencies

To find out whether the respondent's organisations have a design department and R&D department the data a1number, a2orga_a and a2orga_b was used. Six of the ten working with organisations which have less than 50 employees indicated that they have a design department. 30% of the respondents working in companies which employed more than 200
workers also have a design department. 40% of the respondents mentioned that they have R&D department within their organisation (Figure 5.3). From the result we can see that all the organisations employing industrial designers have their own design department. Although only 40% have an R&D departments, these do show that industrial designers contribute in doing research and developing ideas to produce agricultural machinery.

Data b1design shows how long industrial designers have been involved in agricultural design. All the respondents had been involved for more than 10 years. 20% had been involved in designing at least one product and 70% involved with between 2 and 10 agricultural machinery design projects. During the last five years, 60% had carried out agricultural design projects. Variables b2led_1, b2led_2 and b2led_3 were used to identify whether their projects were assigned by management or carried out as research and development projects for the purpose of searching for better designs. 30% of the projects were directed by management, 30% were doing R&D work and 40% carried out consultancy to fulfil assignments given by clients.

Types of machinery and equipment designed by industrial designers can be observed within data c1detral to c1depro6. 40% of the UK industrial designers had been involved in designing tractors. One industrial designer designed cultivators and four out of the ten were involved in designing sprayers. One had been involved in harvester and planting machinery. Two (20%) had designed processing machinery. 40% of the respondents had also worked with other types of agricultural machinery and equipment.

From the frequencies output for data b5invol1 to b5invol7 (other disciplines involved with industrial designers during design projects), the results show that 50% of the ID respondents had worked with agricultural engineers, design 80% with mechanical engineers and 60% with production engineers. Electrical engineers did not show a significant involvement with industrial designers but industrial designers have a good working relationship with other industrial designers since more than 55% indicated this. The UK industrial designers also had a close relationship with marketing people during design work on agricultural equipment. The response was 60%. Involvement of industrial designers with ergonomists is very low with a response rate not more than 11% (Figure 5.4). From this we can observe that industrial designers have relationships with other disciplines, especially with mechanical engineers,
agricultural engineers, production engineers, marketing people as well as other industrial designers.

![Involvement with ID in design projects](image)

The respondents were asked to identify the level of importance of the following factors, categorised under data level a to level g, distinguishing between 'least important' and 'most important'. The frequencies show that 40% believed that 'improving product quality' is the 'most important' with a similar number for 'marketing information'. 70% of the respondents indicated 'most important' for 'end user input' playing a major role in design work for agricultural purposes. The level of importance of 'where the machine is to be used' showed 70% under the category 'most important'. This shows that this factor is quite significant in designing agricultural equipment. 'Increasing sales' shows 40% under category 'more important'. 60% believed that 'company image' has the highest level of importance in designing agricultural equipment.

Data method a to method h were used to find which design methods and processes are used by industrial designers in the design of agricultural equipment in the UK. The results show that 50% have indicated that a PDS was 'always' used in design work, as stated in Table 5.2.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Never</td>
<td>1</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>Quite</td>
<td>2</td>
<td>20.0</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>Useful</td>
<td>0</td>
<td>0.0</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>2</td>
<td>20.0</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>5</td>
<td>50.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 5.2: PDS frequency in uses of design methods
The results show that industrial designer respondents believe that industrial designers have a role in contributing their knowledge, skills and experience in agricultural machinery and equipment design projects.

5.4.1.1.2 The UK's ED Frequencies Results

Thirty-seven respondents (69%) of the ED have been involved in designing for more than 10 years. Table 5.3 shows the involvement of ED in design projects related to agriculture. More than 35% have produced two to four agricultural machinery design projects, and nearly 38% have designed ten and more agricultural machinery products since working as designers in the companies.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38%</td>
<td>3.8%</td>
<td>3.8%</td>
</tr>
<tr>
<td>2-4</td>
<td>35.8%</td>
<td>35.8%</td>
<td>39.6%</td>
</tr>
<tr>
<td>5-9</td>
<td>1.9%</td>
<td>1.9%</td>
<td>41.5%</td>
</tr>
<tr>
<td>10 and more</td>
<td>37.7%</td>
<td>37.7%</td>
<td>79.2%</td>
</tr>
<tr>
<td>none</td>
<td>20.8%</td>
<td>20.8%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 5.3: Frequencies for variable Design Projects Involvement.

Data c1detr1 to c1deoth7 were used to find out what type of agricultural design projects have been carried out by ED. The result shows that not more than 27% of the respondents designed tractors, cultivators, sprayers, harvesters, planting machinery, and processing machinery. More than 37% identified that they have been involved in other agricultural related design projects. If we observe under descriptive statistics in Table 5.4 most means are below 2.00 which shows less than half of the respondents designed this equipment.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>c1detr1 – Tractors</td>
<td>1.83</td>
</tr>
<tr>
<td>c1decult2 – Cultivators</td>
<td>1.74</td>
</tr>
<tr>
<td>c1despr3 – Sprayers</td>
<td>1.77</td>
</tr>
<tr>
<td>c1dehar4 – Harvesters</td>
<td>1.79</td>
</tr>
<tr>
<td>c1depla5 – Planting machinery</td>
<td>1.85</td>
</tr>
<tr>
<td>c1depro6 – Processing machinery</td>
<td>1.79</td>
</tr>
<tr>
<td>c1deoth7 – Others agricultural equipment.</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Table 5.4: Descriptive Mean for variable ‘Types of Machinery’

The contributions from other disciplines in the design process have been categorised into four sections; clarification of the task, conceptual design, embodiment design, and detail design. From the results, ED have identified various disciplines into several stages in the design process. ‘Marketing people' have been identified as contributing their expertise at a level of 73% in 'clarification of the task'. ED specified that agricultural engineers have more
than 58% contribution in all four categories mentioned above. Mechanical engineers’
contribution in designing agricultural machinery and related projects gradually increased from
‘clarification of the task’ i.e. more than 54% to ‘detail design’ i.e. more than 75%.

Production engineers have been categorised as contributing their knowledge and skill mainly
at the ‘embodiment design’ stage with result showing more than 45% response. 59% agreed
that production engineers contribute in ‘detail design’. The result for electrical engineers is
quite low in terms of frequency distribution, with only 37.7% contributing at ‘detail design’ and
less than 22% at the other three stages.

When considering the contribution of industrial designers more than 54% of the respondents
identified industrial designers as being efficient at the ‘conceptual design’ stage and nearly
47% under the ‘embodiment design’ stage. Less than 25% agreed that industrial designers
could contribute at the ‘detail design’ stage. The UK’s ED respondents have put ‘ergonomics’
less than 32% in every stage in the design process. From the results discussed we can see
that agricultural engineering and mechanical engineering are the two disciplines that make
the most contribution in the agricultural equipment design process.

In Table 5.5 the UK’s ED respondents have identified that among the six levels of importance
of the factors, three have shown the highest scores in terms of descriptive means higher than
level 4.00. However this does not mean that the other factors are unimportant in agricultural
projects.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>c3levela - Improving product quality</td>
<td>4.44</td>
</tr>
<tr>
<td>c3levelb - Marketing information</td>
<td>3.80</td>
</tr>
<tr>
<td>c3levelc - End user input</td>
<td>4.00</td>
</tr>
<tr>
<td>c3leveld - Machine to be used</td>
<td>3.75</td>
</tr>
<tr>
<td>c3levele - Increasing sales</td>
<td>4.16</td>
</tr>
<tr>
<td>c3levelf - company image</td>
<td>3.39</td>
</tr>
</tbody>
</table>

Table 5.5: Descriptive Mean for ‘Level of Importance’

From the frequencies distribution output of the three factors showing the highest descriptive
means, the results show that more than 86% of the respondents categorised these factors as
‘more important’ and ‘most important’ in design work. Under ‘end user input’, 70% rated the
level of importance as ‘more important’ and ‘most important’. Table 5.6 shows the results for
the variable ‘increasing sales’. This shows more than 75% under the ‘more important’ and
‘most important’ levels.
Table 5.6: Frequencies for the variable 'Increasing Sales'

Data c4consia to c4consdd were used to find out the relative importance of the following design elements. From the descriptive means output in Table 5.7 below, it can be seen that c4consia (performance), c4consib (reliability), c4consic (functionality), c4consil (safety), c4consim (cost), c4consiy (quality), and c4consdd (product testing) were among the 'design elements consideration' variables which had the highest means score. From the results, it can be concluded that the elements mentioned above were among the most important design elements considered by EDs.
Chapter Five  The UK and Malaysian Quantitative Survey (Questionnaire)

<table>
<thead>
<tr>
<th>c4consly</th>
<th>Quality</th>
<th>4.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>c4consiz</td>
<td>Quantity</td>
<td>3.13</td>
</tr>
<tr>
<td>c4consaa</td>
<td>Manufacturing capability</td>
<td>3.73</td>
</tr>
<tr>
<td>c4consbb</td>
<td>Need mock-ups</td>
<td>2.71</td>
</tr>
<tr>
<td>c4conscc</td>
<td>Need scale modelling</td>
<td>2.33</td>
</tr>
<tr>
<td>c4consdd</td>
<td>Product testing</td>
<td>4.04</td>
</tr>
</tbody>
</table>

Table 5.7: Descriptive Mean for variables 'Design Elements Consideration'

From the descriptive means output for data c5methoa to c5methog (design methods and processes used), the results show that the PDS has the highest 'mean' score (3.64). The second highest 'mean' score (2.70) shows that concurrent engineering and DFMA are the design methods relatively used 'quite' often by ED beside PDS. The frequency distribution result (likert scale used: 1 = never to 5 = always in Figure 5.5) of design methods used shows that more than 55% of the respondents 'always' used a PDS in their design activities. More than 54% 'never' used QFD, FMEA, hierarchical trees or morphological charts in their design activities.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>c5methoa</td>
<td>PDS</td>
</tr>
<tr>
<td>c5methob</td>
<td>QFD</td>
</tr>
<tr>
<td>c5methoc</td>
<td>Concurrent Eng.</td>
</tr>
<tr>
<td>c5method</td>
<td>DFMA</td>
</tr>
<tr>
<td>c5methoe</td>
<td>FMEA</td>
</tr>
<tr>
<td>c5methof</td>
<td>Hierarchical tree</td>
</tr>
<tr>
<td>c5methog</td>
<td>Morphological chart</td>
</tr>
</tbody>
</table>

Table 5.8: Descriptive Mean for variables 'Design Methods and Processes'
The agricultural manufacturers identified as companies for which the nature of activities related to design, manufacture, and sale of agricultural products have been categorised under ED. The researcher wanted to know what quantities of the product were to be made within the responding companies. The result from the frequency distribution shows that the companies tended to produce in 'small batches' rather than in mass production, large batches or one off. 67% of the respondents said that their company produced in 'small batches' and less than 25% mentioned their companies produce in 'mass production', 'large batches' and 'one off'.

5.4.1.2 The UK Crosstabulations Results

A crosstabulation is a table with a cell for every combination of values of two or more variables. To quantify the strength and nature of the relationship between two variables in a crosstabulation, variables from the UK ID and ED data were combined and crosstabulated against these two groups. The chi-square method was then used to see whether the results emerging from the test are significant or not, by relating to the significance level of 0.01 or 0.05.

After the chi-square statistics had been produced, the result of the smallest expected count in any cell was counted. The count is important because if too many of the expected values in a table are less than 5, the observed significance level based on the chi-square distribution may not be correct. It is expected to ignore the result if in the chi-square test more than 20% of the cells have expected values of less than 5.
The variables from the UK's respondents under job function (ID & ED) were combined to crosstabulate all the variables, which will be discussed. For the data interpretation the scale of 1 = least important to 5 = most important is used and for comparison purposes, the rating is 1 as 'least important', 2 to 4 as 'appropriate' and 5 as 'most important'. The researcher had to interpret to achieve some significance level in the chi-square test. From the crosstabulation output on data c3levela to c3levelf by ID & ED, data c3levelf 'company image' obtained the highest chi-square value of 8.74 with a significance level at 0.013 (Table 5.9). Although the number of UK's ID respondents is low six of them chose 'company image' as the 'most important' factor in designing agricultural machinery and equipment while 39 respondents from ED indicated this as 'appropriate'. Data c3levelf was also significant with a significance level at 0.014 between the two groups where 77% of the ID members had indicated the level of importance of 'where the machine is to be used' as 'most important' whereas only 28% of the ED members indicated this. Another 69% of ED members had indicated this level of importance as 'appropriate'.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
<td>ED</td>
</tr>
<tr>
<td>Company image</td>
<td>Least important</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expected count</td>
</tr>
<tr>
<td></td>
<td>Appropriate</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expected count</td>
</tr>
<tr>
<td></td>
<td>Most important</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expected count</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expected count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% total</td>
</tr>
</tbody>
</table>

Table 5.9: Crosstabulation output for variable c3levelf by ID&ED

Because the UK's ID respondents are few compared to UK's ED it is difficult to achieve significance levels between 0.05 and 0.01. More than 60% of ED and 45% of ID respondents indicated a 'most important' for 'improving product quality'. 78% of the ID respondents indicated 'end user input' as the 'most important' factor whereas 45% and 51% of ED indicated this factor as 'most important' and 'appropriate' respectively. The results show that both disciplines put all the factors, i.e. improving product quality, marketing information, end user input, where the machine is to be used, increasing sales, and company image, between 'appropriate' and 'most important' in all cases.

In the following data c4consia to c4consdd are considered which relate to the relative importance of various design considerations during the process of designing agricultural equipment. For the data interpretation the scale of 1 = low priority to 5 = high priority has been condensed into three categories instead of five giving 1 to 2 categories as 'low priority', 3 as 'moderate' and 4 to 5 as 'high priority'. From the results of 30 data, only three of those data have a significance level less than 0.05, which are c4consis (patents) with 0.029, c4consisbb (need for mock-ups) with 0.031, and c4consisdd (product testing) with 0.009.
Table 5.10 shows that the design consideration under category ‘performance’ has shown significant evidence that the two disciplines have identified this as ‘high priority’. 100% of the UK’s ID respondents indicated a ‘high priority’ while more than 96% of the UK’s ED indicated performance as ‘high priority’. Reliability (c4consib) also was indicated by both disciplines as ‘high priority’ with 100% from ID and 88% from the ED respondents. Under data c4consic (functionality), 80% of the ID has indicated a ‘high priority’ and more than 82% of the ED respondents indicated this.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
<td>ED</td>
</tr>
<tr>
<td>Performance</td>
<td>Moderate Count</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>3.8%</td>
</tr>
<tr>
<td></td>
<td>High priority Count</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>% of Total</td>
<td>16.1%</td>
</tr>
</tbody>
</table>

Table 5.10: Crosstabulation output for variable ‘Performance’ by ID&ED

From the result of data c4consid (versatility), ID respondents indicated more than 80% as ‘high priority’ whereas 50% ED respondents indicated this design consideration as ‘moderate’. 70% the UK’s ID have identified ‘easy to operate’ as ‘high priority’ while more than 65% of the UK’s ED indicated this. Under data c4consif (single person operated) show not more than 50% of both discipline regarded this design consideration as ‘high priority’ as shown in Table 5.11. Data c4consig (equipped with additional features for different work tasks) was similar with between 30% and 43% at ‘moderate’ level. Variable power has determined that the ID indicated more that 60% as ‘high priority’ but only 50% of the ED indicated the same level.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
<td>ED</td>
</tr>
<tr>
<td>Single-person operated</td>
<td>Low priority Count</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>20.0%</td>
</tr>
<tr>
<td></td>
<td>Moderate Count</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>40.0%</td>
</tr>
<tr>
<td></td>
<td>High priority Count</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>40.0%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>percentage</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>% total</td>
<td>16.1%</td>
</tr>
</tbody>
</table>

Table 5.11: Crosstabulation output for variable ‘single person operation’ by ID&ED

From data c4consii (environment), c4consij (ergonomics), c4consil (safety), c4consisp (manufacturing processes), c4consisr (maintenance), c4consis (product lifetime), c4consit (competition), and c4consim (cost) shows both disciplines indicated more than 55% as a ‘high priority’ for all the variables mentioned as relatively important considerations. The
highest were from the UK ED who indicated more than 80% as 'high priority' under the 'safety' category for design consideration. Variable sizes (c4consin) does not show as an important factor with less than 27% of the ED indicating a 'high priority' while 20% of the ID indicated this. Variable colour (c4consiu) has show that 50% of the ID respondents indicated a 'low priority' and more than 61% of the ED indicated this. 'Aesthetics' variable has a balanced response from 'low priority' to 'high priority' as well as variable 'quantity' (c4consiz).

The importance of manufacturing capability (c4consaa) has more than 80% indicated as a 'high priority' under ID respondents compared with only 61% of the ED. Data c4consbb (the need for mock-ups) and c4consscc (the need for scale modelling) have shown relative differences between the UK's ID and ED. The result shows that the ID appreciate the importance of these factors in designing whereas ED are less aware of their importance in designing agricultural equipment. More than 60% of the ID indicated a 'high priority' for these factors and less than 27% of the ED indicated this. More than 65% of the ED indicated a 'low priority for scale modelling to be considered during design as shown in Table 5.12.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>The need for scale modelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low priority Count percentage</td>
<td>2 20.0%</td>
<td>36 58.1%</td>
</tr>
<tr>
<td>Moderate Count percentage</td>
<td>2 20.0%</td>
<td>11 17.7%</td>
</tr>
<tr>
<td>High priority Count percentage</td>
<td>6 60.0%</td>
<td>15 24.2%</td>
</tr>
<tr>
<td>Total Count percentage % total</td>
<td>10 100.0%</td>
<td>62 100.0%</td>
</tr>
</tbody>
</table>

Table 5.12: Crosstabulation output for variable 'Scale modelling' by ID&ED

The results discussed show that most of the variables are regarded by both disciplines as 'high priority', though several variables fall under 'moderate' and 'low priority' indicated by ED. This may be because the UK's ED are uncertain of the importance of those design considerations.

Crosstabulation between the UK's ID and ED for the design methods usually used during design is allowed by data c5methoa to c5methoh. For these data the interpretation scale has been reduced to three categories which are 1 and 2 as 'never', 3 as 'useful' and 4 to 5 as 'always' for comparison purposes. Table 5.13 shows 70% of the ID 'always' use a PDS and more than 58% of the ED indicated this. Although the significance level does not achieve 0.05 the results show that the PDS is the design method preferred by the designers in their design work. Under these variables, the only one that meets the level of significance is variable c5methoc (Concurrent engineering) with 0.033. More than 69% of the ID and ED 'never' used QFD and 60% of the ID indicated that they 'never' used FMEA. 65% of the ED also indicated this. Hierarchical trees, morphological charts, and unstructured processes
have never been used by 65% of both disciplines. The results show that PDS and concurrent engineering are the most preferred design methods used by both the UK’s ID and ED.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
<td>ED</td>
</tr>
<tr>
<td>PDS</td>
<td>Never</td>
<td>Count: 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage: 10.0%</td>
</tr>
<tr>
<td></td>
<td>Quite</td>
<td>Count: 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage: 1.9%</td>
</tr>
<tr>
<td></td>
<td>Useful</td>
<td>Count: 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage: 20.6%</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>Count: 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage: 13.2%</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>Count: 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage: 45.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% total: 100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>Count: 10</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>percentage: 100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>% total: 15.9%</td>
<td>84.1%</td>
</tr>
</tbody>
</table>

Table 5.13: Crosstabulation output for variable c5methoa by ID&ED

The researcher felt it was important to distinguish the crosstabulation between the UK’s ID and ED for the level of involvement of industrial designers in agricultural equipment design in the future. The data consists of 24 variables from c7futura to c7futury. The scale of 1 to 3 (1 = No contribution, 2 = useful contribution, and 3 = Major contribution) was used for these types of variables. From the crosstabulation statistical procedure, the UK combined data provided results which demonstrated differences in each group on their perceptions of industrial designers with regard to their level of involvement in agricultural machinery design in the future. These differences could be identified through the crosstabulation tables and also referring to the chi-square and the significance level as stated in table 5.14.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-square</th>
<th>D.F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>c7futura -</td>
<td>3.141</td>
<td>2</td>
<td>0.208</td>
</tr>
<tr>
<td>c7futurb -</td>
<td>2.009</td>
<td>2</td>
<td>0.366</td>
</tr>
<tr>
<td>c7futurc -</td>
<td>2.102</td>
<td>2</td>
<td>0.350</td>
</tr>
<tr>
<td>c7futurd -</td>
<td>6.242</td>
<td>2</td>
<td>0.044</td>
</tr>
<tr>
<td>c7future -</td>
<td>4.189</td>
<td>2</td>
<td>0.123</td>
</tr>
<tr>
<td>c7futurf -</td>
<td>5.085</td>
<td>2</td>
<td>0.079</td>
</tr>
<tr>
<td>c7futurg -</td>
<td>4.795</td>
<td>2</td>
<td>0.091</td>
</tr>
<tr>
<td>c7futurh -</td>
<td>5.630</td>
<td>2</td>
<td>0.060</td>
</tr>
<tr>
<td>c7futuri -</td>
<td>7.228</td>
<td>2</td>
<td>0.027</td>
</tr>
<tr>
<td>c7futurj -</td>
<td>4.472</td>
<td>2</td>
<td>0.107</td>
</tr>
<tr>
<td>c7futurk -</td>
<td>3.743</td>
<td>2</td>
<td>0.154</td>
</tr>
<tr>
<td>c7futurl -</td>
<td>1.356</td>
<td>2</td>
<td>0.58</td>
</tr>
<tr>
<td>c7futurm -</td>
<td>3.764</td>
<td>2</td>
<td>0.152</td>
</tr>
<tr>
<td>c7futurn -</td>
<td>10.443</td>
<td>2</td>
<td>0.005</td>
</tr>
<tr>
<td>c7futuro -</td>
<td>9.536</td>
<td>2</td>
<td>0.008</td>
</tr>
</tbody>
</table>
The table above shows that among 24 variables, data c7futurm (constructing mock-ups) obtained the highest chi-square value of 10.44 with a significance level at 0.005. This is followed by data c7futurp (constructing prototypes) with 0.007. The other three data which meet the significance level are c7futuro (construct scale models) with 0.008, c7futurl (development detail drawing) with 0.027, and c7futurd (conducting related research) with 0.044. Other levels of involvement of industrial designers in agricultural equipment design in the future seem not significant, however, the researcher would like to discuss these variables.

In terms of the involvement of industrial designers in these activities in the future, the results of data c7futura (understanding design needs) has shown the UK's ID indicating a 'major contribution' with more than 77% while only 47% of ED members indicated this. Analysing design problems (c7futurc) shows more than 66% of the ID indicated this as a 'major contribution' and not more than 41% of the ED indicated the same level as the involvement of industrial designers in this area. There was a significant difference in their opinion on the involvement of industrial designers in 'concept selection'. Table 5.15 shows that 77% of ID members indicated that the involvement of industrial designers in 'concept selection' was a 'major contribution', while there were only 30% from the ED respondents indicating this. 42% of the ED indicated that industrial designers have 'no contribution' in concept selection during design of agricultural machinery and equipment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ID &amp; ED</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ID</td>
<td>ED</td>
</tr>
<tr>
<td>Concept selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No contribution</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Percentage</td>
<td>11.1%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Useful contribution</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Percentage</td>
<td>11.1%</td>
<td>26.5%</td>
</tr>
<tr>
<td>Major contribution</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Percentage</td>
<td>77.8%</td>
<td>30.6%</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>49</td>
</tr>
<tr>
<td>Count</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Percentage</td>
<td>15.5%</td>
<td>84.5%</td>
</tr>
<tr>
<td>% total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.15: Crosstabulation output for 'Concept selection' by ID&ED
Chapter Five

The UK's ID and ED indicated a 'useful contribution' by industrial designers involved in agricultural machinery design activities, shown by the results for data c7futurj, c7futurl, c7futurm, c7futurr, c7futurs, c7futurt, c7futurw, and c7futury. ED respondents indicated more than 38% 'no contribution' for material selection by industrial designers but ID members indicated more than 44% in this as a 'major contribution'. This is similar to data c7futuru (production cost reduction) where ID indicated more than 44% as a 'major contribution' by industrial designers while more than 40% of the ED indicated this as 'no contribution'. Both disciplines agreed in data c7futurx (product advertising and publicity) for which the UK's ID indicated more than 44% and ED indicated more than 61% under 'no contribution' of industrial designers involved in agricultural equipment design activities in the future.

From the results of variable 'future', it can be justified that the ID respondents are aware of the involvement of industrial designers in agricultural design activities. The UK's ID respondents with more than 10 years experience in designing have indicated the following factors in Table 5.15 under categories 'useful contribution' and 'major contribution' for the level of involvement of industrial designers in this area. Almost all of the UK's ED have indicated between 14% to 64% as 'no contribution' by industrial designers to be involved in agricultural equipment design work. It can be concluded that the ED respondents are not very sure of the involvement of industrial designers in this area of designing for agricultural activities.

The last crosstabulation test examined data c8skilla to c8skillk. These are used to establish which industrial designer's skills are likely to be of importance in the future in agricultural design if they were to become involved in this field. A scale of 1 to 3 was used for these variables for comparison purposes; 1 and 2 are categorised as 'low importance', 3 as 'moderate', and 4 and 5 as 'high importance'. From the crosstabulation output, data c8skilla (working with other disciplines) has shown both disciplines indicated more than 85% from the ED and 100% within ID respondents have categorised this factor as 'high importance'. They believed that industrial designers must work closely with other disciplines in design work to be able to produce successful design projects.

The ID respondents would like the industrial designers to equip themselves with a good basic understanding of engineering knowledge, indicated by more than 77% as 'high importance' and more than 85% of the ED indicated this. Data c8skillb to c8skilld, c8skilig, and c8skillj have the similar response from both disciplines for which the ID indicated 100% as 'high importance' and more that 80% of the ED indicated this. 55% of the ID and 63% of the ED respondents indicated under category 'high importance' that the industrial designers must have 'good basic understanding of science'. Understanding other designer's approaches shows almost 89% of the ID indicated this as 'high importance' and more than 73% of the ED indicated this. Not more than 60% of the respondents indicated under 'high importance' level
for 'have a good appreciation of other specialisms' by industrial designers in agricultural equipment design practices.

For 'aesthetic specialist', c8skillk, nearly 67% of the ID indicated this factor as 'high importance' while not more than 54% of the ED indicated this. The results show that both disciplines agreed that industrial designers have to become competent in all the factors illustrated in Figure 5.6 as 'high importance' factors in order for them to be involved in agricultural machinery and equipment design.

![Figure 5.6: Industrial designer's skill factors](image)

5.5 Malaysian Data

The researcher has categorised these into two disciplines referred to as 'MID' for Malaysian industrial designers and 'MED' for Malaysian engineering designers for data analysis purposes. MID respondents are not the people involved directly with agricultural machinery
because, as discussed earlier, to date there are no industrial designers involved as in-house designers within agricultural R&D institutions, universities and manufacturing.

5.5.1 Statistical Analyses

The results are discussed in two stages, the first stage covering both the Malaysian industrial designers (MID) and Malaysian engineering designers (MED) with data subjected to frequency and descriptive statistics. In the second stage, these two groups were combined in order to identify the relationship existing between these two groups of respondents. The combined data were subjected to crosstabulation statistics. Malaysian questions are designed to be the same as the UK questions for easy administration and compatible analysis procedures.

5.5.1.1 MID Frequencies Results

The frequencies output on data a1number (number of employees), shows the distribution of respondents by number of employees as summarised in Table 5.16 below. It can be seen that the largest category of respondents who worked in the companies with less than 50 employees which made up 36.5%. The next employed more than 200, made up 25.7%. Nearly 75% of the respondents worked in companies which employ less than 200 and this can be categorised as medium scale in the Malaysian context.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50</td>
<td>27</td>
<td>36.5</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td>51 – 100</td>
<td>10</td>
<td>13.5</td>
<td>13.5</td>
<td>50.0</td>
</tr>
<tr>
<td>101–200</td>
<td>18</td>
<td>24.3</td>
<td>24.3</td>
<td>74.3</td>
</tr>
<tr>
<td>More than 200</td>
<td>19</td>
<td>25.7</td>
<td>25.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.16: Frequencies for variable a1number (No. Of Employees)

From here 59 MID respondents (80%) have 'design departments' within their companies and 50% had 'research and development departments'. 20.3% of the respondents have been involved in designing less than 2 years and more than 55% have been involved in designing between 3 to 9 years. 17 respondents (23%) were involved for more than 10 years in designing. 41% of the respondents involved in designing had been directed by their management, 58% carried out research and development projects, and 32% of the respondents carried out consultancy work to fulfil the demand from their clients.

From the results discussed regarding involvement of industrial designers in agricultural equipment design activities, more than 74% of the MID respondents did not have any experience at all. Only 25% had been involved in agricultural machinery design projects.
Within the last 5 years, almost 80% of the respondents were involved as stated in Table 5.17.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Less than 50</td>
<td>27</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td></td>
<td>51 - 100</td>
<td>10</td>
<td>13.5</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>101 - 200</td>
<td>18</td>
<td>24.3</td>
<td>74.3</td>
</tr>
<tr>
<td></td>
<td>More than 200</td>
<td>19</td>
<td>25.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>74</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.17: Frequencies for variable b4last5 (design agricultural machinery during last 5 years)

Figure 5.7 illustrates involvement of industrial designers with other disciplines during design projects. The most involvement within other disciplines is with other industrial designers, which make up 81% followed by mechanical engineers which make up more than 59%. 2 out of 74 MID respondents have been involved in designing and producing tractors, and the same for cultivator products. More than 13% of the respondents have designed sprayer equipment. Not more than 6% had been involved in designing harvesters, planting machinery, and processing machinery products.

The researcher wanted to observe from the industrial designers' point of view how they identified the contribution of the following disciplines as illustrated in Figure 5.8. For this the design process has been categorised into four sections which are:

- Clarification of the task
- Conceptual design
- Embodiment design
- Detail design
MID respondents indicated by more than 85% that marketing people have to be involved in contributing their expertise in 'clarification of the task' stage and less that 27% indicated that this discipline should be involved in the other three design stages. For agricultural engineers, 67% of MID indicated that they contribute in 'clarification of the task' and 'detail design' stages, 35% indicated in 'conceptual design' and another 48% indicated the 'embodiment design' stage as shown in Figure 5.8.

MID indicated nearly 37% of the mechanical engineers contribute at the first stage i.e. 'clarification of the task', and 23% under 'conceptual design'. 48% indicated 'embodiment design', and 86% of the MID respondents believe this discipline contributes its skill, knowledge and experience at the 'detail design' stage. MID respondents also indicated a high percentage (80%) of the production engineers should contribute at the 'detail design' stage whereas for the other three stages the results show not more than 43% for the first stage, 19% for the second stage, and 36% for the third stage of the design process.

MID indicated that the industrial designers' contribution showed quite a high response within all the categories in the design process. For MID more than 58% fall under the first stage and more than 85% believed that the contribution from industrial designers has to be within the 'conceptual design' stage because they are good in this area. Another 70% of the MID respondents indicated the 'embodiment design' stage, and more than 75% indicated that the contribution of industrial designers has to be at the 'detail design' stage to ensure that the products will be successful in terms of functionality and aesthetics.

The last discipline is ergonomists whose identified contribution within the design process is between 44% to 47% at the first, second and third stages. MID respondents have identified by more than 67% that ergonomists can contribute their capability in the 'detail design' stage. From the results we can conclude that marketing people are best at the first stage, agricultural engineers have a high input in 'clarification of the task' and 'detail design' stages. Mechanical engineers are best at 'detail design' as well as production engineers and
electrical engineers. Industrial designers are good in 'conceptual design' stages although other stages have high percentages indicated by MID respondents. Ergonomists are best in 'detail design' stages. Referring to Figure 5.9 we can observe the importance of these disciplines in contributing to the agricultural equipment design process.

![Figure 5.9: Disciplines with high percentage response from MID respondents](image)

From the frequencies output on data c3levela to c7levelelf, it can be seen that the level of importance of 'improving product quality' has been indicated by 100% of MID under 'most important'. 84% of the MID respondents indicated 'most important' for 'marketing information'. 'End user input' was indicated by more than 80% of the respondents as the 'most important' factor in designing as well as 'where the machine is to be used' which more than 87% indicated as 'most important factor'. A high response for 'increasing sales' had more than 70% categorised under 'most important'. 'Company image' also has been categorised as an important factor in designing, with nearly 62%, indicating this as 'most important'. The results discussed show that almost every one of the factors have been indicated at the 'most important' level in design projects which would be carried out.
The following data consisting of c4consia to c4consdd, describe the relative importance of the various design considerations during design. Table 5.18 shows the descriptive means in which the highest means are identified as the most important design considerations.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>c4consia - Performance</td>
<td>4.62</td>
</tr>
<tr>
<td>c4consib - Reliability</td>
<td>4.42</td>
</tr>
<tr>
<td>c4consic - Functionality</td>
<td>4.81</td>
</tr>
<tr>
<td>c4consid - Versatility</td>
<td>4.03</td>
</tr>
<tr>
<td>c4consie - Easy to operate/use</td>
<td>4.60</td>
</tr>
<tr>
<td>c4consif - Single person operate</td>
<td>3.97</td>
</tr>
<tr>
<td>c4consig - Equipped with additional</td>
<td>3.44</td>
</tr>
<tr>
<td>c4consih - Power</td>
<td>4.01</td>
</tr>
<tr>
<td>c4consii - Environment</td>
<td>4.19</td>
</tr>
<tr>
<td>c4consij - Ergonomics</td>
<td>4.46</td>
</tr>
<tr>
<td>c4consik - Patents</td>
<td>3.62</td>
</tr>
<tr>
<td>c4consil - Safety</td>
<td>4.62</td>
</tr>
<tr>
<td>c4consim - Cost</td>
<td>3.85</td>
</tr>
<tr>
<td>c4consin - Sizes</td>
<td>3.69</td>
</tr>
<tr>
<td>c4consio - Weight</td>
<td>3.63</td>
</tr>
<tr>
<td>c4consip - Manufacturing processes</td>
<td>4.14</td>
</tr>
<tr>
<td>c4consiq - Material</td>
<td>4.10</td>
</tr>
<tr>
<td>c4consir - Maintenance</td>
<td>4.22</td>
</tr>
<tr>
<td>c4consis - Product lifetime</td>
<td>4.05</td>
</tr>
<tr>
<td>c4consit - Competition</td>
<td>3.64</td>
</tr>
<tr>
<td>c4consiu - Colour</td>
<td>3.17</td>
</tr>
<tr>
<td>c4consiv - Aesthetics</td>
<td>3.59</td>
</tr>
<tr>
<td>c4consiw - Brand identity</td>
<td>3.21</td>
</tr>
<tr>
<td>c4consix - Standard regulations</td>
<td>3.93</td>
</tr>
<tr>
<td>c4consly - Quality</td>
<td>4.54</td>
</tr>
<tr>
<td>c4consiz - Quantity</td>
<td>3.26</td>
</tr>
<tr>
<td>c4consaa - Manufacturing capability</td>
<td>4.01</td>
</tr>
<tr>
<td>c4consbb - Need mock-ups</td>
<td>3.89</td>
</tr>
<tr>
<td>c4consc - Need scale modelling</td>
<td>3.93</td>
</tr>
<tr>
<td>c4consdd - Product testing</td>
<td>4.46</td>
</tr>
</tbody>
</table>

Table 5.18: Descriptive Mean for variables 'Design Elements Consideration' by MID

The bold typeface shows the highest means with more than 4.40. This does not mean that the other design considerations should be left aside during design of agricultural machinery. The descriptive means for other design considerations show more than 3.00, which means that almost all the following design consideration are of importance. The most important design considerations as indicated by MID respondents are performance, reliability, functionality, easy to operate/use, ergonomics, safety, quality, and product testing.

In terms of using design methods and processes, the researcher wished to distinguish those preferred by MID respondents during design projects. The descriptive mean shows that PDS has the highest with 3.80 compared to the others which indicated between 2.07 and 2.43. The researcher has categorised this section into three scales from 1 (never) to 3 (always).
From Table 5.19, we can see the results show more than 63% of the MID respondents 'always' used a PDS in their design activities and 21% indicated that they 'never' used this.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>16</td>
<td>21.7</td>
<td>21.7</td>
<td>21.7</td>
</tr>
<tr>
<td>Useful sometimes</td>
<td>11</td>
<td>14.9</td>
<td>14.9</td>
<td>36.6</td>
</tr>
<tr>
<td>Always</td>
<td>47</td>
<td>63.5</td>
<td>63.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.19: Frequencies for variable 'Use of PDS'

For QFD more than 66% of the MID respondents 'never' used this design method while 22% indicated they 'always' used QFD. 56% of the respondents indicated they 'never' used concurrent engineering whereas 29% indicated it was 'always' used. 60% indicated they 'never' used DFMA and 26% of the MID respondents indicated that they 'always' used this design method. FMEA was never used by 64%. For hierarchical tree 63% of the MID respondents indicated they 'never' used it and almost 21% 'always' used it. Morphological charts were 'never' used by 58%. 40% indicated that they 'always' used unstructured processes. Figure 5.10 concluded that the PDS is the most preferred design process among those design methods and processes 'always' used by MID respondents.

The last category to be discussed is the quantities in which the products were to be made within the companies that industrial designers worked. From the frequency distributions 59% of the respondents indicated that their companies 'mass produce' the products. Almost 85% indicated that their companies did not produce products in 'large batches' while only 15%
produced it within 'large batches'. More than 32% of the respondents indicated that their companies produced products in 'small batches'. 91% of the MID respondents indicated that producing products in 'one off' quantity was not done by their companies. The results show that the companies in which industrial designers worked usually produced products in 'mass production'.

5.5.1.2 MED Frequencies Results

Frequency distributions were used to characterise the size of companies or institutions where MED worked. The results show that 55% of the respondents worked in organisations with less than 200 employees and the other 45% worked in companies with more than 200 employees. 63% of the respondents mentioned that they have a design department within their organisation, and 75% also indicated that their organisations had a research and development department.

Among the MED respondents, 35% have been involved in designing agricultural machinery and related products for less than 5 years and 25% had experience in this activity for between 5 and 9 years. 40% of the remaining respondents had been involved in designing for more than 10 years. 42% had carried out design projects which had been assigned by their top management. 75% carried out research and development to improve existing products, and only 22% did consultancy work.

From the data for 'agricultural design projects involvement' and 'agricultural design projects carried out during the last 5 years' we can see that 40% of the respondents have been involved in designing from 1 to 4 products since being involved in this activity. 30% (12) have been involved in between 5 and 10 agricultural equipment design or related projects. Another 30% have not designed agricultural products. Within the last 5 years, 42.5% of the respondents have designed less than 4 agricultural products and 20% have indicated 5 and more design products. The rest of the respondents had not been active in design activities involving agricultural related products within the last 5 years. These made up 37.5%.

Data b5invol1 to b5invol7 discussed the relationship between MED and other professionals in carrying out design projects. Figure 5.11 shows the response rate for MED involved with other disciplines within design projects. MED respondents who had been involved with mechanical engineers indicated more than 77% followed by agricultural engineers with 47.5%. The third professional group MED get involved with was marketing people with 45% indicated, followed by production engineers with 40% involved with this discipline.
Data c1 detr4 1 to c1 depro6, examine what type of agricultural machinery and equipment the respondents have designed after we have observed the experiences and the numbers of products that they have conducted. The researcher had identified numbers of equipment, which he had distinguished before piloting the questionnaires with several representatives. MED respondents have indicated that more than 47% had been involved in designing processing machinery, followed by sprayers with 27.5%. Less than 25% have designed the remainder of the machinery and equipment products.

From the frequencies output for MED data, the results from data c2 depoa1 to c2 depog4 indicated that 77.5% of the respondents agreed 'marketing people' are best in contributing their expertise during 'clarification of the task' because a lot of information is required by this discipline during this stage of the design process. 60% of the respondents believed that the 'agricultural engineers' contributed in 'clarification of the task' followed with 82.5% at the 'conceptual design' stage. 52.5% indicated at the 'embodiment design' stage and another 77.5% of the respondents indicated that 'agricultural engineers' have to contribute their knowledge at the 'detail design' stage.

MED respondents have indicated the highest response rate for mechanical engineers' contribution in designing agricultural machinery and related projects in the design process at the 'detail design' stage with 85%, followed by the second highest response at 'embodiment design' with 60%. 'Conceptual design' stage has been indicated as the third highest with 57.5% and the lowest contribution, which is 'clarification of the task', has been indicated with 32.5%. Contributions from production engineers have been indicated to be best at the 'detail design' stage with 65% and the rest of the design process has been indicated as less than 20% by MED respondents. This is similar for electrical engineers with 55% stated at 'detail design' stage.
Industrial designers contributions are best at the 'conceptual design' stage with 57.5% indicating this, the rest of the design process has been indicated for industrial designers as less than 35%. It is also more or less the same response rate for ergonomists with 45% identified at the 'conceptual design' stage whereas the other design process stages have been indicated with not more than 38%. From the results above and from the Figure 5.12, we can conclude that MED have determined agricultural engineers and mechanical engineers contribution to be among the highest in every stage in the design process compared to other disciplines' contributions within the design process in designing agricultural machinery and related design projects.

![Figure 5.12: Disciplinary contributions in the design process](image)

The level of importance of the following factors was given by data c3levela to c3levelf:

- Improving product quality
- Marketing information
- End user input
- Where the machine is to be used
- Increasing sales
- Company image
For the frequencies output, the results show more than 85% of the respondents indicated 'improving product quality' is 'most important' as shown in Table 5.20.

<table>
<thead>
<tr>
<th>Valid</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least important</td>
<td>2</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Appropriate</td>
<td>4</td>
<td>10.0</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Most important</td>
<td>34</td>
<td>85.0</td>
<td>85.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100.0</td>
<td>100.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 5.20: Frequencies for variable c3levela (improving product quality)

For 'marketing information', MED respondents have identified this factor as 'most important' with more than 62%. 87% of the respondents indicated 'end user input' as the 'most important' factor in designing agricultural machinery and equipment, and 65% indicated 'where the machine is to be used' also falls under 'most important' factor. 'Increasing sales' does not show a convincing response rate because only 50% of the respondents indicated this under 'most important', and 'company image' also was not regarded as very important in designing agricultural equipment with respondents indicating not more than 20% for this factor. From the results we can conclude that the first four criteria mentioned above are the 'most important' factors in designing agricultural machinery and equipment products.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>c4consia</td>
<td>4.43</td>
</tr>
<tr>
<td>c4consib</td>
<td>4.28</td>
</tr>
<tr>
<td>c4consic</td>
<td>4.63</td>
</tr>
<tr>
<td>c4consid</td>
<td>3.58</td>
</tr>
<tr>
<td>c4consle</td>
<td>4.18</td>
</tr>
<tr>
<td>c4consif</td>
<td>3.25</td>
</tr>
<tr>
<td>c4consig</td>
<td>2.90</td>
</tr>
<tr>
<td>c4consih</td>
<td>3.25</td>
</tr>
<tr>
<td>c4consii</td>
<td>3.35</td>
</tr>
<tr>
<td>c4consij</td>
<td>3.65</td>
</tr>
<tr>
<td>c4consik</td>
<td>3.03</td>
</tr>
<tr>
<td>c4consil</td>
<td>4.45</td>
</tr>
<tr>
<td>c4consim</td>
<td>3.50</td>
</tr>
<tr>
<td>c4consin</td>
<td>3.13</td>
</tr>
<tr>
<td>c4consio</td>
<td>3.13</td>
</tr>
<tr>
<td>c4consip</td>
<td>3.68</td>
</tr>
<tr>
<td>c4consiq</td>
<td>3.68</td>
</tr>
<tr>
<td>c4consir</td>
<td>3.90</td>
</tr>
<tr>
<td>c4consis</td>
<td>3.50</td>
</tr>
<tr>
<td>c4consit</td>
<td>3.09</td>
</tr>
<tr>
<td>c4consiu</td>
<td>2.17</td>
</tr>
<tr>
<td>c4consiv</td>
<td>2.60</td>
</tr>
<tr>
<td>c4consiw</td>
<td>2.10</td>
</tr>
</tbody>
</table>
Table 5.21: Descriptive Mean for variables Design Elements Consideration by MED

Table 5.21 above shows the relative importance of a range of design considerations during the process of designing agricultural equipment. The researcher has used descriptive means distributions to determine the most significant design considerations indicated by MED respondents. The high descriptive means show the most preferred though, as mentioned earlier, the lowest descriptive means count do not mean that these factors are not worth considering in designing agricultural machinery and related products.

Performance, reliability, functionality, easy to operate/use, safety, quality and product testing show a high descriptive means count with more than 4.00 and the highest among those mentioned is 'functionality' with 4.63, as we can observe from the frequencies distribution output in Table 5.22 above. The lowest descriptive mean counts among all the following design consideration, as stated in Figure 5.21, is 'brand identity' with 2.10. 17 design considerations fall under descriptive means counts between 3.00 to 3.99. It can be concluded that we could identify in order which is the most important and the least important of the design considerations to be justified during design projects.

The following data c5methoa to c5methog relates to 'design methods and processes usually used' by MED respondents. The results from descriptive means counts show that PDS has the highest count with 3.80 and the lowest descriptive means counts is the 'Hierarchical Tree' with 1.88. Table 5.23 shows more than 72% of the MED respondents indicated that they 'always' used this design method during design projects.
MED indicated that more than 37% 'never' used QFD in their design work, and almost 53% of the respondents indicated this design method falls under the 'useful sometimes' category as well as concurrent engineering, 50% of the respondents indicated 'useful' for this design method. More than 27% 'never' used this design method. DFMA has shown a very high response rate in the 'never' used category with more than 42% indicating this and only 27.5% indicated 'always' used in design activities. A similar response rate occurs for FMEA with 42.5% indicating 'never' used and 22.5% indicating 'always' used FMEA in their design work.

As mentioned earlier the 'Hierarchical tree' method has the lowest descriptive means count and if we observe under frequency distribution, 45% of the respondents 'never' used these while only 5% indicated they 'always' used this design method. The morphological chart has the same response rate as 'Hierarchical tree' for 'never' used but it has a higher response rate under the category 'always' with 12.5% indicated by the MED respondents. Under unstructured processes design method 35% of the respondents indicated 'never' used and 12.5% indicated 'always' used this design method. The results show that PIDS is the design process usually preferred by MED respondents.

More than 57% of the organisations or companies where MED worked produced the products in 'small batches' in contrast to MID respondents. The 'one off method of producing the end product became the second most common with 40% of the MED respondents indicated this. 10% of the respondents indicated their companies produced in 'large batches' and almost 18% indicated that the products were made as 'mass production'.

5.5.1.3 Malaysian Crosstabulations Results

The Malaysian data analysis will be similar to what has been used for the UK data analysis. The crosstabulation procedure was used for the Malaysian data analysis to distinguish the relationships and whether there are any significant differences between MID and MED groups within the variables. In this section, the researcher discusses question 7 (section future), 8 and 9 in section C from the questionnaire.
From the crosstabulation output on future involvement by MID & MED, the researcher had interpreted on the scale of 1 = no contribution to 5 = major contribution became 1 and 2 categories as 'no contribution', 3 and 4 as 'useful contribution', and 5 as 'major contribution'. Table 5.24 shows there were seven variables identified as having a chi-square value at 0.05 significance level and eight variables identified at 0.01 which is a very significant level. The other nine variables seem not significant. From the table below we can see the highest chi-square values of 27.154 was very significant at 0.000 level which was under the category 'concept selection'.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-square</th>
<th>D.F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>c7futura - Understanding design needs</td>
<td>13.526</td>
<td>2</td>
<td>0.001</td>
</tr>
<tr>
<td>c7futurb - Market evaluation</td>
<td>5.091</td>
<td>2</td>
<td>0.078</td>
</tr>
<tr>
<td>c7futurc - Analyse design problem</td>
<td>11.141</td>
<td>2</td>
<td>0.001</td>
</tr>
<tr>
<td>c7futura - Conducting research</td>
<td>9.091</td>
<td>2</td>
<td>0.011</td>
</tr>
<tr>
<td>c7future - Human factors considerations</td>
<td>3.374</td>
<td>2</td>
<td>0.185</td>
</tr>
<tr>
<td>c7futurf - Preparing design spec.</td>
<td>15.352</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>c7futurg - Brainstorming</td>
<td>11.725</td>
<td>2</td>
<td>0.003</td>
</tr>
<tr>
<td>c7futurh - Sketching</td>
<td>16.694</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>c7futuri - Concept selection</td>
<td>27.154</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>c7futurj - Preliminary concept drawing</td>
<td>10.836</td>
<td>2</td>
<td>0.004</td>
</tr>
<tr>
<td>c7futurk - Development drawing</td>
<td>4.900</td>
<td>2</td>
<td>0.086</td>
</tr>
<tr>
<td>c7futurl - Development detail drawing</td>
<td>9.032</td>
<td>2</td>
<td>0.011</td>
</tr>
<tr>
<td>c7futurm - CAD modelling</td>
<td>1.997</td>
<td>2</td>
<td>0.368</td>
</tr>
<tr>
<td>c7futurn - Construct mock-ups</td>
<td>8.631</td>
<td>2</td>
<td>0.013</td>
</tr>
<tr>
<td>c7futuro - Construct scale models</td>
<td>13.863</td>
<td>2</td>
<td>0.001</td>
</tr>
<tr>
<td>c7futulp - Constructing prototypes</td>
<td>7.115</td>
<td>2</td>
<td>0.029</td>
</tr>
<tr>
<td>c7futurq - Testing prototypes</td>
<td>6.397</td>
<td>2</td>
<td>0.041</td>
</tr>
<tr>
<td>c7futurr - Evaluation final design</td>
<td>4.447</td>
<td>2</td>
<td>0.108</td>
</tr>
<tr>
<td>c7futurs - Material selection</td>
<td>6.513</td>
<td>2</td>
<td>0.039</td>
</tr>
<tr>
<td>c7futurt - Understanding prod. capability</td>
<td>8.672</td>
<td>2</td>
<td>0.013</td>
</tr>
<tr>
<td>c7futuru - Product cost reduction</td>
<td>8.490</td>
<td>2</td>
<td>0.014</td>
</tr>
<tr>
<td>c7futuw - Production cost reduction</td>
<td>4.348</td>
<td>2</td>
<td>0.114</td>
</tr>
<tr>
<td>c7futurx - Product advertising</td>
<td>1.064</td>
<td>2</td>
<td>0.579</td>
</tr>
<tr>
<td>c7futury - Increasing sales</td>
<td>3.078</td>
<td>2</td>
<td>0.215</td>
</tr>
</tbody>
</table>

Table 5.24: Crosstabulations – Chi-square output for the MID and MED variable ‘Future’

To distinguish any similarities and differences for each variable, the crosstabulation was applied and for data c7futura (understand design needs), we can observe the differences between MID and MED in indicating the level of involvement of industrial designers in agricultural machinery and equipment design activities in the future. More than 74% of the MID respondents indicated this variable as a 'major contribution' whereas MED respondents indicated this as a 'useful contribution' with 57%.
Table 5.25 shows significant differences between MID and MED under data c7futurc (analyse design problem). No respondents indicated 'no contribution' under this category. The table shows only two categories, which are 'useful contribution' and 'major contribution'. The MID group has put a high emphasis on this variable with almost 70% indicating this as a 'major contribution'. On the other hand, more than 62% of the MED respondents indicated this item as 'useful contribution'.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MID &amp; MED</th>
<th>Row Total</th>
<th>MID</th>
<th>MED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyse design problem</td>
<td>Use</td>
<td>Count</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>contribution</td>
<td>% within MID &amp; MED</td>
<td>63.5%</td>
<td>30.1%</td>
</tr>
<tr>
<td></td>
<td>Major</td>
<td>Count</td>
<td>15</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>contribution</td>
<td>% within MID &amp; MED</td>
<td>37.5%</td>
<td>69.9%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>% within MID &amp; MED</td>
<td>40</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.25: Crosstabulation output for 'Future involvement' by MID & MED

Data c7futurd (conducting related research), c7futurf (preparing design specification), c7futurg (brainstorming), c7futurh (sketching), c7futurj (preliminary concept drawing), c7futurl (development drawing), and c7futurn (construct mock-up) has shown similar patterns in terms of indicating the categories from variables mentioned. MID respondents have indicated all those variables as 'major contribution' with 52% to 70% whereas 57% to 75% of the MED respondents indicated this variable as 'useful contribution'. Data c7futuro (construct mock-ups) has explained a typical crosstabulation output with the chi-square value of 13.86 being very significant at 0.001 level. The result shows a significant difference between these two groups, which has indicated 'major contribution' from MID and 'useful contribution' from MED respondents.

The crosstabulation output from data c7futurs (material selection) reflected that both groups have the same point of view in assigning this variable to the same category. Both groups have chosen more or less equal percentages for both 'useful contribution' and 'major contribution'. MID indicated 48% and MED indicated 45% for this variable under 'useful contribution' and, on the other hand, 50% and 53% of the MID and MED indicated the other category. For the variable 'understanding production capability' 52% of the MID chose 'major contribution' whereas 25% of the MED respondents indicated this.

Data c7futuru (product cost reduction) shows that nearly 55% of the MID respondents believed that industrial designers could make a 'major contribution' in 'reducing the product cost' when involved in designing agricultural machinery and equipment in the future. MED indicated the same category with almost 63%. The results discussed show that there are differences between MID and MED in distinguishing the level of involvement as illustrated in Table 5.24. The involvement of industrial designers in agricultural equipment design activities
in the future has been identified by MID respondents who indicated the following factors under 'major contribution', and MED respondents indicated these variables under 'useful contribution'.

The following variables discuss the importance of the industrial designer's skills in the future if they would like to be involved in these activities. The crosstabulation output for variable c8skillia (working with other disciplines) shows a significant value at 0.077, which indicated that this item is not significant. Both groups have generally accepted and are well aware that industrial designers should work very closely with other disciplines in order to achieve outstanding end products of agricultural equipment. Both groups indicated more than 88% from MID and more than 77% from MED respondents under the 'high importance' category.

Data c8skillib (generating/creating ideas) shows a difference between these two groups in indicating the importance of industrial designer's skill in the future of agricultural equipment design. More that 67% of the MID respondents indicated 'high importance' for this variable while 25% of the MED respondents indicated this as illustrated in Table 5.26.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MID &amp; MED</th>
<th>Row</th>
<th>Count</th>
<th>% within MID &amp; MED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating/ generating ideas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td></td>
<td>4</td>
<td>5.5%</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td></td>
<td></td>
<td>10</td>
<td>25.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>14</td>
<td>12.4%</td>
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<tr>
<td>Slightly high important</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Count</td>
<td></td>
<td></td>
<td>20</td>
<td>27.4%</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
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<td></td>
<td>20</td>
<td>50.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>40</td>
<td>35.4%</td>
</tr>
<tr>
<td>High importance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td></td>
<td>49</td>
<td>67.1%</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td></td>
<td></td>
<td>10</td>
<td>25.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>59</td>
<td>52.2%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>Communication skill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.26: Crosstabulation output for variable c8skillib by MID & MED

Communication skill (data c8skillg) shows a high chi-square value of 16.420 with a very significant value of 0.003 level. This shows that the result will be significantly different between both groups with MID indicating more than 66% for the category 'can communicate with other people at all levels in the company and outside company' as 'high importance' while only 30% of the MED respondents indicated this. It has the same pattern with the data c8skillh (understanding other designers' approaches).

The crosstabulation for data c8skilli (have a good appreciation of other specialisms) and c8skillj (human factors/ergonomics capability) have a very significant value of 0.001. 50% of the MID respondents believed that industrial designers need a good appreciation of other disciplines to enable them to be involved in this type of design, indicating 'high importance' for this variable. Only 15% of the MED respondents indicated at the same level. Table 5.27
shows the difference between these two groups for ergonomics capabilities (data c8skillj). More than 63% of the MID indicated 'high importance' and 30% of the MED indicated this.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MID &amp; MED</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MID</td>
<td>MED</td>
</tr>
<tr>
<td>Human factors/ergonomics capability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slightly low important</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>5.0%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>2.8%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Slightly high important</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>33.3%</td>
<td>50.0%</td>
</tr>
<tr>
<td>High importance</td>
<td>46</td>
<td>12</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>63.9%</td>
<td>30.0%</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>40</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 5.27: Crosstabulation output for 'ergonomics capabilities' by MID & MED

The last data in question 8 section C in the questionnaire, data c8skillj (aesthetic specialist), resulted in a significance value of 0.043 with a chi-square value of 9.843. This means that the result does not show a very high percentage compared with other variables. 43% of the MID respondents categorised this variable under 'high importance' whereas MED respondents indicated this for only 15%. The discussion has provided some meaningful evidence that certain variables have differences in points of view from these two groups in order to identify the importance of the industrial designers skills in the future for them to be involved in agricultural equipment design activities. Certain variables also have proved that there are similarities within both groups. The factors for which both groups agreed were between multi-discipline team, good basic understanding of engineering theory, and good basic understanding of science.

In the variables as shown in Table 5.28, there are three variables identified as having high chi-square values at 0.05 significance level. The other two variables seem not significant because the significance level is more than 0.05.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-square</th>
<th>D.F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C9indcoa – making product saleable</td>
<td>9.170</td>
<td>4</td>
<td>0.057</td>
</tr>
<tr>
<td>C9indcob – improved ergonomics aspect</td>
<td>16.219</td>
<td>4</td>
<td>0.003</td>
</tr>
<tr>
<td>C9indcoc – reduced production cost</td>
<td>5.700</td>
<td>4</td>
<td>0.223</td>
</tr>
<tr>
<td>C9indcod – improving product usage</td>
<td>13.344</td>
<td>4</td>
<td>0.010</td>
</tr>
<tr>
<td>C9indcoe – improved product quality</td>
<td>14.922</td>
<td>4</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Table 5.28: Crosstabulations – Chi-square output for the MID and MED variables contribution
If we observe variable 'making products saleable', c9indcoa, the significance level is just above 0.05 and the result shows that the differences between MID and MED respondents is not too obvious. 40% of the MID indicated this variable at 'significant contribution' and 27% of the MED indicated this. For the data (c9indcob) with a significance value of 0.003 we can observe from Table 5.29 the significant difference between these two groups indicating this variable. More than 53% of the MID respondents stated this variable as a 'significant contribution' whereas 20% of the MED respondents indicated this.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MID</th>
<th>MED</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved ergonomics aspect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal contribution</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>1.4%</td>
<td>2.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Quite</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>4.1%</td>
<td>7.5%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Important</td>
<td>4</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>5.5%</td>
<td>25.0%</td>
<td>12.4%</td>
</tr>
<tr>
<td>More important</td>
<td>26</td>
<td>18</td>
<td>44</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>35.6%</td>
<td>45.0%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Significant contribution</td>
<td>39</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>53.4%</td>
<td>20.0%</td>
<td>41.6%</td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td>40</td>
<td>113</td>
</tr>
<tr>
<td>% within MID &amp; MED</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 5.29: Crosstabulation output for variable c9indcob by MID & MED

The result for data c9indcoc (reduced production cost) is not significant and the result shows quite a different response rate for 'significant contribution' which MID indicated 39% and MED indicated 22%. Data c9indcod (improved product usage) has a high chi-square value of 13.344 with a significance value of 0.010 which means that the significant difference between these two groups is clear. 60% of the MID indicated this variable as 'significant contribution' for industrial designers contribution to agricultural equipment design while almost 28% of the MED indicated this. The same happened to data c9indcoe (improved products quality) for which more than 68% of the MID indicated as a 'significant contribution' and less that 38% of the MED respondents indicated this category.

From the results, we can conclude that there are highly significant differences between MID and MED respondents towards identifying the current contribution of industrial designers to agricultural equipment design activities within these variables discussed.

5.6 The UK’s Quantitative Data Findings

Although the UK’s ID respondents were not as many as ED, the researcher was satisfied with the response which shows that the respondents are qualified in their field. All the UK’s ID had more than ten years experience in designing activities. The result shows that 70% of
the ID have been involved in designing 2 to 10 and more agricultural products such as tractors, cultivators, sprayers, harvesters, planting machinery, and processing machinery.

Both groups mentioned that they have design departments and R&D departments within their organisation although the percentage between both groups is different. The researcher investigated the relationship between industrial designers and other disciplines within design projects. From the data analysis, the results show the ID respondents have made this happen by involving other disciplines during design projects. Mechanical, production and agricultural engineers, industrial designers and marketing people are the ones involved with 50% and above indicated by ID respondents.

The UK's ED respondents have identified marketing people as being best in contributing their expertise during 'clarification of the task'. ED respondents believed that agricultural engineers and mechanical engineers are the people who should be involved from beginning to the end of the projects. Production engineers are best at embodiment and detail design stages whereas the contribution of industrial designers in the agricultural design process has been categorised as being most valuable at conceptual and embodiment design stages.

There are different points of view between both groups. The UK's ID respondents have indicated 'end user input' and 'where the machine is to be used' as the most important factors compared to others in designing. The UK's ED respondents have identified 'improving product quality' followed by 'increasing sales' as the most important factors in designing agricultural machinery and equipment, although ED have also categorised 'end user input' as the top three factors, which have to be considered as important factor during carried out design activities.

ED respondents have fundamentally categorised several design elements which, they feel, have 'high priority' to be considered for designing purposes. These are performance, reliability, functionality, safety, cost, quality, and product testing as the main design elements. Several design methods were mainly used by most designers, especially engineering designers, in their design work. Among the design methods and processes stated, the PDS is preferred within ID as well as ED but they also commonly used concurrent engineering and DFMA design methods.

From the descriptive mean output from question 7 under section C for category 'future', the researcher has identified from both groups that there are similarities and differences in identifying the major contribution of industrial designers in designing agricultural equipment in the future. The UK's ID have identified 'understanding design needs', 'analyse design problem', 'human factors considerations', 'brainstorming', 'concept selection', 'development drawing', 'CAD modelling', and 'material selection' as the major contributions from industrial designers in design practice. The UK's ED respondents added 'preparing design
specification' into the list mentioned as the most important factors to be taken as major contributions from industrial designers who would like to be involved in this activity in the near future.

Data consolidated to discussed the current contribution of industrial designers to this activity. If we consolidate the Likert scales between level 4 and level 5 to one category of 'significant contribution', then we can see the percentage of the UK's ID respondents have increased tremendously. More than 85% of the ID respondents indicated 'making the product saleable', 'improved ergonomics aspects', and 'improving products quality' have 'significant contribution' from industrial designers in this activity. More than 66% indicated the same level for 'reduced production cost' and 'improving product usage'. This means that industrial designers are perceived to have potential in contributing their capability in agricultural machinery and equipment in the near future.

From the crosstabulation output, the researcher concentrated on the results from question 7 and 8 under section C from the questionnaire. The paragraph above has identified descriptive means from the UK's ID and ED but this section discussed the results that arise from combination of variables between both groups. From the results regarding the level of involvement of industrial designers in this design activity in the future, both groups have identified totally different factors from the descriptive means results. In the crosstabulation procedure, we assume that a significance level, of less than 0.05 means that the result is significant. From 24 variables, only 5 variables seem to be significant which are:

- Conducting related research
- Concept selection
- Constructing mock-ups
- Constructing scale models
- Constructing prototypes

The other variables are not significant but they have been discussed in previous sections in order to find any possibility in pursuing the research which will be beneficial in the following chapter in which the researcher thought it necessary to carry out design projects to help to develop meaningful design guidelines for Malaysian industrial designers.

The industrial design skills are important in order for this discipline to become more involved in agricultural machinery and equipment design activities in the future. The result has shown a satisfactory output from both groups which have identified all the factors below as 'high importance' factors for industrial designers to be aware of in order to be effective in agricultural designing activities in the future.

- Working with other disciplines.
• Creating/generating ideas.
• Interaction between the multi-discipline team.
• Being involved from the beginning of the projects.
• Good basic understanding of engineering.
• Good basic understanding of sciences.
• Ability to communicate with other people at all levels within the company and outside.
• Understanding other designers’ approaches.
• Have a good appreciation of other specialisms.
• Human factors/ergonomics capability.
• Aesthetic specialist.

5.7 Malaysian Quantitative Data Findings

The Malaysian quantitative data analysis has also been divided into two categories, the first category related to frequencies and descriptive distribution and the second stage referring to crosstabulation procedure where the variables have been combined to distinguish the similarities and differences between the two groups of Malaysian respondents.

MID respondents to the greatest extent have design departments with 80%, and only 50% have indicated that they have R&D departments within their organisation whereas MED indicate that they have design department (63%) and R&D department (75%). 55% of the MID respondents have been involved in designing activities between 3 and 9 years and 40% of MED respondents indicated that they have been involved more than ten years in design work. 35% have been designing products less than 5 years. 70% of the MED respondents have designed agricultural related products whereas MID do not have any exposure in agricultural design projects, with 74% indicating this. From here we can concluded that MED have more experience in terms of design activities compared to MID respondents.

MID were involved a lot with other industrial designers during design projects. The other professionals involved have been mechanical engineers, production engineers, marketing people, and ergonomists whereas MED were involved frequently with other mechanical engineers followed by agricultural engineers, marketing, and production engineers. The results do not show high percentages of involvement from agricultural engineers with industrial designers because, as mentioned, more than 70% of the MID respondents have not been involved with agricultural design projects.

Contributions from various disciplines stated in the questionnaire have been identified within the design process, which have been categorised by the researcher into four stages as described in section 5.5.1.1. MID indicated that agricultural engineers, mechanical engineers and industrial designers have major contributions within four stages of the design process in order to complete the design projects. MED respondents have indicated that agricultural
engineers and mechanical engineers have a very high involvement at all four stages in agricultural equipment design processes. This means that both groups agreed that mechanical and agricultural engineers have more responsibility compared to others except industrial designers, who have been said by MID respondents to be as important as the other two disciplines.

The MID respondents have distinguished the following factors which are 'improving product quality', 'marketing information', 'end user input', 'where the machine is to be used', and 'increasing sales' as the 'most important' factors in designing agricultural machinery and equipment, indicated by 70% and more, apart from 'company image' which shows almost 63% indicated this. The MED respondents have different ideas in indicating the level of importance of the factors mentioned. 'Improving product quality' and 'end user input' are the most important factors whereas 'marketing information' and 'where the machine is to be used' have less than 62%. 20% has been indicated for 'company image'. It can be concluded that MED are not sure of the importance of those factors within industrial design in designing agricultural equipment.

From 30 design considerations, identified by the researcher, there are similarities between MID and MED points of view in these categories. The categories were compared using descriptive means results, which have high mean value. Both groups have indicated the same categories, which fall under 'high priority' during the process of designing. The categories, which have been indicated by both groups, are:

- Performance
- Reliability
- Functionality
- Easy to operate/use
- Safety
- Quality
- Product testing

'Ergonomics' has been identified by MID respondents as one of the categories which have to be included in the above categories mentioned. The result shows the mean levels which are meaningful to the researcher to identify later in the following chapter in the design project case studies to characterise the involvement of industrial designers. The PDS became the most used design method and process among those illustrated in Figure 5.10. The other design methods were not preferred because the response rate is very low as indicated by both groups, though this does not mean that they are not used at all.

As indicated earlier the majority of MID respondents were not involved in agricultural design projects but were involved with other capital and consumer products. This means that the
products that come out have been 'mass produced' whereas MED indicated that the products they designed had been produced in 'small batches' and 'one off' because to the great extent MED respondents are involved in designing capital products more frequently.

The crosstabulation procedure used to distinguish the differences occurring and to account for whether there are relationships between both groups, the MID and MED respondents. The crosstabulation procedure has resulted in meaningful data, which will be used for further development and will be triangulated with other studies in this research to distinguish the role and potential contribution of industrial designers in agricultural machinery and equipment design activities, especially for Malaysia.

From the crosstabulation output on data c7utura to c7utury, the result shows the chi-square values and significance values, which are 'significant' and 'very significant'. The results have determined the highest chi-square value to the lowest, which can be categorised into:

- Concept selection
- Sketching
- Preparing design specification
- Construct scale models
- Understanding design needs
- Brainstorming
- Analyse design problem
- Preliminary concept drawings
- Conducting research
- Developing detail drawings

The rest of the design factors gradually break down by following the chi-square value as stated in Table 5.24. The design factors elaborated above seem to be parallel to what industrial designers usually use during design activities. The other factors do not mean that they are not valuable in design activities, nevertheless it is worth while highlighting the differences in design activities especially in agricultural machinery and related design projects.

Let us move to another variable that considered the importance of industrial designer's skill, with which they should be equipped to enhance their capability in designing agricultural products. We focussed on variables, which are not significant. From eleven skills mentioned, four are not significant but these four skills are the ones indicated as the highest response rate which showed that the industrial designers need these to enable them to be more confident and have more knowledge for approaching these activities. Those are:

- Working with other disciplines
• Interaction between the multi-discipline team
• Good basic understanding of engineering
• Good basic understanding of science

The other skills identified within industrial designer’s expertise are:

• Creating/generating ideas
• Communication capability
• Human factors/ergonomics capability
• Aesthetic specialist.

The last variable the researcher would like to determine in these Malaysian quantitative findings which MID respondents have identified that industrial designers currently make use of these following factors to contribute in agricultural design activities.

• Making the product saleable
• Improved ergonomics aspect
• Improving product usage
• Improving product quality

5.8 Major findings of the quantitative survey

This section is intended to provide an understanding of the main issues which emerged from the previous sections.

5.8.1 The UK major findings

The quantitative survey results show a number of findings which help to fulfil the aims and objectives of the UK study and answer the research questions. The main findings can be summarised as follows:

• The UK’s industrial designers have identified that industrial designers must be involved in agricultural design activities from ‘clarification of the task’ to producing the ‘detail design’. Industrial designers should be involved throughout the whole design process.

• Agricultural engineers and mechanical engineers, as indicated by engineering design respondents, believed that the engineering disciplines have to contribute their skill, knowledge and experience from the beginning to the end of a project assignment. However they believed that industrial designers are best involved at ‘conceptual’ and ‘embodiment design’ stages.
Chapter Five

The category of product design specification (PDS) is the most beneficial design process used by both sets of respondents during design activities. Concurrent Engineering and Design for Manufacture and Assembly (DFMA) have infrequently been used by both disciplines.

It has been identified that the role of industrial designers in improving product quality, making the products saleable, improving ergonomics aspects and improving product usage can make the most significant contribution in agricultural design projects.

Industrial designers have identified a number of design considerations as high priority in agricultural design work. The top five most important are:

- Performance
- Reliability
- Functionality
- Safety
- Quality

Industrial designers have to equip themselves with other important skills to enable them to fit into this robust design activity which would change their ways of thinking and handling design problems. Industrial designers have to gain good understanding of engineering and science, have good interactions within multi-discipline teams and must be good communicators.

Results have shown the significance of the industrial designer's role and contribution in the field of agricultural machinery design. The analyses conducted also show that ED's have a realisation or awareness of the importance of industrial designers in this field.

5.8.2 Malaysian major findings

The findings from the Malaysian quantitative survey helped to identify a gap which the industrial designers can fill to change the scenario of design activities in Malaysian agricultural equipment design. To enable Malaysian agricultural products in the future to become as efficient as other established agricultural products, it is time for Malaysian industrial designers to take further action.

The major findings from this analysis can be summarised as the following:

- More than 74% of the industrial designers do not have experience in designing agricultural equipment, which means that the exposure of industrial designers in this area is very depressed.
Industrial designers must have close relationships with agricultural engineers and mechanical engineers involved with agricultural design activities to enable them to understand the problems facing these professionals and to work hand-in-hand.

Responses have indicated that industrial designers have the capability to be involved in agricultural machinery design. It has been shown that they can contribute from the beginning of a project up to producing detail design.

Industrial designers have to take the following factors into consideration when they engage in this design activity:
- Market information
- End user input
- Where the machine is to be used

Malaysian industrial designers have to consider all the design considerations during the process of designing agricultural equipment stated in Table 5.26. From those both groups of Malaysian respondents have categorised the 'high priority' aspects to be considered by industrial designers as:
- Performance
- Reliability
- Functionality
- Easy to operate/use
- Safety
- Quality
- Product testing

The design method or process most commonly used by Malaysian respondents is the PIDS. Industrial designers have to study and understand thoroughly this structured aspect of the design process and try to improve their use of it for better communication during agricultural design projects with other team members.

It is been indicated that the design factors illustrated in Table 5.24 are the factors usually used by industrial designers during design projects. This means that these design factors can be carried forward for use in agricultural design projects with some changes to suit the environment.

Malaysian industrial designers have to equip themselves with the following skills to enable them to be successful in approaching these activities:
- Confidence in working with other disciplines in design work
- Good interaction within the multi-discipline team
- Good basic engineering knowledge
• Good understanding of science

• The main contributions of industrial designers in designing agricultural machinery and equipment:
  • Making the product saleable
  • Improved ergonomics aspects
  • Improving product usage
  • Improving product quality.

5.9 Discussion of the UK and Malaysian Quantitative Findings

Based on the postal questionnaire, this section discusses some important issues related to this study which will be used to help generate design guidelines appropriate for Malaysia.

The quantitative results from the UK have shown differences in terms of responding percentages. Nevertheless the UK’s industrial designers have experience in designing agricultural machinery equipment for more than ten years compared to Malaysian industrial designers. The results show a significant differences between the UK and Malaysian industrial designers involved in this area but this could change dramatically. For agricultural products to be competitive in international markets R&D institutions, universities and private sectors must involve industrial designers in agricultural equipment design projects.

Agricultural machinery and equipment design projects require input from different disciplines in order to produce satisfactory products. The results show similarities from both countries which foresee the need to involve other disciplines in these design activities, especially industrial designers. This result confirms the importance of industrial designers becoming involved in this industry.

From the results there are significant differences with regard to the involvement of industrial designers in the design process. The UK respondents believed that industrial designers best contributed at conceptual and embodiment design stages and less than 25% believed that industrial designers need to be involved in the detail design stage. Malaysian industrial design respondents believed that industrial designers have to be involved from ‘clarification of the task’ until ‘detail design’ to be able to complete the design projects. Although there are differences between both countries regarding this issue, the importance of involving industrial designers is beyond doubt.

The level of importance of ‘improving product quality’, ‘marketing information’, ‘end user input’, ‘where the product is to be used’, ‘increasing sales’ and ‘company image’ have indicated differences between industrial designers and engineers from both countries. Industrial designers from both countries agreed ‘end users input’ and ‘where the product is to
be used' are the most important factors in designing agricultural machinery and equipment. Engineering designers have indicated 'improving product quality' as the important factor. The research has identified 'improving product quality', 'marketing information', 'end user input', 'where the product is to be used' and 'increasing sales' as important factors in designing agricultural equipment.

The similarities were identified from both countries where performance, reliability, functionality, easy to operate, safety, quality and product testing have been identified as relatively important in terms of design considerations. Other factors which could be considered important are versatility, power, environment, ergonomics, cost, sizes, weight, aesthetics and manufacturing processes.

The quantitative survey has shown that industrial designers and engineering designers from both countries make use of a PDS more than other design methods. The other design methods most commonly used are Concurrent Engineering and DFMA among the UK's engineering designers.

There are slight differences between the UK and Malaysian respondents regarding the major contribution of industrial designers in designing agricultural equipment in the future. The UK's respondents have identified 'understanding design needs', 'analyse design problem', 'human factors considerations', 'brainstorming, concept selection', 'development drawing', 'CAD modelling' and 'material selection' as the major contribution from industrial designers. Malaysian respondents have identified 'sketches', 'preparing design specification', 'construct scale model', 'preliminary concept drawing', 'conducting research' and 'developing detail drawing' as significant contributions in designing agricultural equipment.

It was established from the results that there are similarities regarding industrial designers' skills which are likely to be important in the future in this activity from both countries. The results have shown 'working with other disciplines', 'interaction within a multi-disciplinary team', 'gaining basic engineering knowledge', 'good in communication' and 'expert in human factors and ergonomics' are skills needed by industrial designers if they are to be involved in agricultural designing activities in the future.

With regard to how industrial designers currently make a contribution to agricultural machinery and equipment design, it has been established that both disciplines from both countries believed that industrial design could make the 'product saleable' and 'improved ergonomics aspects' for agricultural products. Industrial designers are also capable of improving products' usage and improving product quality.
Chapter Five The UK and Malaysian Quantitative Survey (Questionnaire)

5.10 Summary

The quantitative survey has clearly shown the importance of industrial designers becoming involved in a broad range of agricultural machinery and equipment design activities.

The results based on the quantitative survey findings have shown evidence which fulfils the first three aims and objectives of this study. The aims and objectives were:

- To study the design processes implemented by UK industrial designers and engineering designers in the field of agricultural machinery.
- To study the role of industrial design in the agricultural machinery industry.
- To identify the type of design approach that is most suitable for use in agricultural machinery design.

In this study, discussion concentrated mainly on the nature of industrial design in the UK and Malaysia towards the potential contribution of industrial designers in agricultural equipment design. The UK respondents have revealed the involvement and the contribution of industrial designers toward agricultural machinery and equipment design. The results also proved that industrial designers have the capability to get involved with other disciplines in a design team, and has determined the stages in the design process in which industrial designers could best contribute. The importance of the design elements have been distinguished accordingly in providing the researcher with valuable information needed to progress with design projects and propose design guidelines.

The Malaysia quantitative survey results have shown meaningful output which has identified that industrial designers are not aware of the importance of their capability in agricultural machinery and equipment design activities. They have to expose themselves by approaching the organisations involved in this activity to provide assistance in whatever ways possible to change the scenario of typical agricultural designing activity.

The results also have identified the significant input required for industrial designers to be prepared for this design activity and have identified the potential contribution that could be made by them in agricultural design for local and regional use. Industrial designers have to prepare themselves with knowledge which is applicable to this activity not only with engineering skills but also science knowledge because this activity applies to the suitability of the machines from a plantation environmental perspective. The design criteria which the industrial designers usually use during the process of designing have been clarified which give the researcher an opportunity to produce meaningful and useful design guidelines to be used by Malaysian industrial designers who would like to engage themselves in this field.
CHAPTER SIX

Case Studies

6.1 Introduction

In this chapter the researcher carries out two design projects chosen from PORIM and RRIM. These are:

1. Oil palm loose fruit collecting device and
2. Coagulated latex collecting and transporting device.

The project from PORIM (collecting oil palm loose fruits) is a new project. There has been no attempt to design this type of device because they have previously concentrated on large machinery due to government priorities. The project from RRIM (latex collecting and transporting device) is a concept which has to be developed in order to achieve a successful and meaningful product. At the moment a version has been distributed to several rubber plantation workers to try it and it is undergoing field trials to test the feasibility, reliability and functionality of the product.

In this chapter sections 6.2 and 6.3 describe the meaning of the design projects and their limitations within the research programme. The following section 6.4 discusses in detail how the researcher has gone through the design process with the oil palm loose fruit collecting device design project.

Section 6.5 discusses in detail the design process from identifying a design need to producing a detail design for a coagulated latex collecting and transporting device. The following section concentrates on the problems and difficulties encountered by the researcher in the process of producing design proposals for these two projects. The findings from both projects are discussed in section 6.7. This chapter ends with a summary and the subsequent development of design guidelines is discussed in chapter seven.

6.1.1 Aims of the Case Studies

These two case studies were carried out to explore the potential contribution of industrial designers in projects involving Malaysian agricultural equipment. These were done as live design projects carried out by the researcher to investigate two current and significant problems in Malaysia.
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The aims were:

- To provide an opportunity to look objectively at the author's own approach to design, which has been typical of industrial design practice.
- To gain further insight and understanding of the real issues involved in designing for Malaysian agriculture.
- To provide a focus for triangulating the findings from the different areas of this research programme.

6.2 Approach to the Design Projects

The design process has been discussed thoroughly in chapter 2 which defined various design process models available. According to Dieter (2000) there is no single universally acclaimed sequence of steps that leads to a workable design. Different writers or designers have outlined the design process in as few as 5 steps or as many as 25. The important thing for the designers, whichever the design process taken, is that they deliver a good product by the end of the day.

Designing as an activity must be more or less creative, contain procedural and routine aspects, use existing knowledge, and involve some developed skills and their phenomenological realisation. Designing must be applied to an object and process to be designed, and the progress towards defining a system to fulfil a desired purpose characterises designing tasks (Eder, 1995). The design process involves a mixture of product planning, market research, engineering, technology, ergonomics and aesthetics (Williams, 1993).

The process and the activities show the overall sequence of the design process. The design process is very interactive and is constantly changing depending on the scope of work for each designer. The researcher has identified his design process as shown in Figure 6.1, developed as part of his practical work during the last 15 years teaching industrial design to mechanical engineering students at UTM.
The wording in the red box describes the limits of the design projects carried out by the researcher in this research programme.

6.2.1 Delimitation of the Design Projects

This research concentrated on two equipment designs, one from PORIM and the other from RRIM. In these projects, the researcher concentrated on producing design solutions by focusing on the various stages of the design process, as identified in chapter 5 which are:
6.2.1 Delimitation of the Design Projects

This research concentrated on two equipment designs, one from PORIM and the other from RRIM. In these projects, the researcher concentrated on producing design solutions by focusing on the various stages of the design process, as identified in chapter 5 which are:
• Clarification of the task
• Conceptual design
• Embodiment design
• Detail design.

This breakdown of the design process is very broad with overlapping stages. The more detailed breakdown shown in Figure 6.1, based on the researcher's usual practice at UTM, was used as a basis for the two projects.

The researcher had to disregard some of the design considerations such as producing mock-ups, scale models and prototypes although these are important in the process of designing agricultural products. The researcher made use of the knowledge and skill that he has as an industrial designer in these design projects to help to overcome the problems faced by both PORIM and RRIM agricultural engineers.

6.3 Design Project 1

Harvesting oil palm fruits is hard work and usually performed by youngsters or strong men because to cut bunches of oil palm needs strength and energy to bring the fruits down from the trees. Workers have to collect loose fruits from the ground after the fruits have been harvested. Collection of loose fruits is important because each fruit can generate extra income for each worker. The quality of the fruits will decline if they are left for quite some time so it is wise to collect immediately after harvesting the bunches. The problems include the time taken, separating the loose fruits from the plants and debris and the risk from snakes. The fruits nevertheless have to be picked up because it is costly to lose large quantities.

6.3.1 Background

Loose fruit collection has been a non-stop problem contributing to a decline in the extraction rate. This is as a consequence of the labour shortage and unavailability of proper devices or implements to assist in the operation. The loose fruits found at the base of the palm oil tree are shown in Figure 6.2. The percentage of loose fruits increases in areas with tall palm oil trees. These loose fruits have to be collected and the current collections are done manually by hand picking or raking. These techniques are not only time consuming but also inefficient. The percentages of debris, in the case of raking, can reach as high as 60% by weight. (Ahmad et al., 1995)
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Figure 6.2: Loose fruits happened during harvesting

PORIM have developed a mechanical loose fruit collector (Figure 6.3) which utilises a direct suction method with a separator in the pressure line. The suction is generated from an impeller fixed to an air-cooled petrol engine. The engine is fixed to a push-cart fitted with a two-compartment container, one for the fruits and the other for the debris. This push-cart system was designed in 1995 and from then onward this machine has undergone exhaustive field trials. Based on the results and feedback from the estates management, it was found that the push-cart type machine working coverage was low because the operator has to walk and push the collector. A self-propelled type collector machine has to be developed to suit the requirement from the estates. In 1999, the mechanical loose fruit collector known as ‘MK II’ was designed (Figure 6.4) which has undergone various field trials.

The latest design was found to increase productivity per worker compared to the previous collector but until today PORIM is putting more effort into improving the machine in terms of productivity and cost. This machine is not suitable for small and medium scale working, which make up to 80% of the oil palm workers’ population, and it has not made tremendous improvements to the work task in the plantations. It proved to work well in areas accessible to the machine but most of the oil palm trees are planted in undulating areas which this machine cannot access. Palm oil trees are often planted in hilly areas. The oil palm production industry is divided into estates and smallholdings. The surroundings can be
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classed into two types, which are firstly well organised clean plantations, normally belonging to estates, and more overgrown areas which belong to individuals and some of the smallholders' organisations.

Figure 6.4: The latest version of mechanical loose fruit collector (MK II)

From the interviews conducted during three months in Malaysian, the researcher has discussed with several PORIM agricultural engineers his intention to carry out design projects. They urged that the researcher focused on the projects related to small and medium scale palm oil industries. Many investigations have been carried out for producing loose fruit devices for small holding workers (Figure 6.5). Unfortunately at present not a single successful device has been designed for this level of people, who can't afford to buy the mechanical loose fruit collector if it is available in the market.

Figure 6.5: Manual oil palm loose fruit collection device.

Oil palm industries have to undergo several stages before the end product can be exported to the countries, which use palm oil for their products. Palm oil has been scientifically proven to be low in cholesterol and can be transformed into many type of products such as cocoa butter equivalent, vegetable gee, vegetable fat etc. At the moment, PORIM is still doing research using palm oil as a substitute for diesel. In the future it is possible for palm oil to be
used as fuel to run vehicles which normally use diesel. PORIM is also undertaking research to use palm oil trunk for furniture, which can last longer.

Oil palm trees were recognised to be profitable trees some thirty years back. The palm oil plantation process can be categorised into four stages:

- Crop and plantation care
- Fruits harvesting
- Collecting and transportation
- Processing

Harvesting can be done after trees reach seven to eight years old and will be carried out in two stages, one for low trees and the other for higher trees. First, the stalk has to be removed followed by cutting the fruits. The fruits are left on the ground and collected later on the same day. A plantation is divided into several stages for harvesting. Normally they will be harvested every three to four days so within a month, fruits are collected from six to eight times. The workers will come back to the same tree after three weeks, sometimes longer than that.

Collecting oil palm fruits is a tiring process, especially in a hilly area because the workers have to carry the fruits in limited numbers of bunches. Three to four fruits can be placed in a wheelbarrow and carried to the end of each row. Normally the terrain will be divided into several sections and in each section there will be at least one wider space to enable lorries and tractors to move around the hill to collect fruits, to transport workers, to bring fertiliser and pesticide from factory to plantation area etc. Collection of oil palm fruits is also divided into two stages, first, collecting the fruit bunches then loose fruits. Palm oil plantations usually have their own processing plant to produce palm oil. Smallholdings usually sell their fruits to traders.

Palm oil processing undergoes several stages, all being controlled by machine operators. The only problem during processing is how to avoid wasting all the fruits shell, stem etc. At the moment a small percentage of this material is used as natural fertiliser for certain garden and vegetable plants but the problem is the smell. Most of the waste is destroyed either by burning or burying. In this process there are not so many difficulties, the machine operators and quality controller have to maintain the operation running smoothly to achieve high palm oil qualities.
6.3.2 Clarification of the task

This stage included realisation of the design needs, analysing and definition of the design problem, and research. This stage has to be specified adequately because the design activities will be generated from this stage and if this is done inadequately various problems can result during the process of designing. This stage should start by writing down a problem statement, which expresses as specifically as possible what the problems are. It is easier for the designers if they receive a concise design problem from their management or clients because it is already clear what they should come out from the clear statement given. However, not all design tasks are well defined and the designers have to work hard to define the problems which should be considered before design activities start.

Before starting to attempt to solve this problem the researcher sat down and discussed with PORIM agricultural engineers what exactly the problem is. During one week at PORIM, the researcher had the opportunity to visit the plantation and observe the work carried out by the workers to see and understand the actual problems facing them. The workers were also questioned to gain more information on the problems.

Once the problem was understood a design brief was produced as a very short statement describing the problem to be addressed. It must not be so detailed that the designer doesn't have the freedom to be creative.

After these have been covered, a design specification has to be produced to enable appropriate design concepts to be generated for further development. This is the stage in the design process where the researcher applied his own skill and knowledge to solve the problem set out in the design brief and satisfying the specification as closely as possible. The specification can be modified throughout the project before the final design stage as long it fulfils the need and the criteria set by the management or by the clients.

6.3.2.1 Loose Oil Palm Fruits Collecting Device

Every palm oil plantation during harvesting has to waste a lot of time asking workers or labours to collect loose palm fruits. This has to be done because each fruit means a lot to the company or individual. If the fruits are left for some time it will destroy the qualities of the end product so somehow it has to be collected. The solution might be a mechanism, device or instrument to do the job. The loose fruits is very costly when it is in large quantities.

Project Brief:
Loose palm fruits happen when a fruit bunch is cut down from the tree. They spread over the ground where the fruit bunches fall. These happen to all the fruits in the plantation during harvesting. The normal procedure, involves workers collecting manually by picking or
brushing all the loose fruits, bringing them together near each tree then placing in a bucket or plastic bag. This procedure is time consuming. There is a need for some kind of mechanism, device or other type of instrument to help the industry to overcome the problems of loose palm fruit collection.

**Design Problem:**
- Oil palm fruits are scattered throughout the area during harvesting.
- Oil palm fruits may be mixed with all types of rubbish.
- Always collected separately from palm fruit bunches.
- If left out for some time the fruits deteriorate.
- Picking or collecting loose palm fruits is very time consuming.
- Buckets or plastic bags with loose palm fruits are quite heavy to transport.
- Usually this work is done by elderly people, women and children.

**Initial Design Specification:**
- The device must be capable of picking up the loose fruits.
- It must able to move easily on the rough ground surface and along the hills or terraces.
- It must be very easy to use, and not have any complicated controls.
- It must be completely safe for the user and also to the fruits.
- It must able to be transported by the user after collecting the fruits.
- It must have the capability to do the job quickly and consistently.
- It must be neat and attractive.
- It must be cheap to operate.
- The cost must be reasonable.
- Single-person operated.
- Easy to maintain.
- Not too heavy

The researcher has to understand the environment of the palm oil plantation and what are the restrictions and obstacles that have to be taken as priority factors before any design work can be carried out. The design focuses on producing devices which could be afforded by individuals, and smallholders as well as workers in the estate.

Plantations owned by individuals normally range between 12 to 30 acres. The palm oil trees produce profits from 5 years (Figure 6.6) after being planted in the plantation and the fruits can be harvested for up to 25 years. The tree then has to be replanted because:

- It too high to harvest
- It is not economical
- The fruits are damaged badly after falling from very high trees
- Too many loose fruit occur
Figure 6.6: The left diagram shows the young trees ready to be planted in the plantation (1 year old) and the right diagram shows trees more than 25 years old.

The plantations are divided into sections, with the distance from one end to another of 400 meters. At the end of each section there will be a road known as a 'collection road' (Figure 6.7). Lorries use this road to collect bunches of oil palm fruits left by workers after they finished harvesting the fruits. Workers work in two directions – 200 meters on both sides. Harvesting is done every 3 to 4 days on the same plantation because not all the trees in each section produce fruits to harvest. Individual farmers and smallholders also do different types of work to gain extra income by planting vegetable fruits, fishing, making traditional craft etc. On the occasions they do not harvest, they do cleaning, pruning, clearing, use pesticide or fertilise the area. Transporting bunches of oil palm fruits is done by lorries (Figure 6.8) and loose fruits are carried by motorcycles to the processing plant.

Figure 6.7: Bunches of oil palm fruits left on collecting road ready to be transported to processing plant

Figure 6.8: Lorries used to transport oil palm fruits to processing plant and motorcycles used to transport loose oil palm fruits.
The planting distance from one tree to another is between 8.5 metres to 9 metres (Figure 6.9), and the numbers of trees planted in each acre vary between 52 to 60 trees. The distance between rows in each planting area is 7.5 to 8 meters. The economical distance from the plantation to the processing plant is within 50 kilometres radius. As mentioned the fruits cannot be left for too long in the plantation to avoid deteriorating in terms of quality.

![Figure 6.9: The distance between trees in the plantation](image)

Picking loose oil palm fruits is exhausting especially for elderly people, women or children and these are the people who help to gain extra income for the family. Every single loose fruit means a lot to them. Sometimes they are faced with unpredictable risks such as dangerous animals, for example snakes, which are encouraged in the plantations to prevent the fruits from being eaten by mice. Elderly workers and women usually suffer from back problems because they have to bend quite often to pick loose fruits, scattered in the bushes as illustrated in Figure 6.10.

![Figure 6.10: Loose fruits have to be picked by individuals in bushy areas.](image)

### 6.3.2.2 Preliminary design concept

Having gained an understanding of the situation of the plantation and identified the main problems the next stage was to start producing several preliminary designs, which address the problems.
Figure 6.11: First preliminary concept idea for oil palm loose fruit collecting device.

Figure 6.11 shows one preliminary concept idea which the researcher felt solved certain areas within the design problem and answered some of the design specification stated at the beginning of this section. This concept shows a device of a pulling type and the centre of gravity is offset to allow the back part to always touch the ground. The handle can be adjusted to allow any age and any height of user to use this device comfortably. The workers can either brush the loose fruits and gather in one place or it can be brushed straight into the device by using another device to replace the broom usually used by workers. This brush is designed to suit the main collecting device. The end of the broom is made of thin metal plate mounted with plastic to avoid any damage to the fruits. It can easily be replaced when worn out. The workers can push the handle until the front part touches the ground and loose fruits are pushed into the container. If the container is quite hard to push down, the workers can step on top of the container for loading loose fruits. Then the container is pulled to another location for collecting purposes. Loose fruit can be poured straight into a sack and transported to the processing plant.

The following diagrams illustrate different types of preliminary concept idea that were examined. These preliminary concept ideas have differences in terms of operating in the plantation and also a different way of collecting loose fruits. Concepts were evaluated by looking at all aspects with respect to design considerations to determine the best. The researcher proceeded with four preliminary concept ideas for further development.
The above diagram shows a different type of preliminary concept using a manually propelled mechanism. The worker has to push the device forward to allow the loose fruits to be collected and pushed towards the polybag located on the handle. When the polybag is full with oil palm fruits, it then can be replaced and the work task continued. The problem with this device is at the mechanism part where it cannot separate the debris from entering the polybag. Also it is not possible to collect loose fruits in bushy areas and near to the tree trunk. The other problem observed from this method was that the mechanism is always in motion when the device is moved from one place to another. This could wear the system quite quickly.

![Punching/pushing type of collecting devices](image)

Figure 6.13: Punching/pushing type of collecting devices

Figure 6.13 shows two preliminary concept ideas which used punching or pushing movements to collect loose fruits. The left diagram is vertical type where the worker goes around where the loose fruits are situated, aligns the device with loose fruit and pushes the device down to allow the fruit to pass the rubber diaphragm, and so the process goes on. The fruits will push one another up until the container attached to the pole is full. The principle works but it may take too much time for the workers to finish the task and the quantities collected are not sufficient. This is the same for the concept on the right hand side of the diagram. The only difference is the position of the pole and the container for the fruits to be collected.

![Self propelled type of collecting loose fruits device](image)

Figure 6.14: Self propelled type of collecting loose fruits device.
The next preliminary concept idea as shown in Figure 6.14 illustrates the use of a rotating brush driven by a rubber belt from the front wheel. This concept has the same problem as the concept in Figure 6.12. The advantage of this concept is that it collects more fruit. It still cannot stop the debris from entering the container and the other problem which might occur is the rotating part stopping or becoming damaged by contact with hard objects. Also the belting might wear out quickly because of vigorous use by the workers. The worker has to tilt it up to move to another location but if they fail to do this then the possibility of damaging the rotating part is very high because it will keep rotating as the front wheel touches the ground.

![Figure 6.15: Carried type of device for collecting loose oil palm fruits](image)

Figure 6.15: Carried type of device for collecting loose oil palm fruits

Figure 6.15 illustrates a concept, which has the similarities with concept Figure 6.11. The differences between the ideas are the size and method of transporting the device from one location to another. This concept requires the worker to lift up the device to move to another location (Figure 6.16). The problem the researcher could identify were unwillingness of workers to carry the device, most probably they would pull the device and the likelihood of damaging the bottom part of the device is very high. Although the material used for the device is strong and quite light for them to carry, the possibility of pulling the device on the ground is always present. From the observation it is easy to visualise how the workers would treat this device, and to prolong the life of the product will be impossible. It is also not suitable for the children. Although the handle can be adjusted for carrying position the total height is not ergonomic for them and it will be quite heavy if the device is full with loose fruits.
Figure 6.16: Way of lifting the device to move to another location

Figure 6.17 shows another type of preliminary concept idea, which has a high capacity for loading loose fruits in the container. The advantage of the idea is that the worker does not have to unload the fruits from the container, they can be transported straight to the processing plant using a motorcycle. The motorcycle passenger can hold the handle by folding in the back wheel to allow smooth movement during transport. The container is designed to support up to 40 to 50 kilos of loose fruits. The front mechanism is manually slid up and down to collect the fruits. The sliding part will be at the upper position when it is not used to collect loose fruits. The problem foreseen from this concept is that the product will be very costly because of the size and the moving mechanisms. Even with careful design these systems could increase the total price of the product. During discussions with the workers it was found that they are willing to spend not more than RM100.00 (approximately £18.00). Smallholder workers usually get help within their organisation management by spreading the payment over several months.

Figure 6.17: Lifted device type

The next preliminary concept idea in Figure 6.18 was based on a trolley or pushchair. The whole body was supported with a structure. It has four wheels for easy manoeuvring in the plantation. The sack is filled with loose fruits and when it is full, the sack can be taken out by
loosening the top ring and replacing with a new sack. The difference from the typical work task is that this collection method is equipped with the device that can be pushed easily instead of a small sack bag that has to be carried manually from one place to another. The method of collecting will be the same as current practice. The workers use brooms to brush loose fruits and gather them in one place, then the workers use their hands to place all the loose fruits into the sack. The worker has to bend down several times to pick and put the fruits into the sack. This will obviously create back injuries if he or she has to perform this type of collecting for the whole afternoon.

The other problem with this concept is the choice of the wheels. The thickness of the wheel has to be suitable to the environment and the diameter of the wheel has to be appropriate because the cost of the wheel is quite expensive. The total cost of the product could reach more than that expected. The rear wheel can be folded for easy transportation to the processing plant if the worker decide not to dismantle the sack from the unit as described from diagram in Figure 6.17.

Figure 6.18: Trolley type

Figure 6.19 shows a preliminary concept idea derived from the device usually used by workers working for the council. The researcher used this principle to come out with a device which can be used for collecting loose oil palm fruits. The principle seems to be functional but in terms of suitability, economics and reliability it can be questioned. The researcher feels it is not suitable for use in collecting loose fruits because the quantity that can be collected is minimal and workers have to have another container with them to fill with loose fruits. The other problem which might arise is how loose fruits which have been collected remain stable in the compartment. Workers will also face difficulty when collecting loose fruits in bushy areas.
The diagrams below show completed arrangements for devices to be used for collecting loose oil palm fruits in palm oil plantation. The principle used is a wheelbarrow type. In this concept, the design uses only two wheels instead of four. This will reduce the cost of the end product because the wheel is the most expensive item in the product. The stick used to collect and push loose fruits into the container is the same thing, which has been discussed earlier in this section. The advantage of this concept is that the container can be separated from the structure after it is full. Workers can place full containers at collecting points and carry on with collecting the remaining loose fruits. The problem which might occur is when the container is full and the worker would like to replace with an empty container, it is hard to lift the heavy container. The other problem is to balance the device during manoeuvring in the plantation when the level is undulating and the device has to cross from one row to another, especially when it is covered with bushes.

The researcher decided to develop four out of the ten preliminary concept ideas discussed earlier. These preliminary concept ideas are from Figures 6.11, 6.15, 6.18 and 6.20. In identifying which are the outstanding preliminary concept ideas for further development, design criteria are considered to fulfil the product design specification requirements. The
design criteria have been specified by the researcher based on information from the interviews and questionnaire survey. These are:

- Performance
- Function
- Easy maintenance
- Easy handling
- Safety for users
- Easy transporting
- Manufacturing cost
- Weight
- Size
- Life in service
- Operation procedure
- Aesthetics
- Ergonomics
- Materials
- Environment friendly
- Cheaper operation

Researchers' evaluation are based on his own observations and his skill and experience. In deciding which concepts should be carried on for further development the design criteria above were considered in an informal process towards achieving an outstanding design. In chapter 7 the value of using Pugh's concept evaluation chart is discussed.

After evaluation of the preliminary concept ideas, the next step is to develop the chosen concept. This stage, referred to as the concept development stage, will still be classified under the conceptual design phase. According to Dieter (2000) conceptual design is the process in which the design is initiated, carried to the point of creating a number of possible solutions, and narrowed down to a single best concept. Conceptual design is the phase, which requires the greatest creativity, involves the most uncertainty, and requires coordination among many functions. This stage is the most demanding stage in the design process because every aspect of design consideration has to be fulfilled to achieve the minimum defects in the final design proposal before it can be tested in the field.

6.3.2.3 Concept Development

Concept design aims to produce design principles for the new product. These should be sufficient to satisfy customer requirements and differentiate the product from others on the market. Concept design is about producing a set of functional principles of how the product will work and a set of styling principles for how it will look. According to Baxter (1995) to have
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a successful concept design, designers have to generate lots and lots of concepts and then
select the best among all the concepts available. Concept design includes the stage of
product development, which usually demands the greatest creativity.

From the preliminary concepts, four have been identified for further development towards a
final version of a design proposal. The researcher will limit the number of illustrations on this
section to concentrate on two concepts just to show how he has gone through from
preliminary concepts into developing those ideas and derived a final design proposal which
fulfils the design specification requirements.

Figure 6.21 shows the final version of concept development, derived from preliminary
concept ideas where the working principle is from a wheelbarrow type of device. The
diagram above is divided into three parts. The sections in colour use plastic as the material,
grey in colour is the structure made from metal and the other part is the wheel which can be
found, bought or ordered direct from the supplier if the unit is going to be produced in
quantity. Before the design reached this extent a large number of development sketches had
been produced to identify the best options for the product. Figure 6.22 shows the
development to find the possible solution for a structure to hold the container, how to fix the
wheel firmly to the structure and which is the best option for the overall arrangement for the
product.
Figure 6.23 shows the structure used to support the container with two type of material forms illustrated. The bottom left shows the structure using round metal tubing to form the structure and the other uses rectangular sections. The top sketches describe the front part of the product which functions as a scoop, although it is not used to scoop the oil palm loose fruits because the fruits will be brushed from the ground along this area into the container. The idea of having this separated is for easy maintenance and easy replacement if damaged.

![Figure 6.23: Development searching for suitable structure and 'scooping' part](image)

The container used in this concept as mentioned in section 6.4.2.2 can be taken out from the main product for the purpose of easy transportation to a processing plant if the quantity of loose oil palm fruits are too many on that collecting day. The worker can estimate how many containers are sufficient. If the worker feels that one is enough because there are not so many bunches of oil palm to be cut down, then the worker can use a motorcycle to pull the device straight to the processing plant. Figure 6.24 shows the shape of the container, the structure to strengthen the container, the arrangement when the container is not in use and detailing of where the container will attach to the structure.

![Figure 6.24: Development for the container](image)
The next preliminary concept to be discussed is from Figure 6.11. The principle of this idea is the pulling type and the worker either uses a handle or their feet to push the device so that the front section touches the ground and oil palm fruits can be pushed into the device. The device comes with two units which are the main collecting device and the stick used to gather and push loose fruits into the container. The stick is an option depending whether the users would like to have it or not. Figure 6.25 elaborates how the rear wheel is going to look and what is the best solution to fix to the main body. The body will naturally rest in the position where the rear wheel touches the ground to allow loose fruits to stay secure in the container.

![Figure 6.25: Arrangement of rear wheel](image)

The following diagram shows method of collecting loose fruits into the container. As mentioned, collecting using this device can be performed in two techniques, which either use the handle or feet i.e. when the container is nearly full with loose fruits. The part where the feet will be placed is designed using a different material to protect the body from damage. This section has to be designed efficiently to avoid breakage when frequently used.

![Figure 6.26: Method of pushing the device downward to scoop in loose fruits](image)

The researcher with the help of his supervisor, has carried out some evaluation on the developed concept idea. The idea totally came from the researcher’s point of view to show
that industrial designers have the skill and knowledge in designing agricultural equipment if
the opportunity is given to them to be part of a team. As mentioned earlier the use of design
evaluation charts will be discussed in the following chapter. The intention is to develop
design guidelines to help Malaysian industrial designers who have the intention of joining this
type of agricultural machinery and equipment design activity. The researcher evaluated the
developed concept designs by considering the design criteria set earlier and focused on
achieving the requirements stated in the design specification as closely as possible. Figure
6.26 is the design chosen as the one which will proceed into more detail to see the problems,
advantages and how the mechanism will look to give an idea of how it should be assembled
later.

6.3.2.4 Detail design

Detail design in this section is not taken to the stage where the final design could proceed to
manufacture of the end product. This detail design section, which gradually evolved from the
clarification of the task until a proposed final design, would not eventually require so many
modifications or changes if it had been evaluated by members in a design team.

Figure 6.27: Final concept design proposal

Figure 6.27 shows the final concept design proposal. The following diagram (Figure 6.28)
shows the knob detail arrangement to secure the handle to the body. It has several
components, consisting of washers, bush, bolt and knob placed to the body on the main
device. The material for bush and washers are from plastic types, which should avoid a lot of
friction. The bolt is placed from the inside of the device and fastens firmly with the knob.
Figure 6.28: Assemble detailing of the handle to the body

Figure 6.29 shows a section of the device. The purpose of this drawing is to show how the total device looks. The diagram shows the inside part of the section secured to the shaft of the wheel and how the wheel compartment aligns with the main body. It also shows the additional material placed on top of the body where it is used to step the device down while collecting loose fruits. There is no partition inside the device to keep it smooth for fruits to be unloaded from the device. Nothing can stick and the inside compartment can be kept in good condition.

Figure 6.29: Section drawing for proposal final concept design

In the final proposal concept design does not show the detailing of how the handle can be adjusted to the height required by the users. Figure 6.30 shows the procedure as an alternative to be used by any ages and height. Before use the worker has to adjust to their suitable height to avoid any pain occurring during the process of collecting fruits. The researcher used only one knob on each end to minimise the cost of the product and the system has to be designed precisely so that the two plates of the handle do not oscillate when the product is used.
Rubber production and the rubber-related manufacturing industry are among the most important agricultural-based industries in Malaysia and a lot of effort is being made in Malaysia to increase the efficiency of rubber-related manufacturing industry. Rubber production is carried out in both estates and smallholdings. An estate normally covers a very large area, with 40 or more hectares of cultivated land. The estates are labour intensive so the owners hire workers. Smallholdings have an average plot not more then 3 hectares. A family owns these small plots of land and they have to do the work themselves since they could not afford to pay for hired labourers.

In this design project, the researcher studied in depth the problems of collecting coagulated latex. Although there are hundreds of problems in rubber-related industry, collecting coagulated latex was highlighted. The issue of how industrial design could contribute to improve the current situation is discussed in the following section.

6.4 Design Project 2

To plant rubber trees, whether in the smallholdings or in the estates, there are several steps. Young rubber trees have to be selected from the best stock. There are two most popular methods to grow young rubber trees, which are stump budding and polybag budding (Figure 6.31). Stump budding is preferred because it reaches maturity faster compared to polybag budding. Good maintenance of rubber trees such as regular weeding, proper cover crops control, adequate fertiliser and pesticide will produce a higher latex yield.
Tapping involves severing the latex vessels in the bark. It is essentially a process of controlled wounding of the tree to produce latex. Tapping allows the planters to regulate the production of rubber. Tapping has a number of methods and once a better system of tapping is found, planters are recommended to use the new system so as not to damage the tree and to prolong the yield stimulation. Milk collection is the most popular. This method requires the tappers to go round and collect after tapping is finished. Now the tappers also like to collect coagulated latex which is quite easy compared to milk collection because it can be collected on the next day. Also the tapping work task can be performed straight away after emptying the cup.

The effort of upgrading the efficiency and productivity of rubber-related manufacturing industry includes the effort to produce high-yielding clones of rubber. Efforts have to be made to improve the organisational structure of the rubber industry in the smallholding sector and to advise the rubber estate management on methods and procedures that should be adopted. There are various procedures to be carried out before the natural rubber is turned into consumer products etc. There are:

- Crop and plantation care
- Tapping
- Collecting and transportation
- Processing

As mentioned this research concentrated on collecting and transporting coagulated latex. There are three methods of rubber collection:

- Milk collection
- Coagulated latex collection
- Polybag collection
Within these three, milk collection is the most popular. The latex is collected from the cups hung on each tree and transferred to a collecting bucket. In the estates, buckets full with latex are placed by the roadside in the plantation and lorries belonging to the estates collect the buckets and transport them to the processing plants (Figure 6.32). Smallholders usually transport their latex to the collection point or processing station by motorcycle, bicycle or 'kandar' stick (Figure 6.33).

It may be appropriate to make the distinction between crop lifting and crop collection. Crop lifting involves emptying latex from cups into buckets and is normally performed by the tappers themselves, or with the assistance of family members, and can be considered as an intrinsic part of the tapping operation. Collection means the tapper carrying latex in buckets slung on a kandar stick as illustrated above to the processing plant or factory (Hussain, 1986).
The researcher visited RRIM station at Sungai Buluh, Selangor during his three months in Malaysia. From the interviews, RRIM agricultural engineer mentioned that he has to change his concept from producing high-tech mechanical devices to devices which can be afforded by low income individuals and smallholding workers. These people generate more income for the country than the estates according to Bachik (1999) as illustrated in Figure 6.34. The first product that he produced was known as the 'Lanca-GM' which is a multi-purpose transportation device.

![Figure 6.34: Malaysian rubber Production in 1998 by Sector (000 tonnes)](image)

The purpose of producing this device is to assist in reducing the problems of collecting coagulated latex in new exploitation areas as an experiment toward enhancing traditional type of collecting, and also to increase the worker's incomes. This product had been tested in several plantations and it is proven to reduce operating workload (Figure 6.35). RRIM agricultural engineers tried to produce this product for less that RM80.00 (£14.50) because the workers can't afford to pay more.

![Figure 6.35: 'Lanca-GM' used in rubber plantation](image)
From the researcher's own observations in the plantation, almost all the workers have made a few modifications to suit their working environment. The most obvious is that they fasten the device to their motorcycles, which they use to travel to and from the plantation (Figure 6.36). From the worker's feedback, this 'Lanca-GM' can be used for other purposes such as transporting fertiliser to the plantation and water to the cultivated ground for other crops planted by workers for extra income. The main reason RRIM agricultural engineers designed this device was to help workers to collect latex and coagulated latex. After visiting a new experimental exploitation system area in one of the rubber plantations in Pahang, we found out that this device has been used for other purposes rather than collecting coagulated latex. There were a lot of things that the engineer has to look at to reduce the weaknesses apparent during first observations on the product.

The researcher observed that there were several things which he felt could be changed to make the product more successful in terms of shape, jointing, easy manoeuvrability, attaching to motorcycles, and unloading the goods. The researcher discussed his intention with the RRIM engineers to undertake this project for his case study to provide industrial design input to the product for research purposes.

### 6.4.2 Design process used

In this design project the researcher still used the same design process mentioned in Figure 6.1, which he has used in teaching industrial design in UTM, and in his design activities within universities and consultancy work. He intended to use his knowledge and skills in producing a design proposal to enable the product to perform well and ensure that it has the capability to be marketed regionally, not only for the purpose of collecting latex and coagulated latex. The product could also be used for other purposes rather than activities in the plantations.
6.4.3 Coagulated latex transportation design project.

Coagulated latex is a form of milk changed to coagulated form that has been left for one or two days after the rubber trees have been tapped. It is collected and at the same time rubber trees are tapped, the workers do not have to come back in the afternoon on the same day to collect latex because the management in this particular plantation had decided to have the coagulated type of latex. This case study concentrates on a product, used to collect coagulated latex.

At present in this new experimental area, the workers use plastic sacks and plastic containers to transport their coagulated latex from plantation to the collection point as shown in Figure 6.37. These methods create difficulties for the workers during loading and unloading the goods. These methods require two people to perform the work task because it is heavy to lift a plastic sack or container onto the motorcycle and lift it down at the collecting point. The other difficulty is to take out the coagulated latex from a plastic sack and also the quantity collected is small compared to using the ‘Lanca-GM’.

As before a project brief, design problem statement and design specification were generated in order to fulfil the requirements of rubber plantation workers.

Project Brief:
Coagulated latex is collected on the following day after rubber trees have been tapped. Rubber trees are planted either in plain or hilly areas and the plantation may be very overgrown. Workers walk from tree to tree collecting coagulated latex and at the same time tap the trees. When the bucket is full with coagulated latex, they gather it at the end of the plantation and carry on with the task. They will then put it either in plastic sacks or plastic containers and transport it to a collecting point. This method is very tiring and time consuming. A product has been produced to overcome the problems but is still under
development. The product has shown improvement on the current practice and it has to be
developed further to overcome several weak aspects. This could turn it into a more
successful product.

Design Problem:
- It is heavy to lift the plastic sacks and plastic containers from motorcycles.
- Coagulated latex left along the roadside has a high percentage of rubbish mixed with it,
  which reduces the income.
- It is very uncomfortable riding a motorcycle in the plantation, which has no proper road.
- The current practice has to have at lease two workers to perform the work task.
- Collecting coagulated latex is very time consuming.
- Unloading coagulated latex from plastic sacks is quite difficult.
- The quantity collected is small and the workers have to commute several times from
  plantation to collecting point.
- The motorcycles are damaged quickly because the parts are exposed to coagulated latex
  liquid.
- The incidence of back injury is high.

Design criteria:
- The transportation device should be able to be driven in plain and hilly areas and also
  along the terraces.
- The device must traverse rough ground or muddy sites and climb gradients.
- The width of the device enables it to move freely along the terraces.
- The tyre design must suit the soil and must be suitable for both plain areas and terraces.
- The compartment size must reduce the workers' need to commute several times.
- It is more practical if a single person can operate it.
- The price of the vehicle must be reasonable to give smallholders the opportunity to own
  it.
- The device can be attached to a motorcycle to drive the goods straight to a collecting
  point or processing plant.
- The device must not be too heavy to avoid any difficulties during operating along
  terraces.
- The device has the possibility to be used for different purposes.
- Easy to maintain and repair any minor damage during operation without having to send to
  a workshop.

Initial Design specification:
- The device must be capable of transporting coagulated latex.
- The device could be used to collect coagulated latex from tree to tree.
- It must able to manoeuvre easily on rough surfaces, along the hills and terraces.
- It must be easy to use.
• It must be completely safe for the user and other workers.
• It should have the capability to perform other work tasks.
• It must be neat and attractive.
• The cost must be quite reasonable.
• Single-person operated.
• Easy to maintain.
• Not too heavy.
• Material chosen has to be suitable for the environment.

6.4.3.1 Preliminary design concept

The researcher produced several preliminary design concepts after gaining an understanding of the design brief, design problems, design criteria and design specification mentioned above. The sketches concentrated on the overall shape to acquire the suitability for collecting coagulated latex and also to have the possibility to be used for other purposes. Figure 6.38 shows the first preliminary concept idea derived from the existing product. The existing product, shown in Figure 6.35, has a semi-circular back different from the diagram shown which has changed the position and the material used. The following diagram in Figure 6.39 shows several preliminary concept ideas to generate alternative concepts.

![Figure 6.38: Preliminary concept idea derived from existing product](image)

![Figure 6.39: Preliminary concept ideas for coagulated latex transporting device](image)

Figure 6.40 shows another type of concept which focused on the idea of a compartment so that the quantity of coagulated latex can be maximised. The diagrams show two-dimensional
sketches to accelerate the ideas and help the designers to come out with other types of concept ideas.

Figure 6.40: Preliminary concept ideas

The following diagram shown in Figure 6.41 have different styles, illustrated in three-dimensional sketches. The researcher wanted to have a clear view for further development of the chosen concept ideas. Several geometrical shapes were tried to distinguish the most suitable in terms of simplicity in making the product, the strength, the loading capacity and the aesthetics of the product.

Figure 6.41: Preliminary concept ideas in three-dimensional shape

From these sketches the researcher was able to identify the most outstanding preliminary concept ideas and proceed with developing those ideas to fulfil the requirements stated in the design criteria and design specification.

6.4.3.2 Concept development design stages

The concept development stage required the researcher to express his skills, experience and knowledge to maximum capability because this stage required a full understanding of how the product is going to perform, what are suitable mechanisms, how the materials are chosen and how the mechanisms worked. The researcher would like to show the stages from preliminary concept ideas into development of those ideas to reach the final design proposal. It is useful to the design team to evaluate and focus more detail into the design before it is
ready to go into detailing and prototyping to observe the functionality of the product by testing it in the field before it is manufactured.

Figure 6.42 shows the development stages derived from preliminary concept ideas from Figure 6.39. The first sketch illustrates the form and the position when coagulated latex is being unloaded from the device. The front section has been angled for ease of scooping. The second diagram shows the form, structure and material proposed. It also shows the position when it is tilted for unloading purposes. The compartment is made from metal and wood. The wood is used to minimise the corrosion problems because latex contains a corrosive liquid. The third diagram shows how the handle is fixed to the main structure. These ideas will be evaluated and the suitable handle for the product will be identified in the following section.

The following diagram (Figure 6.43) shows concept development design to find and to detail the arrangement of the material. The diagram illustrates the possibility of the wood being fixed to the welded metal structure to add strength. The diagram shows how the overall structure will look when assembled. The only part not included in this diagram is the handle, which would give an overview of the total design.
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Figure 6.43: Development ideas showing the material arrangement and final design proposal

Figure 6.44 shows a development which the researcher determined from Figure 6.39. It shows the position of the door to unload the goods from the device. The material chosen is the same as used in the previous product. The door is opened from right to the left and the device is tilted down to allow coagulated latex to be scooped out from the device to a lorry to be transported to the factory. The diagram also shows the type of locking device used in this product to ensure that the door is secure while transporting the goods from plantation to collecting point.

Figure 6.44: Development stages to show the mechanism and the position during unloading the goods

Development from preliminary concept ideas has shown various alternative solutions, which determined the project could proceed until the ultimate design can be produced. The diagram in Figure 6.45 shows the final concept development stage which the researcher is optimistic can perform the work tasks within rubber plantations as well for other purposes such as
transporting fertiliser, pesticide, equipment used during pruning, clearing and cleaning from the house to the plantation. For this concept the use of material is differentiated into two sections. The top part of the product uses metal and the bottom part uses wooden to give maximum strength to the product. The purpose of doing this is the ease of replacing the material if the bottom part is damaged. One disadvantage of this concept is at the opening section where the door could become damaged during tilting the device to unload the goods.

These case studies have demonstrated that industrial designers have the potential to be involved in agricultural machinery and equipment design activities. The researcher limited his illustrations to identify a basic scenario of how he practises design activities within his university and in carrying out consultancy work. The next section discusses the chosen developed concept and the detailing part, which he felt was necessary to focus on providing various options for the design team to consider in the final design.

6.4.3.3 Detail design

According to Baxter (1995) “detail design takes what ever output arises from embodiment design and determines, in detail, how the product will be made”. He added that in detail design, designers have to decide which components will be bought in, which will be manufactured, a specification must be prepared for each component and the output from detail design is a full ‘product specification’. All those specifications set the targets for the product’s performance and appearance and quality control procedures to show how this is achieved during production”.

Cross (1991) described detailing as the last phase of the design process. The quality of the work in this phase must be good, otherwise delay and expense or even failure will be incurred. Dieter (2000) also defined the end of the design process to be detail design. The
The first task of detail design is to complete the detail drawings. One important thing that the designers have to decide is whether to make a component in-house or to buy it from an outside vendor. Testing has to assure that the components and assemblies meet the requirements laid down in the product design specification.

The researcher would like to express his terms of detail design in this section, which he found parallel to what has been described above. Detail drawings showing all the dimensions for production purposes are not provided but the diagrams show the detailing of components, illustrate their functioning and indicate how they may be produced. Design considerations such as producing scale mechanism mock-ups to see how well the system works in principle would have been important in a full design project.

Figure 6.46 shows the final concept design derived from the concept development discussed earlier.

It is inevitable that there are weaknesses in this final design because it has arisen from researcher's point of view only. He took the design problem and design specification mentioned as a general rule to emerge with preliminary ideas, development and gradually come out with a final design. The following diagram in Figure 6.47 shows the detailing part of the final design, which helps to identify the issues in producing the end product. The diagram shows the supporting leg, which allows the product to stand freely by itself and how the supporting leg is folded towards the body for easy manoeuvring in rubber plantations. The diagram on the top right hand side shows the detailing of the components used to fix the leg to the main body of the product.
Figure 6.47: Detailed design for supporting leg

Figure 6.48 illustrates the position of the supporting leg, which is fixed at the rear of the product. It is suggested to be produced separated from the main body and then fitted with extension plate from one end to another for extra strength. Both legs are attached with metal plates to allow workers to pull it out and in when necessary. Workers can use their feet to put it out when they want to leave the device to proceed with collecting coagulated latex around steep areas in the plantation. They also can push it back when they are ready to take it along the plantation for collecting purposes and transport it to a collecting point by attaching the handle to the back of the motorcycle. The bottom left hand diagram shows the handle fixed to the body. It is not welded for easy replacement if the handle is broken.

Figure 6.48: Detailing the position of supporting leg and handle to the main body.

This product has to have some sort of safety device to avoid any dangerous incident occurring during the work task. Figure 6.49 shows how the braking system was installed in the design. The fibre strip is used attached with steel cable at the end near the handle. This
safety device is important when the product is used in hilly and steep areas. The product is also equipped with suspension to avoid high impacts and also to prevent the product from bouncing too much during transporting goods to collecting points and transporting equipment back to the house. The diagram shows the handle structure fitted to the main body. The handle is supported with metal plates and fitted at the bottom of the product as well as the middle part of the handle fitted at the back to ensure stability and secure it firmly to the main structure. The tyres have to be suitable to the environment because the ground can be varied from one place to another in the plantation especially in hilly areas. Before the designers choose the type of wheel, they have to undergo several tests to assess the right width and diameter for the product because, as mentioned earlier the wheel is the most expensive part within the total product.

![Diagram of handle structure fitted to the main body](Image)

**Figure 6.49: Detailing on braking, suspension and handle attachment to the body**

The detail illustrations as discussed can show the design team whether the system suggested by the researcher could function correctly. It is stressed again that in normal procedures during a design project the researcher would produce various mechanism models to ensure the systems work perfectly before proposing a final version of the design. This design project was intended to show the role and potential contribution from industrial designers involved in agricultural machinery and equipment design activities, especially for the Malaysian context. The following section discusses the findings from both design projects.

### 6.5 Findings from Design Projects

The loose oil palm fruits collecting device and coagulated latex transportation device have differences but the same design process has been used. The differences between these two projects are mainly that latex collection and transportation devices already exist but the loose oil palm fruit collecting device is totally a ‘new to the world’ concept. At present not a single manual device has been designed for the purpose of simplifying the work task in palm oil plantations and estates. The brush and plastic sack is the only equipment used.
The product designed by RRIM agricultural engineers to improve the process of collecting and transporting coagulated latex is still in the experimental stage with several design issues to be considered to perfect the product. From observation in the field, the researcher found that the handle is not positioned in the right place, which tends to bend and crack the body structure. The arrangement of the door to unload coagulated latex most of the time created problem for the workers. The coagulated latex stuck tightly because the structure of the frame is not designed properly in order to remove the coagulated latex from the product effortlessly. The other problem the RRIM engineer and researcher realised is that when the device is in motion without load it tends to be unstable and is quite dangerous to the users when driven on the road. A lot of ideas arise after observing the device used in the field.

The oil palm loose fruit collecting device is a new design concept and the researcher had to conduct an investigation thoroughly to find the requirements and potential benefits. It was necessary to understand the surroundings very precisely to enable the device to work effectively and for the workers to welcome using the device. Understanding the crops, the environment and the users was found to be essential in order to produce a successful device. It was clear that it will be quite difficult to change the user's current practice in collecting loose fruits especially they have to invest an amount of money. Fewer difficulties were found in designing an acceptable coagulated latex transporting device because there is a product which can be used as a model, even though the current device is not successfully designed. Much information was obtained on a visit to one of the plantations in Pahang where planters used this device for the purpose of testing it in the actual environment while it is in the experimental stage. To design these two products the researcher has to pull together something new or arrange existing things in a new way to satisfy a recognised need of these two plantation users.

6.5.1 Design process used

Design processes vary and designers sometimes change or modify the process to suit to their style or the particular projects. In this chapter the researcher focussed on the design process which he used for the last 15 years after graduating. This is divided into ten steps as shown in Figure 6.1. His existing familiar process was used in order to observe the strengths and weaknesses when applied in the field of agricultural equipment.

The design process above iterated from one level to another within the process. Of course full projects are a team effort and require input from different professionals. If the project is very simple and does not require many design members in a team, the researcher always worked very closely with production engineers. In this chapter the two design projects explore the method usually used. The work concentrated from 'realisation of need' up to 'detail design' stages.
6.5.1.1 Clarification of the task

It is easy to observe that clarification of the task must establish a clear aim. The market research, opportunity spotting and design specification can all be seen as means to that end. The researcher has produced two design briefs to identify the aim of the projects. For the designer, a more detailed specification is needed describing what features the product must have and how it might be made. It is observed that sometimes the designer needs a degree of flexibility in the specification.

Thorough research had to be conducted on palm oil because no product has been designed for collecting oil palm loose fruit manually by individuals and smallholders. PORIM designed a powered machine but it is not fully used by estates and it is not available in the market. Investigation into how palm oil trees are planted, what the plantation looks like, what are the percentages of loose fruits occurring during harvesting, what are the problems facing the workers during collecting loose fruits, what is the time spent in collecting and transporting, who usually performs this work task, what type of injury usually occurs during performing this work task etc. has to be carried out to understand the problems before attempting to design a product. Understanding human factors is essential because the method of performing this work task depends on how the system is used. Direct observation of the process of collecting and transporting oil palm loose fruits also had to be carried out as well as talking to the workers about the difficulties in performing this work task.

Collecting information for a product designed to collect and transport coagulated latex from plantation to collecting point was not as difficult as collecting data for oil palm loose fruits. Serious observation was carried out from early in the morning until the workers finished in the early evening. Observation to find out the advantages compared to existing collecting and transporting shows the important issues to be: the product weakness, product manoeuvring in the plantation and on the road with and without goods, the relationship or interaction between the product and the person who uses it and the composition of the structure for strength.

The researcher produced design criteria after looking through all the aspects during observation on the real thing and conducting informal interviews with the workers. This confirmed the importance of gaining information from the users early in a project. It is important for every designer to produce sufficient information before any attempt to be taken in designing a product. As mentioned by Baxter (1995) there are two important thing to remember:

- The better the planning, the more chance the product has of commercial success.
- The more time spent in planning this section the more time will be saved later in product development.
6.5.1.2 Preliminary concept design

The preliminary concept design is to produce design principles for the new product which should satisfy customer requirements. Preliminary concept design set about producing a set of functional principles for how the product will work and a set of styling principles for how it will look (Baxter, 1995). When the researcher has a clear understanding of the task, he/she has reached the point where he/she is ready to generate preliminary design concepts which will be developed before a final product proposal is chosen. According to Baxter (1995), good preliminary concept design requires the use of intuition, imagination and logic to come up with creative solutions to well-defined problems. The main difficulty in generating preliminary concept design is freeing our mind sufficiently to come up with original concepts. Simply using imagination may allow us to generate a handful of new concepts.

Ten preliminary design concepts for an oil palm loose fruit collecting device have been accomplished. The researcher produced these preliminary design concepts derived from the information gathered and the requirements detailed in the product design specification. The researcher chose four preliminary design concepts, which he believed had more advantages than the other. The other preliminary design concept principles were still to be considered during the development stage to facilitate the development of new concept ideation. The researcher did not use any specific available methods in evaluating the preliminary concept design. However evaluation methods are discussed in chapter seven concurrent to design guidelines. The one which had the closest relationship with the product design specification was chosen for further development.

The collection and transportation of coagulated latex is a major problem, and the workers would like a device to help them transport coagulated latex in large quantities from the plantation to the collecting point. There are problems with the existing device. Bending and damage to the main body of the device occurs during unloading of the goods and the moving of the heavy load on undulating surfaces in the plantation. The researcher focused on producing preliminary design concepts based on the overall form of the product to fulfil the requirement as well as the product design criteria and product design specification. Shape and form are the main criteria in producing the coagulated latex collecting and transporting device design. After going through the design evaluation, the best preliminary design concept was chosen for further development so as to enhance its suitability for use in the rubber plantation as well as for other transportation purposes.

6.5.1.3 Design development

Design development begins with a preferred preliminary design concept. At this stage the researcher explored forms to make the product look aesthetically pleasing. The researcher managed to show through sketches how the mechanisms would look and should function.
according to expectations. On paper, the functionality worked well although there were no mechanism prototypes to prove the movement parts worked perfectly. The Ideas which had the most or nearest criteria towards product design specification were chosen for further development and the design development stage shows in more depth how the principle should work in order to have a successful product design.

The development design stage is central to innovative design. In this stage the researcher has put sufficient experience and knowledge into choosing the right material and standard components available in the market or the easiest way to produce the product. The position of every component has to be arranged systematically to avoid the possibility of the product being easily damage during the performance of the work task. Several design concepts were developed to produce appropriate form and the suitable functionality for the completed product.

The researcher would like to express his capability of producing various development design concepts. However, there are various steps which have to be considered during this stage which a design team would have to be involved in to speed up the process towards achieving the final design. A great deal of evaluation and testing has to be carried out during this stage, particularly designs which involved agricultural machinery and equipment. In keeping with the current trend for utilising computer-aided design and computer-aided engineering, at this stage the drawing must be exported into the computer system so as to start the decision making as early as possible in the design process. Unfortunately, the researcher could not afford to have all these considerations in this study. The researcher played his part as the industrial designer in the process by producing possible alternative solutions for the team members to consider and modify if necessary to achieve the best product.

The researcher showed how the system should worked to give clear visualisation to members in the design team those at management level or to their clients. With two-dimensional drawing which illustrated in 2D and 3D sketches can provide clear information to the viewers on how the system worked and what the end product should look like. With this information they should find it easy to become involved in providing comments and suggestions to improve the product. The designers should decide whether the development design provided could stand the weight of the goods, is suitable with the environment, the material selection is suited to the product before the design proceeds to the detailed design stage.

Before the design concept to be developed was chosen and the detailed design was proceeded with, the researcher discussed thoroughly with his supervisor and his colleagues the advantages and disadvantages of the product. They are engineers and have an engineering point of view. They provided valuable criticism and suggestion to improve the mechanism which could make the product more suitable for the users and easier to
manufacture. As mentioned previously, this project is an individual project and the researcher, as an industrial designer, would like to determine the possibility and need to involve industrial designers in agricultural machinery and equipment design activities, specifically those in the competitive Malaysian region, as well as the global market.

6.5.1.4 Detail design

Detail design according to Dieter (2000), Baxter (1995) and Cross (1990), consists of completing the detail drawings, doing technical analysis, a specification for each component and deciding whether the product or components are to be made in-house or bought from an outside vendor. Detail design from the researcher’s point of view in these design projects is intended to distinguish the capability industrial designers could provide in agricultural design projects.

In industrial design practice most of the detailing required would be developed by producing mock-ups, scale models and full-scale mechanism prototypes to observe the functionality and at the same time provide most of the dimensions. These design projects have concentrated in terms of detail illustrations in order to give an understanding of how industrial designers undertake design projects.

Conceptual and detail design stages tend to merge into each other. There is not always a clear dividing line between the two, but the transition from concept to detail design can be termed concept development. Many detail design issues can be considered in the concept development stages by proposing and evaluating design ideas, and means or methods are needed to help designers to do this quickly. Engineers may use layout drawings for this, or nowadays a 3D CAD package. The industrial designers can use drawing skills to generate ideas and to illustrate options in pictorial form as seen in the case studies. The visual nature of this approach has been seen to assist discussion between designers and with managers and clients. For example this was observed at JCB where a rendering of an early design proposal for a new cab was prepared for a meeting by senior staff. An overall view was shown with some key parts illustrated in more detail to stimulate and direct the discussion.

In the first design project, the loose oil palm fruits collecting device, the illustration consists of detailing of the mechanism so we can appreciate how it works. Also the diagram shows the sectional view of the overall picture of the completed product, which has been identified as the final proposed design. The illustration shows a system where the users can adjust the height to suit to their ability which shows that human factor analysis has identified the appropriateness of the product to the users. The diagram showing the front view, illustrates the finished form and in normal circumstances, the dimensions have been considered before these diagrams are done.
The second project, has shown more detailed illustrations to provide a better understanding to the viewers or to the design team how this product may be fabricated and how the system works. The leg system that functioned as a supporting device illustrated in the detail section shows the mechanism worked while the product is left on its own in the plantation or at the user's house. The position, the height and the mechanism used in normal procedure have been clarified during the development stage but in this case to give better visualisation, the researcher has used this illustration method to ensure the viewers understood how the system works.

Detailing on the braking system is shown to give an idea of one method and of course there are several other options which could be considered to replace the one illustrated in the diagram. Similarly the suspension part where the researcher feels that there must be a better way to install this component on the product to give more steady manoeuvring on undulating surfaces.

These drawings can help people to visualise how the product will be used in the environment and also to visualise the problems which may occur during performing work tasks with this product. This method could help to speed-up the design process, which is essential to Malaysian rubber and palm oil industries, as well as other agricultural industries.

6.6 Difficulties encountered in the design projects

The problems and difficulties encountered during conducting these design projects can be divided into two main categories, which are:

- Producing a new product
- Time taken

The researcher had to conduct thorough research to obtain reliable information before any attempt in producing such a product for the workers in palm oil plantations. To introduce a new product is quite difficult when for ages they have performed using their familiar method even though there is the possibility that the product can make the work easier and reduce injury to them. They would like to have the product and experience it before they decide to have their own. It is quite impossible to turn this project into reality unless the government helps this industry to grow and assigns any institution to produce several hundred units and distribute to the workers to prove that this product is worth while.

Another problem encountered during these design projects arose in trying to effectively evaluate the design proposals, particularly later in the concept development stages. This was partly due to the time constraints. The researcher couldn't explore the full potential of his skill, experience and knowledge in these projects in terms of producing scale models, full-
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scale models and prototyping. He has always put these factors as essential in design activities to achieve a successful product. Unfortunately it was necessary to disregard these stages, although in the quantitative survey the results show that those design considerations are important in designing agricultural equipment. Without having those in the design process it is quite difficult to prove that the concept is workable. Also a more comprehensive PDS would have helped the evaluation.

Other problems were the difficulties in interacting with palm oil industry and rubber industry workers frequently to gain more information and ask their opinion while carrying out design projects. The other problem is to get individuals in this department to have the same interest as the researcher in conducting this study. Also this study would be more meaningful if engineers had worked closely with the researcher in the same study but using a different approach to find out whether this would help one another to achieve a successful design.

In spite of these problems the researcher has produced meaningful evidence by different approaches to suit the time limits during his study in this university. It has been shown that the illustrations in this chapter could give a better understanding to the viewers and help them in evaluating the possible ways to improve the design before it is ready to be manufactured.

6.7 Findings of the Malaysian Case Studies

In these case studies the researcher has conducted two design projects with regard to Malaysian agricultural problems faced by agricultural engineers to satisfy the needs of middle and small-scale farmers. Designs must evolve, they are not produced in a few steps. It was found that visual material is very important throughout this evolutionary process.

In these projects the researcher experienced conducting real agricultural design projects in order to ground the research in the Malaysian cultural situation. Throughout working with these projects the researcher used his skill, knowledge and experience as an industrial designer to fulfil the requirements whereby the end product could perform the work task and the users would be able to purchase the product. He had to bear in mind such things as the need for the product to be as simple as possible because complex mechanisms would create problems for the users in maintaining it.

A very basic design specification was produced early in the project and the industrial designer's usual practice is to bear the points in mind as he goes through the design process. This was possible for the two case study projects, but if more complex equipment is designed by a team this would not be an effective way of working. Therefore the design guidelines proposed in Chapter 7 will make use of the design specification in a much more systematic way.
From preliminary ideas and development stages it was found that the visualisations which have been produced helped a lot in communication, clarifying understanding of many design issues and creating more ideas for further development.

Iteration is important in design (see Chapter 2, p 34) and very large iterative loops should be avoided if possible. It was observed during the design projects that proposing designs by means of pictorial renderings is a very effective way of driving the iterative process.

A means of acquiring an understanding of the users, tasks, crops and context is especially important for a new-to-the-world design, such as the palm fruit collection device, because an existing product cannot be observed in use. First-hand experience of the plantation was therefore essential. If this project had been carried out by a team it would have been necessary to communicate that experience to other members of the team who had not spent time on the plantation, and therefore it is important that the design guidelines should include a means of doing this. In Chapter 7 'scenario illustration and analysis' is proposed as a means of achieving this.

The difficulties of evaluating the more developed design proposals, as mentioned in section 6.6, are addressed in the design guidelines by introducing a later scenario evaluation stage.

6.8 Summary

Two design projects considering an oil palm loose fruit collecting device and coagulated latex collecting and transporting device have been discussed in this chapter. Carrying out these two projects has led to a greater understanding about the role and potential contribution of industrial designers in the field of agricultural machinery and equipment design. The objectives of this section were to find out how industrial designers may be involved through the design activities when using a familiar industrial design approach. The projects were also used to find out about which design process stages could best involve industrial designers and finally to provide suggestions and recommendations on how industrial designers might improve agricultural machinery and equipment design activities.

These two design projects together with the results from the qualitative and quantitative surveys have produced sufficient information and evidence to show that industrial designers have a vital role in agricultural design activities. This valuable information has highlighted a need for a design methodology or guidelines for Malaysian industrial designers in order to work with agricultural engineers to produce competitive agricultural products. The guidelines must assist designers throughout the project, but particularly at the stages of developing an early understanding of the users and the context of use, and when evaluating the later design proposals. In the next chapter these are addressed by introducing scenario analysis.
at two stages. Also incorporating a more comprehensive PDS to be used throughout the process has been seen to be necessary. The importance of visual information has been constantly reinforced.

In Chapter seven the development of the design guidelines is discussed. It is a method or procedure to help industrial designers to conduct systematic design projects as well as to work with other disciplines in the design team.
CHAPTER SEVEN

Development of Design Guidelines

7.1 Introduction

In this chapter, the researcher triangulated the findings from the literature study, qualitative and quantitative surveys and case studies before an attempt was made to propose design guidelines. The aim is to provide a design methodology appropriate for Malaysian industrial designers. The objectives of the design guidelines are to involve industrial designers in this area, to guide industrial designers to work systematically, to help them to work with engineers and with time constraints during projects, and to convince them that there is a role to play in agricultural equipment design activities.

So far there have been no specific design processes for use by Malaysian industrial designers. They usually use the design processes available, modified to suit to their needs. This chapter is intended to develop a design process guideline or technique appropriate to industrial designers by incorporating the skills and capability that they have into the design process. This will meet the fourth aim of this research.

This chapter has been categorised into several sections, section 7.2 gives an overview of the importance of design methods in the design process. Section 7.3 elaborates the research programme phase, which triangulated the research activities during this study.

Section 7.4 discusses the proposed design process guideline followed by a discussion in section 7.5 on how the proposed process will be used in practice. In section 7.6, the researcher has identified several problems and difficulties encountered in developing this approach. Observations made on this approach are discussed in section 7.7 and the knowledge gained from this study is discussed in section 7.8. Section 7.9 elaborates the findings gained from interviews to verify the value of the approach and the next steps to be taken before introducing this proposal. This chapter ends with a summary in section 7.10.

7.2 Overview

This section is intended to show the importance of design methods which will be focussed on agricultural design activities but may be applicable to other design fields. The product design process can be applied to several different ends, from consumer goods and appliances to complex engineering systems such as an electric power generating station. The principles and methodology of design can be usefully applied in different situations.
The product design process has stages to be fulfilled to ensure the end products are successful and it is common practice during design projects to involve repeated trials or iterations. Design is a creative process, and all new creations of the mind are the result of trial and error. The product design method starts with knowledge of the state of the art. When a need is identified, it must be conceptualised as some kind of model. The design concept must be subjected to feasibility analysis until an acceptable product is produced (Dieter, 2000).

7.2.1 The Need for a Methodology

The interviews and postal questionnaire survey indicate the necessity for Malaysian industrial designers to be involved in this area. However, from the industrial designers' perception they prefer to work in comfortable offices and are reluctant to become involved in the agricultural industries. It is essential that industrial designers and engineers are able to work together effectively in teams.

A methodology has been structured especially for industrial designers, particularly in Malaysia, but these design guidelines could also be used by other disciplines for design projects.

The aims of these design guidelines are to guide designers to:

a. better understand the users and the working environment
b. follow the design stages systematically
c. work within time limits allocated by the clients
d. work very closely with other disciplines in the design team
e. complete the project faster

With design guidelines, designers can discipline themselves by ensuring that they will not lose track of their design projects. Without design guidelines some of the projects have to be abandoned because designers take a lot of time in solving the problem and sometimes detour from what they are supposed to produce.

The design guidelines, proposed are not an entirely new method but a combination from many methodologies that can be found today. Many designers, especially engineering designers, have produced a successful design methodology and have proved it by using the methods. Engineering design has several methods that can be employed such as product design specification (PDS), concurrent engineering (CE), Failure Mode and Effect Analysis (FMEA) and Quality Function Deployment (QFD).

With a new approach to design guidelines, Malaysian industrial designers should have more interest and willingness to participate in this activity which up to now has been avoided.
Chapter Seven

Development of Design Guidelines

Malaysian industrial designers should have some encouragement to become involved in this area which traditionally has been the monopoly of engineers all the way through design projects.

7.2.2 Product Design Method

According to Cross (1989) any identifiable way of working, within the context of designing, can be considered to be a design method. The most common design method can be called the method of design by drawing that is to say, most designers rely extensively on drawing as their main aid to designing. He emphasised that design methods are any procedures, techniques, aids or tools for designing. They represent a number of distinct kinds of activities that the designers might use and combine into an overall process. Industrial designers are good in producing fast sketches and renderings. This is very useful in generating fast ideas especially during phase 2 and phase 3 from Figure 7.2 and at the same time get feedback from all the members in the design team.

A successful designer usually follows some sort of method in responding to the challenge of a design problem. The design methods may have evolved over many years, and the designers may not be able to explain them in precise words. Nevertheless, the design method is a part of his or her method of operation. No one can outline the steps of a single design process that will be correct for every situation. By the nature of design, the process used will vary to some extent, depending on the type of system or device to be designed.

7.3 Triangulation of the Research Programme Phases

This section is intended to triangulate the findings from the literature study, interviews, postal questionnaires and case studies. Figure 7.1 shows the relationship of the elements of the research programme, which consists of three main components conducted during this study before an attempt was made by the researcher to propose design guidelines.

![Figure 7.1: Research programme phases](image-url)
Many issues have arisen in the different phases of the research which are relevant to a design methodology for Malaysia, and hence are used as a basis for the design guidelines. The main points which have emerged in the different phases are briefly listed below, followed by a summary of the key points which are supported by the different research methods.

7.3.1 Literature Search

- Design is universal and it is a technology needed by all human beings.
- Design is a creative, multidisciplinary and evolutionary process.
- A design should not only serve its purpose but should look as if it were made for that purpose.
- Design also must have some constraints in pursuing a design project.
- Design is not a process or activity which can show a sudden output in just a moment but is a process which takes times to achieve.
- Design needs research and investigation before some form of product could be produced in terms of conceptualised ideas.
- A very low percentage of Malaysian industrial designers are involved in agricultural design activity.
- Labour shortage in the plantation is becoming a very big issue because youngsters prefer to work in the factories.
- Malaysian crops are unique and need specific products to perform the work task.
- The UK agricultural machinery industry is well established compared to Malaysia and the involvement of industrial designers in this area has changed the look of the product tremendously.
- Industrial designers need to have full commitment to meet the demands and reduced timescales in producing new products.
- Sketches and mock-ups are important forms of communication in the design projects.
- In design, iteration is crucial to make sure that the design project continues on the right path.
- Evaluation throughout a design project has to be considered important to make sure that the product meets the requirements identified at the early stage of the design process.
- Engineering designers have various design methods and procedures whereas industrial designers do not have specific design methods.
- Industrial designers should equip themselves with engineering knowledge to have a very close relationship with engineering designers because both disciplines have much in common and together can produce excellent products for the users.
- There is a role for industrial designers to play and contribute in agricultural equipment design in Malaysia.
7.3.2 Interviews

- Industrial designers have to understand the whole process of the agricultural environment which is understanding the crops, soils, materials and production.
- At present, no Malaysian industrial designers work in agricultural machinery and equipment, whether in R&D institutions, agricultural universities and agricultural manufacturers private sectors.
- It has been shown that agricultural machinery and equipment design activities need multi-disciplinary people in the design team and the industrial designer is one of the essential disciplines involved. The UK industrial designers have shown a significant contribution towards improving agricultural machinery and equipment products by being involved closely with other professions in the design team. For example the products of JCB.
- The drawing skills of industrial designers should be utilised effectively within design teams because drawing is one of the most powerful aids to express, generate and communicate ideas.
- Physical modelling is one of the formats which industrial designers are used to employing and this factor may be considered essential in many agricultural design activities. It helps in developing ideas and improving understanding during discussion.
- Industrial designer's skills such as human factors, ergonomics and aesthetic values are important aspects to be incorporated to produce successful end products.
- Communication is vital among designers to avoid any conflict. Also good communication could promote the design to other manufacturers.
- Communication using aids such as mock-ups, scale and full scale models are important, especially to communicate with people with have no experience in understanding drawing.
- Industrial designers have to equip themselves with basic engineering and science knowledge to enable them to work closely with engineers.
- Industrial designers have to be involved in the early stage of the design process because it is not effective to ask them to be involved in the middle or later stages.
- Industrial designers work in less structured ways compared to engineers, and seem not to have specific design processes to work with during design projects. This is very different in engineering design where they have successful design methods.
- The design methodology used by Malaysian industrial designers is very basic and does not show the importance of every stage within the design process.

7.3.3 Postal questionnaires

- Malaysian industrial designers use some of the engineering design methods but modified to suit to their needs.
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- The skills that industrial designers have could be an advantage in order to speed up the design process, especially in the early part. It is essential to include the skills of industrial designers in the design guidelines.
- Industrial designers have the capability to increase the product quality, making the product saleable and improve ergonomic aspects.
- Performance, reliability, functionality, quality and safety are the important design considerations which industrial designers have to contribute to during design.
- Industrial designers have to have a good understanding of engineering to enable them to work closely with engineers. Malaysian industrial designers have to have a close relationship with engineers in order to co-operate and help Malaysia to produce demanding agricultural machinery and equipment products.
- Industrial designers have to understand the requirement from the end users, market information and where the machine is going to perform to avoid coming out with futuristic concepts which do not meet the objectives.
- Industrial designers have to prepare a PDS thoroughly because this design method is the one invariably used by other designers. The research has shown that ED commonly use a PDS, but do not make extensive use of other formal design methods. It is recognised that the Design Specification is not a design method as such but is an essential part of the design process. However it was included in the postal survey with design methods because industrial designers do not always construct a PDS in a rigorous way as engineering designers are trained to do.

The postal survey confirms that ID can contribute in many ways within the agricultural design process, from the beginning through to detail design, and should play a full role in the design team. Although there were small differences between UK and Malaysian responses regarding the major contributions which can be made by ID the results were broadly similar. Industrial designers from both countries agreed that ‘end user input’ and ‘where the product is to be used’ are the most important factors to be taken into consideration in designing agricultural machinery.

Significant ID contributions suggested by the survey are summarised as:
- Understanding design needs and analysing design problems
- Conducting research
- Human factors considerations
- Brainstorming and concept selection
- Preparing design specifications
- Sketches
- Preliminary concept drawings
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- Development drawings
- Constructing scale models
- CAD modelling
- Material selection
- Developing detail drawings

Any design methodology used should enable ID to contribute in all these ways.

7.3.4 Case studies

- The design process used by PORIM agricultural engineers has shown evidence that industrial designers need to have a design process which is more detailed, concise and in which the iteration loops between stages are small.
- It has been shown that the design process which the researcher normally used in his work has to be changed to suit agricultural design activities.
- The researcher's experiences from the case studies carried out in chapter 6 show that new ideas such as 'scenario illustration and analysis' and 'virtual scenario evaluation' have to be integrated in the design process where designers, especially industrial designers, have the skills to visualise the present work task from the field and produce a paper representation to enable better understanding by other disciplines.
- Industrial designers have to understand the problems before any attempt is made to produce conceptual ideas.
- Industrial designers are good in producing preliminary concept ideas which are essential for providing ideas to other designers for further development.
- Engineering drawing and quick sketching are totally different. Industrial designers can produce detailed designs in terms of sketching to assist visualisation and teamworking. The researcher found out that drawing could become an important aid within the design activities because it helps in communicating with others easily, enabling them to understand what the product would look like and to instantly contribute their ideas for further improvements.

In the case studies the researcher immersed himself as a designer in the subject to observe some of the difficulties and better understand the requirements of the design methodology to be proposed.

Two of the most important points which arose are as follows:

A new-to-the-world product is particularly difficult to design because of the lack of previous experience to draw on. The palm oil loose fruit collection device was completely new. The researcher's experience confirmed that first-hand knowledge and understanding of the users,
the crop and the environment was essential before attempting to produce design proposals. With no existing model to learn from the designer must understand the tasks, the difficulties and the working culture of the users as a basis for the design work. Therefore the methodology of the design guidelines must help in doing this.

Many design problems become apparent with hindsight. This was shown in Section 6.5 with the coagulated latex transportation device when problems occurred due to the latex being difficult to remove because of the form of the structure. Also the device was unstable in motion and hence dangerous when driven on the road. These problems were only recognised when observing the product in the field.

This suggests that design proposals should be carefully examined with respect to the working scenarios before prototyping is carried out. A way of assisting this must be incorporated in the design guidelines to help to anticipate these types of operational problems.

7.3.5 Overall Findings from the Research Phases

The major points triangulated from the research phases and which helped in formulating the design guidelines are discussed below.

7.3.5.1 Design approach

There was unanimous agreement that multidisciplinary team-working is essential, and that industrial designers should play their part as full members of the team from the beginning.

The research has shown that designers commonly use a PIDS, but do not make extensive use of other formal design methods. A PIDS must be an integral part of the design methodology.

7.3.5.2 Understanding customers and context:

The literature makes it clear that quality is central to design in any field. Quality must be seen as an overall requirement to satisfy customer needs and wants, and this was reinforced strongly in the interviews.

The need to understand the users, crops and working environment is crucial. A whole system approach is necessary which considers not only machine performance but the environment, the crop and the people. The real wants, needs and requirements of users are often difficult to establish, and their capabilities, sociocultural influences and attitudes must be considered. Therefore the designers must be able to put themselves in the position of the customers and
users. This is not always easy to do and methods or techniques which help them to do this would be useful.

First-hand experience of the working environment is essential for designers. This may not be possible for every member of the team so a high quality information channel to the design team is required.

Skills needed in design include problem-finding, not just problem-solving.

7.3.5.3 Malaysian culture:

Very physical working practices are involved in agricultural work, therefore human factors and safety issues are very important.

Operators may be semi-skilled and often are not highly trained. Many will be women, children and elderly people.

Malaysian agricultural machinery and equipment imported from abroad and modified to suit the environment has not been very successful.

7.3.5.4 Design characteristics of agricultural machinery:

Production volumes are relatively low for many agricultural products, and large investment is not usual. Therefore many proprietary components and subsystems must be used and long development programmes are seldom possible. Prototypes are often sold once they are working. Therefore the conceptual design phase is crucially important to ensure a successful design. Imagination and ingenuity are as important as the technology.

The design emphasis, therefore is on conceptual design and product architecture to integrate various systems and subsystems into a successful product entity. This process is very familiar, in fact fundamental, to industrial designers because of their approach of designing holistically “from the outside-in”. Of course the engineering problems are not trivial, but many key decisions must be made at the overall concept or system level, and therefore industrial designers are qualified to make a major contribution in synthesising and directing the design.

Industrial designers need a sound appreciation of engineering if they are to work effectively with engineers.
7.3.5.5 Communication in design:

Throughout the research there has been strong evidence of the importance of visual communication.

Good communication during the design process is important:
1. within the design team
2. with managers, marketers and financial people
3. with customers and clients

The power and importance of visual communication was stressed frequently during the interviews and was apparent in much of the literature. Visual media were essential to the case studies.

It became clear that it must be assumed that many of the people outside the design team cannot read engineering drawings or understand technical issues in any depth, so the form in which the design information exists at any stage is crucial to communication. Industrial designers have highly developed skills in communicating design ideas and proposals:

- hand renderings are a fast and powerful form of visual communication
- CAD output is useful, especially 3-dimensional modelling
- physical models and mock-ups can be very valuable

It is helpful to maintain communication with customers and users as designs develop because user requirements and attitudes are hard to establish, especially for new products. Visual material such as renderings, CAD models, physical models, photos and video can be a valuable means of communication with potential customers and users and other parties. These formats are the ‘tools of the trade’ for industrial designers.

Therefore it is essential that the researcher produces design guidelines for industrial designers to help them when pursuing design activities concurrent with agricultural engineers. Although there will be differences in the design processes used within the design team, it is important to ensure that industrial designers do not feel inferior within the design team because their activities are oriented more towards engineering.

The design guidelines must link the need for designers to understand the users, crops and environment with the skills of industrial designers and engineers.
7.4 Design Guideline Proposal

The researcher has produced a proposed design guideline (Figure 7.2) based on the findings of the research programme intended to assist the design process and lead to more effective use of industrial designers.

The proposed design process guideline would be used by industrial designers who would like to be involved in agricultural design, as well as for other design activities. The design guidelines have been developed with specific regard to agricultural projects within plantations in Malaysia. It is hoped that this can be extended to other types of projects in the future. This proposed design guideline is intended to be used in parallel with other design processes known to engineers. Both disciplines could use their own design process but the objective in performing a design project is to have a successfully designed product as the final outcome. The designers should use the design method most suited to them and industrial designers could use the proposed design process as their guideline to overcome the problems which arise during the design project.
Within agricultural equipment design, industrial designers are involved from the ‘scenario analysis’ up to the final design development and it is advisable that industrial designers work very closely within a multi-disciplinary team. The ‘scenario analysis’ could be presented to other members of the design team (Figure 7.3) either by sketches, illustrations or other media that are available to give an overall view of what actually happens in the particular activities under discussion before any attempt could be made to produce a product.

When the process has reached the design proposal stage and the design team is satisfied with the final design proposal then working drawing must be produced and the process continues until the end of the design process stages where the product is ready to be marketed. Before the design proposal stage is arrived at the ‘virtual scenario evaluation’ stage is carried out in which design members in the design team will analyse the proposed product, which is illustrated in Figure 7.8, after this the design team will carry out
modifications, if necessary, until all the requirements from the PDS and all team members are satisfy.

Stages 1 to 4 in phase 2 are the essential sections where all the potential problems are identified in order to formulate the PDS. This phase has been designed accurately because it will be used all the way through during the design project. The researcher has labelled this section as the 'design checklist'. Designers have to come back to this section if any problems occur during the design project. Nevertheless from phase 1 to phase 6 designers have to iterate within the design process. There are several evaluation techniques available within the engineering design process to identify the most promising concepts. The outstanding evaluation techniques available include the 'controlled convergence matrix method', the 'profile chart evaluation method' and the 'rating and weighting evaluation methods' (Ben, 1995).

Mock-ups, scale models and full-size models are often important to understand in more depth the aesthetics and the functionality of the design. It is not necessary to implement these activities every time a design project is performed but for certain projects it is necessary to look at the system in 3-dimensions in order to gain a better understanding of the product as a whole.

7.4.1 Scenario Analysis

This 'scenario analysis' is a new method in this proposed design guideline and the purpose of having this method is to give a better understanding of the problems that arise in plantations with regard to all aspects of plantations. The designers have to gain first hand experience by putting themselves in the real situation and understanding the problems faced by the users before they can start putting the ideas in order to solve the problems on paper. Observing and trying the work tasks as a form of action research could help them identify the problems precisely and help them to develop appropriate solutions to these problems.

After clarification of the design needs, the 'scenario analysis' is produced. Industrial designers are required to produce a set of illustrations describing the topography of the plantation and the present working methods highlighting the problems which occur during the process. Discussion and brainstorming take place during this sessions to look at all aspects especially the problems faced by the users (Hussain et al, 2001).

As an example Figure 7.3 shows a series of illustrations showing the scenario in a palm oil plantation with young trees and older trees. The diagram shows the proportion between the trees and the worker. It is easy to harvest oil palm when the tree is below ten feet high and the percentage of loose fruit is very low compared with trees more than ten feet high. In the latter case, workers have to use a long pole, which is quite heavy to carry and at the same
time harvested oil palm fruit from one tree to another. The illustration also shows the planting method on a plain and in a hilly area. In addition, the diagram illustrates a plantation which has a clear surrounding a plantation full of bushes. The diagram also shows the distance workers walk in the plantation. Workers have to walk 200 metres on both sides. The fruits are left along the roadside to be collected and transported to the factory by lorries. One of the diagrams shows a bunch of oil palm fruit and loose fruits, this is relevant as the main interest of the researcher is overcoming the problems involved in collecting loose oil palm fruit. This diagram elaborates what the plantation looks like and the situation the workers face when collecting the product from the plantation. The diagram also illustrates the typical practice of collecting loose fruits in palm oil plantation. The work is performed by the elderly but is usually done by women who have to accompany their husbands to earn extra income. The collecting process is very exhausting especially when the surrounding is not very clear.

Figure 7.3: Scenario in oil palm plantation
Figure 7.4 illustrates the industrial designers' first impressions and the possible ideas of how the problems involved in collecting loose oil palm fruits in the plantation and transporting them to the factory could be solved.

7.4.2 Generate Heading Questions – Stage 1

This stage has to be a team effort and the researcher has divided this into two sections which have to be achieved in order to have a clear perspective of the problem which has occurred or might occur during the carrying out of the design project and with the product itself. The first section known as the 'main task' is illustrated in Figure 7.5, which uses the
Figure 7.5: General headings for agricultural loose oil palm fruit collecting device
It is not only ideal for an agricultural design project but for other product design. This method was chosen because it has the freedom for the team members to put down what they think appropriate and the diagram can be expanded until every member of the team is satisfied with the headings. Figure 7.6 below is a key to make use of Figure 7.5.

<table>
<thead>
<tr>
<th>Shows the needs and demands to produce product/equipment/machinery or a device for agricultural industry.</th>
</tr>
</thead>
<tbody>
<tr>
<td>This means that designers, team members and others can start with these parts as a first stage to study and understand what the important things are which can be highlighted to produce an excellent PDS.</td>
</tr>
<tr>
<td>This oval means that after going through the first step, team members can proceed with this stage to recognise further information towards designing agricultural equipment/machinery/devices.</td>
</tr>
<tr>
<td>Designers and team members are advised to continue with the next stage, which concentrates on quality and manufacturing/production to enhance the understanding of the project.</td>
</tr>
<tr>
<td>The oval described ‘process method’ and ‘testing’ can be either at the beginning, middle or last stage because depending on the situation of the project.</td>
</tr>
<tr>
<td>This line shows that there are possibilities to focus together with the red oval items for better understanding and producing more meaningful solution.</td>
</tr>
<tr>
<td>This dotted line represents second thoughts which can possibly be combined with the ‘existing products’ with ‘use’ and ‘task performance’ because these three interact excellently with each other.</td>
</tr>
<tr>
<td>The oval shaded with colour means that there are interactions between those of the same colour. The designers and team members have to look at the next task of the guideline after understanding the scenario of the bubble diagram under the main task category.</td>
</tr>
</tbody>
</table>
This oval stands by its own but when looked at with the next task (task 1 and task 2) it gives a clear understanding of what to look for, and a meaningful PDS will arise from it.

Figure 7.6: Key in understanding the diagram of Figure 7.5

The second section which is expanded from the 'main task' of the first bubble diagram as illustrated in Figure 7.5, is known as the 'first task' and this task is expansion from the main factors taken from the 'main task' bubble diagram. This 'first task' also uses the bubble diagram method in order to express the ideas in more detail. This might arise after team members gain a better understanding of the 'scenario analysis'. The details of the 'first task' are included in Appendix VIII.

'Task performance' is an example extracted from the 'main task' bubble diagram and under this heading there are four sub-heading branches derived from the 'first task' bubble diagram. From these four categories, the design breaks down into more branches to understand the content of this category in detail, for example we take one sub-heading 'machine' in Figure 7.7 and we may describe the content under this category as:

- How the 'machine' should perform in the plantation?
- What are the capabilities of the 'machine' to make it suitable for the plantation?
- What are the 'problems' encountered by the users in the plantation?
- What are the 'problems' faced by the users of existing machinery if any?
- How has the 'work task' been done?
- What is the 'time' taken for the existing work task?
- What type of 'skill' is required for operating the machine?
- What will be the 'cost' of the product?
- How easily can the user 'handle the equipment'?
The sub-headings can be expanded and can be branched as far as possible to maximise the understanding of the problems. The headings and sub-headings are advised to be in one word or as few words as possible to allow the design team to elaborate it further without any obstruction, and therefore the understanding of the problem will be more meaningful. From these headings and sub-headings the design team could identify more detail from all the categories and from each category can produce several phrases to explain the problems which might occur during the design project.

7.4.3 Generate Checklist Questions — Stage 2

In this stage all the design team are involved in gathering and identifying the questions derived from stage 1. From all the categories elaborated as headings and sub-headings, those categories have to be described in more detail by formulating them into phrases. A lot of ideas may arise from just a single word to express the problems which could occur and to assist better understanding before a PDS can be formulated.

Questions formulated have been derived from the ‘first task’ bubble diagram and at this stage the researcher has identified this as ‘second task’. There will be a standard form and the questions designed have to be arranged according to the priority of the category, identified in ‘main task’ of the bubble diagram, Figure 7.5. Still using ‘task performance’ as an example. Figure 7.5 shows ‘system operation’ as one of the sub-heading branches from ‘task performance’, and from here several sub-headings emerge. Table 7.1 shows the example of ‘second task’ in which the questions are designed to help in understanding the problems more deeply. The questions should be as many as possible and success depends on the design team producing meaningful questions.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Descriptions</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Not sure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Can new design collect palm oil loose fruits faster than the current practise?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Can new design overcome labour shortage?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Can we confirm that the new design will last longer to avoid changes too often?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Can new design double the collection rate?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Can new design be used as a transportation device?</td>
<td></td>
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<td>6</td>
<td>Can new design perform the task on any surfaces and slope?</td>
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<td>7</td>
<td>Can new design perform different work tasks?</td>
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</table>

Table 7.1: 'Second Task' - Understanding nature problem — Task performance
The questions arising will be organised carefully in a form provided and this set of questions can be passed to other team members or within a group of multi-disciplinary people. They will sit together to answer the questions in the space provided. After all the information is gathered the design team should have a firm basis for developing the PDS. The detail of this 'second task' can be found in Appendix IX.

7.4.4 Formulate Product Design Specification (PDS) – Stage 3

According to Pugh (1990) the PDS is our basic reference and we must attempt to meet the specification produced by the design team. During the design activity, there may be good reasons for changing the basic PDS. It must be considered as an evolutionary, comprehensively written document which, upon completion of the design activity, has itself evolved to match the characteristics of the final product.

The contents of the PDS will be derived from written questionnaire and from questions emerging in the 'second task', which include all the categories mentioned. This PDS has been designed in two sections; the contents of the specification and the categories of discipline, involved in the project. The category section could be expanded depending on how many disciplines are involved in the project.

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>Use</th>
<th>Task Performance</th>
<th>Marketing</th>
<th>Perceived Quality</th>
<th>Manufacturing/Production</th>
<th>Social Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td></td>
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<tr>
<td>The device must be able to be operated by any gender and children.</td>
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<td>It must be very easy to use, and not have any complicated controls.</td>
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<td>The device must help in improving the way of working aspect.</td>
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<tr>
<td>It should attract young adults to work in the plantation.</td>
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<tr>
<td>A single person should operate the device.</td>
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<tr>
<td>The product should benefit by users, estates and smallholder's organisation.</td>
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<tr>
<td>Ergonomics</td>
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<tr>
<td>Elderly users can operate the device.</td>
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<tr>
<td>The device must be manually operated.</td>
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<tr>
<td>The user doesn't have to be fit to perform the work task.</td>
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<tr>
<td>The device doesn't need any formal training to be used.</td>
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<td>The device should avoid back problem that occurs in current practise.</td>
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<td>It must be easily lifted although the device full with goods.</td>
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<tr>
<td>The device must be easily access for parts replacement and repairing.</td>
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<td>It can be adjustable to users comfort if necessary</td>
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<tr>
<td><strong>Effect on crops and land</strong></td>
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<tr>
<td>The device must be safe to be used on crops and plantation area.</td>
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<td>The product must be light to prevent damaging the land surface especially terraces – contact pressure</td>
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<tr>
<td><strong>Size</strong></td>
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<tr>
<td>The width of the product must not exceed 60 centimetres.</td>
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<td>The height of the product must not exceed 40 centimetres.</td>
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<tr>
<td><strong>Weight</strong></td>
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<tr>
<td>The weight of the product must not exceed 5 kilos.</td>
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<tr>
<td><strong>Used new design/product</strong></td>
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<tr>
<td>The device must be able to pick loose palm fruits.</td>
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<tr>
<td>The products should increase the user’s monthly income.</td>
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<tr>
<td>The users should own the product.</td>
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<tr>
<td><strong>System operation</strong></td>
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<tr>
<td>The product must be easy to store.</td>
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<tr>
<td>The device can be used for fruits transportation purposes.</td>
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<tr>
<td>The device can also be used for different work tasks. (not only for agricultural purposes)</td>
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<tr>
<td><strong>Situation</strong></td>
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<tr>
<td>The device should be used in any situation in the plantation.</td>
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<tr>
<td>The device should easily manoeuvre along the terrain.</td>
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<td>The product can be easily carried from one place to another in the plantation.</td>
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<tr>
<td><strong>Product life span</strong></td>
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<tr>
<td>The product should last longer.</td>
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<tr>
<td><strong>Cost</strong></td>
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<tr>
<td>The cost of the product shouldn’t exceed RM100.00 (£17.00)</td>
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<tr>
<td><strong>Publicity</strong></td>
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<tr>
<td>The publicity should not affect the cost of the product.</td>
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<tr>
<td>The product must be excellent to enable marketing worldwide.</td>
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<td><strong>Labour shortage</strong></td>
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<td>The design/product should help to solve labour shortage problems.</td>
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<td><strong>Performance</strong></td>
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<td>The product should stand foreseeable overloads.</td>
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<td>The product should perform the work task quickly.</td>
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<td>The product should double the collection rate.</td>
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<td><strong>Environment</strong></td>
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<tr>
<td>The product should stand cold, harsh and moist conditions.</td>
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<td>The product should not corrode.</td>
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<td><strong>Product appearance</strong></td>
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<tr>
<td>The colour must be variable to suit the user expectations.</td>
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<td>The product should have appropriate texture for ease of handling.</td>
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<tr>
<td>The shape of the product should be attractive to the users.</td>
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<tr>
<td><strong>Reliability</strong></td>
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<tr>
<td>The working method should withstand the product life span.</td>
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<tr>
<td>The materials used must withstand the roughness of the environment and use.</td>
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<tr>
<td><strong>Safety</strong></td>
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<tr>
<td>The device must be completely safe for the users.</td>
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<td>The device should be fitted with any safety requirements needed.</td>
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<tr>
<td><strong>Quantity</strong></td>
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<tr>
<td>Expected manufacture between 40,000 to 50,000 units per year.</td>
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</tbody>
</table>
Standards and regulations
The product must meet the regulations by the organisation.
The product must be a new approach.
The designers must search in world patents organisation to avoid copying.

Maintenance
The product must have easy maintenance.
The product shouldn’t need regular maintenance.

Testing
The product must undergo through testing before being produced.
The designers must involve users in testing the product.
The product must undergo field-testing.
The product must undergo safety testing.

Material
The material chosen should enable reasonable misuse.
The material should last for more than 5 year.
The material chosen must stand the temperature and humidity of the country.
The designers must use easily available materials.

Government
Agricultural equipment/machinery should increase the country’s income.
More agricultural related industries should be encouraged.

Private sectors
Should help to implement government vision.
Generate more job opportunities.
Should be competitive with manufacturers abroad.

Research & Development
Developing new products for agricultural purposes.
Generate new agricultural manufacturers.

<table>
<thead>
<tr>
<th>Standards and regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>The product must meet the regulations by the organisation.</td>
</tr>
<tr>
<td>The product must be a new approach.</td>
</tr>
<tr>
<td>The designers must search in world patents organisation to avoid copying.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance</th>
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<tbody>
<tr>
<td>The product must have easy maintenance.</td>
</tr>
<tr>
<td>The product shouldn’t need regular maintenance.</td>
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</table>

<table>
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<tr>
<th>Testing</th>
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<tbody>
<tr>
<td>The product must undergo through testing before being produced.</td>
</tr>
<tr>
<td>The designers must involve users in testing the product.</td>
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<tr>
<td>The product must undergo field-testing.</td>
</tr>
<tr>
<td>The product must undergo safety testing.</td>
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</table>

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<thead>
<tr>
<th>Material</th>
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<tbody>
<tr>
<td>The material chosen should enable reasonable misuse.</td>
</tr>
<tr>
<td>The material should last for more than 5 year.</td>
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<tr>
<td>The material chosen must stand the temperature and humidity of the country.</td>
</tr>
<tr>
<td>The designers must use easily available materials.</td>
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<tr>
<th>Government</th>
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<tbody>
<tr>
<td>Agricultural equipment/machinery should increase the country’s income.</td>
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<tr>
<td>More agricultural related industries should be encouraged.</td>
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<table>
<thead>
<tr>
<th>Private sectors</th>
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<tbody>
<tr>
<td>Should help to implement government vision.</td>
</tr>
<tr>
<td>Generate more job opportunities.</td>
</tr>
<tr>
<td>Should be competitive with manufacturers abroad.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Research &amp; Development</th>
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</thead>
<tbody>
<tr>
<td>Developing new products for agricultural purposes.</td>
</tr>
<tr>
<td>Generate new agricultural manufacturers.</td>
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</tbody>
</table>

Table 7.2: PIDS for oil palm loose fruit collecting device

The designers gather the output from the disciplines taking part in this project and list those specification elements according to the priority as decided among the disciplines. As mentioned earlier the PDS can be changed when necessary. Figure 7.2 shows that stage 3 and stage 4 are parallel and it is advisable that these two stages are developed at the same time.

7.4.4.1 Formulate Detail Questions – Stage 4

Stage 4 is a continuation from stage 2 where designers developed into more detail some of the questions which they think need to be expanded for better understanding. This stage is purposely for designers and the detail questions will be developed by them as they are the people who are most familiar with the problems. The questions developed are used in parallel with the PDS to ensure that the product will meet the requirements both of the PDS and the questions in stage 4. The detail of this stage can be found in Appendix X.
7.4.5 Concept Design Evaluation Stage

The researcher thought it necessary to focus on a particular evaluation method to select the outstanding conceptual designs. Industrial designers normally select what they think is best for them without going through a formal process to highlight the important aspects in selecting concepts for further development. In this study the 'controlled convergence matrix method' developed by Pugh (1990) has been used. The datum chosen may be the existing product or, we can take what we believe is the outstanding concept as a datum. The other concepts will be placed in the columns and the weighting of each concept will be derived from the design criteria stated on the left-hand side of the table.

The following legend is used in consideration the concept/criteria against the chose datum which are:

+ (plus): meaning better than, less than, less prone to, easier than, etc., relative to the datum.
- (minus): meaning worse than, more expensive than, more difficult to develop than, more complex than, more prone to, harder than, etc., relative to the datum.
S (same): meaning same as datum. If there is any doubt whether a concept is better or worse than a datum used this legend.

The researcher used the conceptual design project, discussed in chapter six, concerning an oil palm loose fruits collecting device. Under criteria the researcher has identified the essential things which were felt to be important in evaluating those concepts. Table 7.3 shows the conceptual designs compared with one chosen as the datum because at the moment there are no such products used in palm oil plantations for the purposed collecting loose oil palm fruits. The chosen concepts are identified by bold typeface.
### Table 7.3: Oil Palm Loose Fruits Collecting Device Conceptual Design Stage Evaluation Matrix

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<td>Easy handling</td>
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<td>Safety to user</td>
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The following evaluation concentrates on the selected conceptual design which the researcher has developed in more detail. The development of the selected concept designs has used criteria derived from the product design specification, identified in stage 3 under phase 2 from the design process guideline.

### 7.4.5.1 Concept Development Evaluation Stage

Generating conceptual ideas is done without putting limitations and constraints on the industrial designers and allows them to produce a wide range of ideas. Industrial designers have to be aware that the product they create for the market has to be both functional and nice looking. The concept ideas must not be so futuristic that it is hard for other disciplines to manufacture it.

Conceptual ideas have to be expanded into more detail in order to gain a better understanding. It is also necessary to consider various technological approaches to understand the basic conceptual ideas and to assure that the product can meet engineering compatibility.

The concept development stage is an expansion from conceptual ideas and after having gone through the evaluation, the researcher needed to focus and proceed with the four conceptual ideas for further development. In the evaluation chart shown in Table 7.3, the second, fifth, seventh and ninth concept ideas have the highest score in terms of + (plus). These concept ideas have gone through various developments and the researcher tried as hard as possible to meet all the requirements stated within the PDS.

The evaluation chart, identified several criteria to be fulfilled. Although the PDS shows a large number of criteria but for this stage the criteria have been reduced. The idea of having this evaluation stage is to identify the suitability of the product to meet the major requirements.

The same procedure was used to evaluate the concept development ideas. Table 7.4 shows the output of the evaluation in which four of the chosen concept ideas have been evaluated by comparing against the datum which the researcher felt is the best among all the ideas. From the output we can see that the fourth concept development has shown the highest score. For further development the researcher focussed on two ideas, the one with the highest score and the one used as a datum.
<table>
<thead>
<tr>
<th>Categories:</th>
<th>Concept development drawing/sketches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users: The device must be able to be operated by any gender</td>
<td>![Image]</td>
</tr>
<tr>
<td>It must be easy to use.</td>
<td>S  S  S  S</td>
</tr>
<tr>
<td>The device must improve the working method.</td>
<td>S  -  -  +</td>
</tr>
<tr>
<td>A single person should operate the device.</td>
<td>-  S  -  S</td>
</tr>
<tr>
<td>The product should benefit users.</td>
<td>S  S  S  S</td>
</tr>
<tr>
<td>Ergonomics: Elderly users can operate the device.</td>
<td>S  -  S  S</td>
</tr>
<tr>
<td>It must be easy to move around.</td>
<td>S  S  S  S</td>
</tr>
<tr>
<td>Size</td>
<td>+  S  -  -</td>
</tr>
<tr>
<td>Weight</td>
<td>+  S  -  S</td>
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<tr>
<td>The device capable to perform the work task.</td>
<td>-  -  -  +</td>
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<tr>
<td>The products should minimise energy usage.</td>
<td>-  -  -  +</td>
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<tr>
<td>Installation: The product must easy to store.</td>
<td>S  S  S  S</td>
</tr>
<tr>
<td>Cost: The product cost shouldn't be more than RM100.00 (£16.00)</td>
<td>S  S  -  -</td>
</tr>
<tr>
<td>Performance: The product should performance the work task precisely and perfectly.</td>
<td>-  -  -  +</td>
</tr>
<tr>
<td>Environment: The product should stand with corrosion.</td>
<td>S  S  S  S</td>
</tr>
<tr>
<td>Product appearance: The shape of the product should be attractive.</td>
<td>-  S  +  +</td>
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<tr>
<td>The colour must suit the user expectation.</td>
<td>S  S  S  S</td>
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<tr>
<td>The texture for handling should be excellent.</td>
<td>S  S  S  S</td>
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<tr>
<td>Safety: The device must be completely safe for the users.</td>
<td>S  -  -  +</td>
</tr>
<tr>
<td>Maintenance: The product must be easy maintenance.</td>
<td>S  S  +  +</td>
</tr>
<tr>
<td>The product shouldn't need regular maintenance.</td>
<td>-  S  S  +</td>
</tr>
<tr>
<td>It is an advantage if it is free maintenance.</td>
<td>-  S  S  S</td>
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<tr>
<td>Material: The material chosen should enable to stand misuse.</td>
<td>-  S  +  +</td>
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<tr>
<td>The material should last for numbers of year.</td>
<td>-  S  S  +</td>
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<td>+  2  0  3  10</td>
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<td>-  9  6  9  2</td>
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<td>S  13  18  12  12</td>
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</table>

Table 7.4: Oil palm loose fruit collecting device concept development evaluation
7.4.5.2 Final Design Development Evaluation Stage

This stage is where the design team was to finalise the outstanding product design. This design idea needs to proceed with all the necessary evaluation in terms of engineering aspects, manufacturing, production, marketing etc. to ensure that the project carried out has met with all the requirements which have been agreed from the beginning of the project. The involvement of other disciplines will be more in-depth at this stage. When it comes to the detail design, designers have to harness their knowledge of materials, techniques of analysis, technology of the situation, environment of the component, quantity, life, overload, loading, aesthetic appeal, and many more factors. In this stage, designers have to take into account the interfacing of each component with those adjacent to it and its effect on the whole.

The evaluation chart for this stage has been improved and the criteria have also been increased. The finished diagram is placed on the right and left hand side of the evaluation chart. The criteria of the product design specification are placed in the middle. The evaluation technique is different from the one used in the other two evaluations because this final development evaluation does not have an outstanding product as a ‘datum’ for comparison.

For this evaluation, both final design developments have been evaluated with each other using the same legend which are + (better than), - (worse than) and S (same). Designers have to evaluate these two products with all the knowledge and experience that they have in order to identify the chosen one for final modification to avoid any problems in other aspect such as material selection, production limitation, human factors disorders etc. The main differences in this design process guideline is the section which the researcher found to be very important in the guideline is the inclusion of ‘scenario analysis’. This section will enable the design team to see how the proposed design can be used in the actual environment, related to the ‘scenario analysis’ shown at the beginning of the project. Industrial designers will illustrate the proposed design product in the form of illustrations showing how the product can perform in the plantation and how the users may treat this product.

Table 7.5 shows both final design developments evaluated using most of the criteria found in the product design specification. From the evaluation the result shows that the product on the left-hand side has the highest score with 9 +, 3 – and 27 S compared to the other design. In this design process guideline which the researcher has produced, the involvement of industrial designers as mentioned earlier will be paralleled with engineers who will use their existing design process in the design project. The essential stages of industrial designer’s involvement will be from phase 1 to ‘scenario analysis’ early in phase 6. The rest will involve all the disciplines in the design team.
Table 7.5: Oil palm loose fruits collecting device final development evaluation

<table>
<thead>
<tr>
<th>+ (Better than)</th>
<th>- (Worse than)</th>
<th>S (Same)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Users:</strong> The device must be able to be operated by any gender.</td>
<td>S</td>
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<tr>
<td>It shouldn’t be complicated to use.</td>
<td>S</td>
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<tr>
<td>The product must be able to collect loose palm oil fruits.</td>
<td>S</td>
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<tr>
<td>It should attract young adults to work in the plantation.</td>
<td>S</td>
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<tr>
<td>A single person should operate the device.</td>
<td>S</td>
<td>S</td>
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<tr>
<td>The product should benefit users, estates and smallholder’s organisation.</td>
<td>S</td>
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<tr>
<td>+ The product should be moved steadily in the plantation.</td>
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<tr>
<td>+ The product must have suitable tyres to suit to the ground, if wheels are used</td>
<td>-</td>
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</tr>
<tr>
<td><strong>Ergonomics:</strong> Elderly users can operate the product.</td>
<td>S</td>
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<tr>
<td>The product must be manually operated.</td>
<td>S</td>
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<tr>
<td>The user doesn’t have to be fit to operate the product.</td>
<td>S</td>
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<tr>
<td><strong>Performance:</strong> The product should stand overloads.</td>
<td>+</td>
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<tr>
<td>+ The product should perform the work task quickly.</td>
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<tr>
<td>The product should double the collection.</td>
<td>S</td>
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<tr>
<td><strong>Environment:</strong> The product should withstand corrosion.</td>
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</tr>
<tr>
<td><strong>System operation:</strong> The product should’t have complicated mechanisms.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>The product:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The products should increase the user’s monthly income.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>The users should own the product.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Situation:</strong> The device should be used in any condition in the plantation.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>+ The device should easily used along the terrain.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Product life span:</strong> The product should last more than 5 years.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Labour shortage:</strong> The design/product should enable to solve labour shortage.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>+ The width of the product must not exceed 50 centimetres.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>+ The height of the product must not exceed 60 centimetres.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>+ The length of the product must not exceed 80 centimetres.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>+ The distance between handle and container shouldn’t exceed 50 centimetres.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Weight:</strong> The weight of the product must not exceed 20 kilos.</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>- The product should be loaded up to 50 kilos</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Product appearance:</strong> The shape of the product should look robust.</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>The colour must suit the working surrounding.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Safety:</strong> The device must be completely safe for the users.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>The product has to comply with safety regulation.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Standard regulation:</strong> The product must meet Malaysian standards.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Maintenance:</strong> The product must be easy to maintain.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>The product shouldn’t need regular maintenance.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Users should repair the product if it is damaged.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td><strong>Material:</strong> The materials choose should enable the product to stand misuse.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>It is essential to use Malaysian materials.</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>The paint use on the material should withstand the liquid from coagulated latex.</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

Table 7.5: Oil palm loose fruits collecting device final development evaluation
7.4.6 Scenario Analysis for Proposed Final Design Development

The purpose of having this second stage of scenario analysis, stated in Figure 7.2 is to give better understanding of the consequences of the proposed final design idea. This method is included in the design process to give useful information to the design team as well as to the clients to evaluate the advantages and disadvantages of the proposed design. They can observe through illustrations how the proposed product is used in actual situations in the plantation.

The aim of this method is to give an idea to other members in the design team whether there is any need to modify the design before progressing to the next step. The scenario analysis used could provide some evidence that the product should perform as the designer intended. Of course before reaching this point, testing in terms of mock-ups, scale models, and mechanism testing may have been used.

After scenario analysis the design team could proceed with the detail engineering aspects to produce the end product. Although it has been mentioned that industrial designers should focus their efforts in certain phases they still have to understand the limitations so that the conceptual ideas would not be so futuristic that it is impossible for them to be produced. Industrial designers should follow a project all the way through to the production stage to enable them to develop their understanding when engaging with new agricultural design projects.

Illustrations in Figure 7.8 show a series of diagrams of the proposed product being used in the plantation where the actual working process should be performed when the design becomes reality. This scenario analysis stage should benefit the design team in understanding how the new proposed product should be operated in the real environment.
7.5 How will these be used in practice?

In engineering disciplines there are various design processes and methods which have been proven by their use in design activities. Design of consumer or capital products undergoes similar procedures as in other disciplines, whether from mechanical, electrical, civil, agricultural engineering or any other design disciplines as well as industrial designers. Industrial designers usually adopt those design processes and methods and to some extent reorganise them to suit their needs to enable them to work more systematically. The industrial design process is generally made up of the following phases:

- Investigation of customer needs
- Conceptualisation
- Preliminary refinement
- Further refinement
- Final concept selection
- Control drawings
- Co-ordination with engineering, manufacturing, and vendors (Ulrich et al 1995)

The researcher has come out with a design process guideline for industrial designers but this is not an entirely new concept. It is a means of achieving a situation where the proposed design guideline could simplify the design activities carried out by industrial designers working in parallel with engineering designers. Industrial designers have to work within a
framework which allows them creative freedom but also helps them to work in every stage in the design process with other disciplines in the design team.

The new ideas which the researcher introduced in the design process guideline were 'scenario analysis' which the researcher found could help the design team to understand the methods and problems of the current practice. The method was found while carrying out the design project where discussions were held with several designers and engineers and they found out that this technique is essential to be implemented in the system. It gave better understanding of the environment, the plantation, the users and ideas about how the proposed design product will suit the situation before any further design work is carried out. The approach is used in two stages, firstly identification of design needs, and secondly evaluation of the final design development.

Another new approach is to identify a lot of alternative problems by group ideation (stage 2 in Figure 7.2). Four stages have to be done after the scenario analysis. The first stage is done as team brainstorming to produce problem headings. The researcher has clarified two types of bubble chart in this stage giving main headings and sub-headings. The second stage develops questions derived from the bubble chart and these questions are used to formulate a product design specification, which forms the third stage. Before generating conceptual designs, the designers can develop more detailed questions for their own reference in parallel with the product design specification. The second and third stages have their own format, which will be used by team members to evaluate the conceptual design ideas.

The research showed that an important factor to be included in the design process guideline was the skill that industrial designers have. Industrial designers are able to produce fast conceptual ideas and this advantage has to be highlighted. Nowadays, new computer-aided industrial design (CAID) tools such as 'rhino 3D', studio tools and 3D studio have a significant impact on industrial designers because by this manner, industrial designers can potentially generate a greater number of detailed concepts more quickly, which may lead to more innovative design solutions. Before this can be implemented industrial designers have to use their imagination to produce preliminary conceptual ideas but they have to control the freedom to avoid unnecessary deviations from the requirements stated in the product design specification.

Evaluating preliminary concepts, concept development and final concept idea stages should undergo proper evaluation using systematic techniques. Industrial designers as well as other design team members, especially engineers, have to undergo these evaluation stages together to narrow the options down. The researcher has adopted Pugh's evaluation techniques as illustrated in Table 7.3. Industrial designers and engineers have to identify the necessary criteria to be used in evaluating the ideas, which are different from preliminary concept ideas up to the final concept. The number of criteria used increases from one
evaluation to another to fulfil the product design specification requirements and answer the
questions, which have been developed by industrial designers to make design work easy to
conduct.

The proposed design process guideline is designed to enhance Malaysian industrial
designers involvement in agricultural equipment design activities. Most products that are
used and operated depend critically on industrial designers for commercial success. This
design process guideline can be used in practice by industrial designers to create a particular
product with the involvement of other disciplines to ensure the final design meets the product
design specification requirement.

The proposed design process is a guideline and it is not necessary for industrial designers to
follow exactly what has been proposed. From the qualitative survey several UK industrial
designers said that they have their own design method which helps them to follow the design
process within the time frame which they have to deliver the end product to their customers.
Malaysian industrial designers do not have a specific design process to use and it is time for
them to have some sort of reference for their own advantage. As mentioned it does not have
to follow exactly what has been proposed but at least they have some ideas how to plan and
work through all the way from identification of customer needs to manufacturing the end
product.

7.6 Difficulties encountered In the research

Any research programme conducted will face problems and difficulties. This is the challenge
that a researcher has to take to enable him to gain knowledge from the problems and
difficulties that have occurred. In producing this proposed design process guideline the
researcher encountered several problems and difficulties which are:

- To produce a new design process approach is quite challenging because a number of
design processes are available in engineering design but very few in industrial design.

- To derive a bubble chart approach in conducting the brainstorming session incorporating
the required numbers of 'headings' is quite challenging and needs to be developed over a
number of real projects. The 'headings' will evolve as they are implemented in the
proposed design guideline.

- Producing generic questions to help towards producing a product design specification is
not easy. The researcher worked hard in producing related questions to the problems
occurring in the design projects undertaken.
• The product design specification has to be used in the conventional way and as a basis for an evaluation chart for designers to assess importance of the characteristics from the point of view of different disciplines in a design team.

• The other new approach is producing a different set of questions intended to speed up the design work, which are evolved from the main question and related to the product design specification. These questions are more detailed and are intended for the designers own reference as well as the product design specification.

• Choosing the right method for concept evaluation also faced a problem because industrial designers normally evaluate concept ideas without any formal evaluation method. The researcher had to identify a suitable method for this purpose because it has been proven relevant during testing the design process. The researcher would like to stress that this method is essential for industrial designers to evaluate the conceptual ideas in the future.

• Models and mock-ups could not be used during the case studies in order to show the complete design project as it would normally be performed by designers.

7.7 Observations on the Proposed Design Process Guidelines

The main findings from the proposed design process guidelines based on observations so far are:

• The value of 'scenario illustration and analysis' using visual formats to better understand the working environments.

• The value of 'virtual scenario evaluation' in giving a better understanding to all the disciplines involved in the design projects of how the new proposed design might perform in the plantation and the suitability for the users before deciding to proceed with further development.

• Time spent could be reduced tremendously if brainstorming sessions could be utilised effectively in producing stage 1 to stage 4 under phase 2 in the proposed design process guideline as illustrated in Figure 7.9.

• Free concept generation from industrial designers could give an overview of how the product will look. This will help the design team to evaluate conceptual ideas related to the product design specification.
- The product design specification is designed not only for the purpose of identifying design criteria but it is also used in evaluation for different disciplines to enhance the importance of each criteria from different points of view.

- The researcher has covered the benefit to Malaysian designers of using specific design evaluation methods in choosing the appropriate preliminary conceptual idea, development concept idea and the final development design. The method is very convenient and systematic and appropriate for Malaysian designers.

- The proposed design process guideline is intended to be the beginning step for Malaysian industrial designers to become involved in agricultural equipment design activities to help Malaysia produce agricultural products.

- Although the proposed design process guideline is not an entirely new concept the new methods and approaches proposed could benefit the designers, especially industrial designers, by following the stages systematically.

- The proposed design process guideline is divided into phases, which is important in terms of managing the design projects taken because each phase could be used to specify the time frame needed before continuing to another phase. This approach also lowers the overall project risk.

7.8 Knowledge created

Knowledge created at this stage in producing this proposed design process guidelines can be specified as:

- The value to industrial designers of having a design process to follow during design projects.

- The usefulness of the new 'scenario illustration and analysis' stages to give an overall picture and understanding to the design team members of the current practice, the problems faced by the users, the conditions on plantations and to be aware of existing products and methods.

- The importance of giving the opportunity to the industrial designers to use their skills in producing conceptual ideas plus development and to allow the design team to evaluate and specify quickly the concept ideas which meet the product design specification requirements.
• The value of incorporating Pugh's design evaluation technique to identify outstanding concepts. This technique has not been used within the Malaysian design team context.

7.9 Interviews Conducted to Evaluate the Proposed Design Guidelines

Five interviews were conducted in 2001 with selected respondents who have different backgrounds within engineering and industrial design. The purpose of conducting these interviews was to obtain evidence to assess the value of this product design guideline in practice and to identify possible improvements. Interviews have been conducted with Mr. D. Hitchcock, director of ICE (Institute of Consumer and Ergonomics), Mr. P. Wormald, a Loughborough University industrial design lecturer, Mr. R. Sulaiman a Ph.D. researcher from Cranfield University and also an automotive consultant, Mr. M.S. Ismail a Ph.D. researcher and also an engineering product designer from Coventry University and Mr. A. Dartnall a freelance industrial designer who designs consumer and industrial products.

The first impression when the design process guideline was shown to the interviewees, was that they assumed it was a complete design process. They were very positive about the process after it had been explained and they suggested that several phases should be included in the diagram after phase 6 to show the complete design process. In this study the researcher concentrated from phase 1 to phase 6 because at these phases the contribution of industrial designers is greater.

Dartnall (2001, interview) expressed his concern that, as an industrial designer, he would not be happy using a structured process if it constrained his creative freedom. It was explained that the guidelines were not intended to control or constrain free thinking or idea generation, but to help to guide the project and assist team working. He accepted this, but felt that some industrial designers might feel that the process would constrain them when they see it on paper for the first time.

The literature search, and survey had shown that industrial designers do not have their own design process to hold on as engineers do. Unanimously they said that they used engineering design processes which they adapt and modify to suit their needs. On some occasions they used various design approaches to fulfil the requirements of the management who had defined the design process to be used within their organisation.

Developing a design process guideline is very challenging if, when it is implemented, it is able to complete with any current design process. The qualitative, quantitative survey and case studies conducted have shown the importance of understanding the problems faced by the users and how the proposed product could perform in the plantation. Industrial designers will produce a range of illustrations explaining the environment of the plantation, the crop's arrangement, the current practice in the plantation and the problems faced by the users. In
Figure 7.2 the researcher names this method 'scenario analysis'. This method has been strongly supported by Hitchcock, Wormald, Sulaiman and Dartnall (2001, interview) because it is very useful in terms of presenting the overall picture of the plantation and how work is done in the current situation. Hitchcock then stressed that this method is very valuable because it covers three major things in the illustration which ergonomists always consider who is doing the task, what are they doing and where are they doing it? He felt that graphical representation was the best communication method at this stage. He felt the small pictorial drawings were very useful and because every picture speaks for itself the written words were not entirely necessary.

Wormald (2001, interview) suggested that digital images and/or video may be used to aid the initial scenario analysis stage because it cannot be assumed that all designers have the high level of graphical skills needed to illustrate the working environment as effectively as the researcher. It was agreed that a variety of visual media could be used at this stage.

Hitchcock, Wormald, Sulaiman, Ismail and Dartnall were convinced of the value of the method proposed because it could help members in the design team understand, and this method could also be used in other design projects. They accepted that it is often impossible for all the members, a team to go to the plantation to observe and experience the work task for themselves. By understanding the scenario through this means of 'visual explanation' the team members could quickly gain enough information to have meaningful discussion.

Sulaiman and Ismail (2001, interview) suggested that scenario analysis could be replaced with a different name to differentiate between the first and second scenario analysis stages in Figure 7.2. The researcher has therefore identified the first as 'scenario illustration and analysis' and the second as 'virtual scenario evaluation' as stated in Figure 7.9.

The use of 2D and 3D models in design activities has been proven and strongly recommended by Hitchcock, Wormald, Sulaiman, Ismail and Dartnall because these methods can speed up the concept development stage and help to identify the problems and weaknesses during development of concept ideas. Dartnall stressed that prototyping has to be conducted as early as possible and it is essential to know what are the factors the designers would like to find out from it. This includes simple mock-ups used as early as possible to stimulate iteration in the project.

Iteration is very important throughout the design process to make sure that the designers are on the right track. Sulaiman believed that the chart shown in Figure 7.2 is quite understandable, but it could be more clear if it could include 'yes' and 'no' within the stages in the design process. 'Yes' means that the designers could proceed with the following stage and 'no' means the designers have to go back to the initial problem or previous stage to check what has made the problems occur. Figure 7.9 has included this approach. Hitchcock
and Dartnall also felt that the iteration in Figure 7.2 is quite confusing and suggested that the loop of iteration has to be frequent and small in scale.

The researcher found out in conducting the case studies that it is important to conduct a brainstorming session to identify problem areas before a PDS is constructed. The bubble chart method is appropriate to be used in this stage where designers have no limits and need to throw and bounce the ideas around. Wormald agreed with the method and suggested the 'headings' proposed are used as a starting point for the members in the design team to start with because it is easier to change something than to start with a blank sheet. More headings could be added or removed as required. Ismail supported what Wormald had mentioned but he would like the 'main task' and the 'task 1' of the bubble chart to be combined to make it easy to follow where the brainstorming session could perform smoothly. Hitchcock (2001, interview) found the bubble chart quite complex and needed better explanation. This is discussed in section 7.4.2.

Another new approach included in this design guideline is the detail question formulation beside the PDS. The purpose of these detail questions is to guide designers on the right path; they are generated by themselves to be used for themselves along with the PDS. Sulaiman (2001, interview) believed that designers think they know what should and should not be incorporated in the product and it is rational for the designers to have these sort of questions to help them endeavour to appreciate the design problems. The PDS is a basic reference and detail questions help them to understand the problems more deeply. Ismail and Sulaiman believed that the design checklist stage is very important because this section has to be referred to all the time during a design project. Hitchcock agreed with the 'design checklist' section and he thinks that the system should work nicely if the PDS has all the criteria illustrated in 'scenario illustration and analysis'. He could see the benefit and the value within the design process.

Industrial designers have training in producing fast sketches and this could help a lot for the design team to visualise the ideas and contribute their ideas for further development. In industrial design, systematic evaluating has not been practised widely. The researcher has adopted the evaluation matrix chart in order for industrial designers to evaluate the ideas according to the requirements stated. Unanimously all the respondents agreed that industrial designers have those talents and should deliver those skills wisely. They support the use of evaluation charts to select the outstanding concepts and Hitchcock suggested that the concept design in the final design evaluation stage could be evaluated thoroughly by alternating the loser and the winner accordingly to test the results from the evaluation output. Dartnall suggested that models and prototyping also has to be evaluated at every evaluation stage concurrent with the sketches as early as possible in the project.
Before approaching the final design stage, scenario analysis has been introduced again to give a better understanding of how the proposed product design would perform in the plantation and how the users should handle the product. Wormald and Ismail believed that this method could give first hand information to the design team on how the proposed product should perform in the real environment. The method is quite unique but it proves to work. This stage is not yet producing an actual product. The method used is to show how the new product should be used in the plantation before any changes are made for improvement. It is advisable to name this stage differently and the researcher has identified it as 'virtual scenario evaluation' (Figure 7.9) because of the nature of showing the proposed product in the real environment.

Sulaiman was quite convinced with the proposed design process because he could see the involvement of the design team start from the beginning, especially identification of the problems, generating questions and PDS as well as evaluating concept development to final design development until 'virtual scenario evaluation'. Hitchcock, Wormald, Sulaiman, Ismail and Dartnall (2001, interview) agreed and suggested that the proposed design process guideline:

- Is quite easily to follow and understand
- 'scenario illustration and analysis' and 'virtual scenario evaluation' is a very valid proposal
- it could be used for other design projects with several changes to suit the projects
- the method should have a written procedure on how to make use of the system
- make use of the existing bubble chart as first starting point for other design teams. The elements may than be developed to suit the various projects
- more visual material could be used to illustrate some stages in the design process

In terms of putting various colours in the diagrams, Sulaiman and Ismail urged the researcher to consider the colour scheme because certain colours could end up black when photocopied. Improvements to the colour scheme have been made (Figure 7.9) which is quite different from the previous proposed design process guideline (Figure 7.2).

The interviews have provided evidence that the proposed design process guideline in Figure 7.9 by introducing the 'scenario illustration and analysis', design checklist, incorporating industrial designers skills with other designers, introducing design evaluation matrix charts and 'virtual scenario evaluation' gives designers, especially industrial designers, the opportunity to be involved effectively in agricultural equipment design activities.
7.9.1 What are the next steps?

The design process guideline is a new approach which the researcher would like to introduce to Malaysian industrial designers and it is the intention that this approach could convince them to become involved in these design activities. The University Technology of Malaysia (UTM) is the only university in Malaysia and throughout the region that has industrial design and mechanical engineering students under the same department within the faculty of
mechanical engineering. There are ten industrial design lecturers at the moment. The researcher has the opportunity to test this proposed design process among lecturers in the faculty to participate in a project which is funded by the Malaysian government under IRPA and companies. The researcher also could test this method within industrial design and mechanical engineering students with different approaches which are:

- Industrial design and engineering students use this proposed method during carry out the same design project at the same time.
- Industrial design students use this method whereas engineering students used other engineering methods available in design project.
- Industrial design students divided into two groups, one group to use this proposed design process and the other group to use existing design methods.
- The same procedure above will be used with engineering students to see the effectiveness of the design process.
- Industrial design students to use engineering design process and engineering students use this proposed design process guideline conducting the same project.

From the results gained the researchers' intention is to produce several papers from the tests conducted. The results will give the opportunity to evaluate and transform this proposed design process guideline into more successful and valuable piece of work for industrial designers working in the universities, R&D institutions and companies, as well as for consultancy work.

7.10 Summary

A methodology comprising design process guidelines has been proposed based on the findings from the literature study, qualitative and quantitative surveys and case studies. The objective in producing this design process guideline was to establish a systematic design method for Malaysian industrial designers to enhance the opportunities for them to be involved in this industry.

The findings from this chapter have fulfilled Aim 4 of this research which was:

- To develop appropriate methodology and techniques to help industrial designers to contribute in the design of agricultural machinery relevant to Malaysian circumstances.

The results show that the industrial designer's skills and knowledge can contribute significantly from the early stage of the design process. This approach helps to identify the problems as quickly as possible at the beginning of the design projects. Industrial designers have the capability to convey the information in order to give an overall understanding of the whole scenario of the particular situation.
The method of identifying the main problems of the projects can generate sufficient questions related to the projects, which easily can proceed to produce a product design specification for designers to fulfil. A format is proposed to make the method easily managed. The good visualisation and imagination of industrial designers has to be fully used within this proposed design process guideline to generate conceptual ideas, from preliminary concepts to final development ideas. The evaluation charts introduced in this approach are important to help industrial designers critically examine every single concept produced and to assist development to increase the effectiveness of the ideas. The value of the approach has been strongly endorsed by five design professionals.

Finally it is hoped that this proposed design process has made the contribution of industrial designers more useful in the design of agricultural equipment for Malaysia. It is also expected that these design process guidelines will help the importance of industrial design to be recognised by other disciplines, especially agricultural engineers, in contributing to product development and market success in Malaysia.
8.1 Introduction

Human creativity and design significantly influences life style. The existence of industrial design has substantially changed the Malaysian economy and most significantly imports and exports. However, the era of industrial design in Malaysia is still young compared to other industrialised countries such as Europe, the United States of America and Japan. Nevertheless, Malaysian industrial designers have played an important role in the production of high quality products, competitive with those produced by industrialised countries, including cars, motorcycles and domestic products. The industrial designers try to incorporate local social values into their designs to ensure that the design is acceptable to the local communities as well as acceptable by other users abroad.

Findings from the qualitative and quantitative surveys and case studies have been triangulated in order to establish the importance and the potential contribution of industrial designers in agricultural design activities. The results gained have been used to propose design guidelines for industrial designers to use within the design team during agricultural designing activities.

This guideline provides a design process methodology for Malaysian industrial designers to use for guidance throughout a project. It represents a new approach, which combines several design methods and processes gathered from engineering design as well as the researcher’s own experiences as an industrial designer and design lecturer in UTM. This design guideline is intended to help and give confidence to Malaysian industrial designers in order to help agricultural R&D institutions, universities and government bodies as well as the private sector in creating products which fulfil the needs of the users. Successful products may then be exported.

This final chapter discusses the role and contributions of Malaysian industrial designers in section 8.2. Section 8.3 deals with the conclusions of this thesis and recommendations and suggestions for future work are presented in the final section, 8.4.

8.2 The Role of Industrial Designers in Malaysian Agricultural Machinery

The era of industrial design in Malaysia has come to a position where they must play their part and contribute not only in producing domestic products but capital products as well. We can see how industrial designers in industrialised countries play an essential role working
hand-in-hand with other disciplines, especially engineers, to boost their products in world markets. They play an important role in the production of high quality products, competitive with other manufacturers.

Malaysian industrial designers cannot stand alone in arriving at a conclusion regarding the design of the product. They have to co-operate with other disciplines, especially in this case with agricultural engineers, who need their help to improve many aspects to create successful and suitable new products required by the users.

The industrial designers have to realise that designing agricultural machinery and equipment is not an easy task. To appreciate the factors that influence the effectiveness of a product they should be more flexible in understanding other fields and gain more knowledge to be able to work in parallel and communicate during the design activities. Good understanding and communication not only develop a product which has good form and style but also has excellent functionality.

Industrial designers should be cognisant of the overall marketing and the users to promote a greater harmony between them. Marketing and users can provide valuable information before any attempt is made to produce conceptual ideas, and within the design process high quality communication will contribute to better output. Industrial designers must be able to design a product which satisfies the needs and tastes of the users because they are the ones who will buy and use the product. The scenario analysis stages within the proposed design guidelines provide a mechanism for this communication.

The potential contribution of Malaysian industrial designers towards designing agricultural machinery and equipment has been discussed and established in the research findings. The case studies carried out in chapter 6 demonstrate that industrial designers have the capability, skills and knowledge to enable them to be involved in the design activities. The literature and the qualitative and quantitative surveys also showed evidence that the potential contribution from industrial designers in this activity is crucial, especially for the Malaysian context.

The quantitative survey showed that Industrial designers could improve product quality, make the product more saleable, improve ergonomics aspects and improve product usage in agricultural equipment. Design elements such as performance, reliability, functionality, safety, quality, safety and product testing are the elements which have to be given priority and serious consideration during design work.

For agricultural machinery and equipment the design emphasis is on the conceptual design, product architecture and design for manufacture. The work involved in adding value by the integration of components and subsystems into a successful product is a process very
familiar to industrial designers, because of their holistic approach of designing 'from the outside-in'.

Therefore, in Malaysia, the local industrial designers should not only concentrate on mass produced consumer goods but also move forward towards an involvement in more challenging and demanding fields such as agricultural equipment design work. Involvement in this area and working hand-in-hand with agricultural engineers could change the design approach currently used which is modification and reconstruction of existing products. This practice has proven to give no advantage to the industry because the products imported from abroad were not suitable for the Malaysian environment and the changes carried out on the products have made little difference.

Industrial designers have to play their role by putting themselves into the plantations to observe and experience what problems occur. They also have to understand the problems of the users and what are the suitable devices for them in terms of performing the work task in more enjoyable ways and seeking how to attract youngsters back to work in the plantation rather than in the factories.

It is urged that Malaysian industrial designers take the challenge and engage themselves with agricultural engineers to change the products to compete with other agricultural products in international markets. In time Malaysian agricultural products should be exported abroad. This will generate income and jobs for Malaysian people, as well as increasing the agricultural output by more efficient farming methods.

8.3 Conclusions

The research findings show the need for a broad-based approach to design of agricultural equipment taking account of both technological issues and the design context, and they clearly confirm that industrial design is relevant and has an important role to play. It has become clear that, for effective design, an understanding is required not only of the task, crops and the working environment but also of the people who will buy and use the products, including their capabilities, attitudes and sociocultural influences.

When we talk about industrial design, first and foremost people will think about aesthetics, how the product looks, feels, smells, or sounds. The other aspect industrial design is known to be good at is in making sure that the product meets all human interface requirements. The research has shown the importance of industrial designers' involvement in agricultural machinery and equipment design activities. This is especially true for Malaysia because nowadays they cannot be treated purely as artists who know how to create products aesthetically but ignore the functionality. Industrial designers have to be involved from the
early stages of the design process otherwise there may not be sufficient scope to develop appropriate concepts. They must have a good working relationship with other disciplines to ensure that the projects run smoothly and produce successful end products.

Industrial design skills are valuable not only in designing the product itself but also in facilitating communication and understanding during the design process. Good communication between members of the design team and with outside parties is important during design. Hollins et al (1990) quoted from Alexander that 'innovative design does not sell itself but it depends on the creative communication skills and positive commitment of marketing staff working in conjunction with designers to ensure the commercial success of a product.' (p. 62)

The research also found that it is essential for design teams to communicate effectively with non-technical people such as financial controllers, managers, clients and potential users. The need for visual media which can be easily understood by non-designers was a recurring theme, especially in the interviews. CAD is useful in the later design stages but the graphic skills of industrial designers can provide a most valuable input at any stage of a project.

Industrial designers need to constantly upgrade their skills and knowledge as well as equip themselves with other basic knowledge such as engineering, management and economics. That knowledge is required to ensure industrial designers can work effectively with other disciplines, especially interacting with engineers, marketing, users/clients and management. One design method which is fundamental to design is the PIDS, and the researcher took this opportunity to integrate this into his design guideline as one of the essential factors.

The design guidelines could be considered as the researcher's contribution to knowledge whereby from the survey and case studies he had derived this proposed approach for Malaysian industrial designers. Industrial designers have to take the challenge by migration to this area working hand-in-hand with other disciplines especially agricultural engineers, to change their design culture. Understanding the nature of the design problems by introducing 'scenario illustration and analysis' could provide an overall perception for others in order to develop questions and formulate a PDS more effectively in a very short period. The capabilities of industrial designers have also been utilised to come out with quick preliminary concept ideas and then develop those to ensure an outstanding final concept can emerge for further development. Evaluation techniques usually used in engineering design have been adopted to ensure that industrial designers have a systematic approach to evaluate and choose the outstanding design concepts for further development which meets the requirements to satisfy the users. 'Virtual scenario evaluation' is also a new stage in this proposed design guidelines to assist team members to evaluate the final proposed design before it proceeds to the stages of 'final modification' (Figure 7.9).
Chapter Eight  Conclusions, Recommendation and Future Work

The findings from surveys and case studies have confirmed that there is an essential role and significant potential contribution for industrial designers in the field of agricultural machinery design. The proposed design approach could benefit Malaysian industrial designers involved in this area and help to create a competitive environment within agricultural products. The proposed design process has not been tested in the real world but it has been discussed with selected professional designers to assess the potential benefits and possible improvements for the design guidelines. The technique and principles were strongly endorsed and it appears to be very useful to Malaysian designers. Some more work has now to be done to ensure the method is fully understood and easy to manage before it can be claimed as a successful new design methodology for industrial designers.

Traditional methods of teaching design in Malaysian universities have to be revised. Latest technologies have to be implemented and brought to the students. The research indicates that industrial design students have to be supplied with fundamental engineering and science knowledge to ensure they are aware of the key issues when conducting design projects. The lecturers have to teach students how to integrate the concepts to embody the design specification laid down for a product which includes an awareness of the principles of mechanical design, engineering materials, manufacturing technology and other related fields of study such as fluid mechanics, heat transfer and electrical technology.

The researcher developed the aims and objectives of the research to be fulfilled during this study in order to identify the important and useful means to enable industrial designers to play their role and contribute their expertise in agricultural design, especially for the Malaysian context.

The first objective was:
To study the design processes implemented by UK industrial designers and engineering designers in the field of agricultural machinery.

The literature study and results from the qualitative survey showed that industrial designers do not use specific design processes during design work. This is different from engineering designers who tend to use several design methods available within their profession. The Malaysian interviews showed that they used the same design methods as engineers but with some modifications to suit them. Several UK industrial designers mentioned that they have produced their own design process which proved to be working well, but couldn't share with the researcher because it is their confidential company strategy. Industrial designers have to develop a design process to enable them to work systematically and interact well with other disciplines in design work.

The second objective was:
To study the role of industrial design in the agricultural machinery and equipment industry.

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Visiting several companies and R&D institutions, and discussing, observing and interviewing industrial designers has resulted in valuable findings on the usefulness of having industrial designers working along with other disciplines, especially engineers, producing agricultural products. They proved that the industrial design role in this area is important and this has made the researcher determined to further the investigation in order to help agricultural design practice in Malaysia.

The third objective was:
To identify the type of design approach that is most suitable for use in agricultural machinery design.

The surveys conducted within the UK and Malaysia have resulted in an understanding of several design approaches which have enabled the researcher to propose design guidelines for industrial designers. This will allow the essential industrial designer's skills to be incorporated with engineers in this area. The problems facing agricultural design work by engineers have been looked into and the researcher has considered how industrial designers could fill the gaps.

The fourth objective was:
To develop appropriate methodology and techniques to help industrial designers to contribute in the design of agricultural machinery relevant to Malaysian circumstances.

Results and findings from the surveys have produced sufficient information supported by the case study design projects resulting in a new approach of design process guideline suitable for industrial designers. The researcher has gone through the process with sample ideas and believes that it can be workable in practice with further refinements to strengthen the means of conducting the process in a simple manner.

Producing design guidelines can initiate a new era for Malaysian industrial designers to participate with agricultural engineers in producing competitive products. The researcher has tested the design guideline proposal on paper with professional designers which has shown that it can help Malaysian industrial designers to speed up the design process and work effectively with other disciplines. The design guideline can also be used for other consumer product design activities. Further work can now be carried out to perfect the system.

8.4 Recommendations and suggestion for Future Work

If the country is to advance, it has to have an all round development in every sphere of activity, including agricultural industry. Without research and development the growth of the economy of the country cannot be guaranteed. To ensure sustained development R&D
activities should be pursued in every industry with the talents available internally. This section will provide a brief outline of how to proceed with further investigations which might improve understanding of the role and contribution of industrial design in the field of agricultural machinery.

The qualitative surveys were conducted and the questions used in interview survey were to gather the information needed from experts in his or her discipline. It is recommended that for the future more interview questions are based on how industrial designers could contribute their skills, experience and knowledge within the design team in agricultural machinery and equipment design projects. It is suggested that besides interviewing the respondents, further observation during design activities in the design studio should take place.

Quantitative surveys could focus into more detail questions considering industrial designers contribution towards this area, going deeper into the design methods used within industrial design and engineering design process. Elements in the design process are many and it is advisable to concentrate on a few which future researchers could highlight, such as functionality. How aesthetics could help improve the selling of the products? The important thing with this research method is to try to convince the respondents how important this survey is, how valuable is the information from them and how to make them respond and return the questionnaires.

Industrial designers have to work very closely with other disciplines in the design team in order for them to participate in this robust design activity. For further investigation in the near future it is suggested that interview questions focus more towards integration between industrial designers and engineers working together in the design projects.

In terms of case studies for future work it is recommended that industrial designers work closely with engineers to have a better understanding of the interaction between industrial designers and agricultural engineers working together in the same project. Industrial designers know what are the advantages that they have and can try to merge these together with what engineers could do. Future researchers could identify any loopholes which could be filled by industrial designer's skills and experiences.

The design guideline process developed in this thesis aimed to help Malaysian industrial designers to work with other disciplines, especially agricultural engineers. The researcher has produced a process, which is appropriate to this area as well as other design activities from identification of design needs to producing a final concept design. It is suggested that future researchers could implement it during case studies to establish the successful aspects and to make improvements for the future. This may be done with student groups and with practising design teams.
Future research could further the findings at several stages in the design guideline which may include:

- The method of using 'scenario illustration and analysis' should be more precise and better specified in order for design team members to understand more clearly and help to generate valuable information.

- The method of developing headings and sub-headings with regard to particular design projects could use computers in order to shorten the time spent.

- Simplification of the question chart for easy evaluation by design team members.

- Simplification of the question form for designers to make it easy to organise and gather all the information generated by design team members.

- Identify opportunities for incorporating various design packages, which have suitable interfaces such as material selection and manufacturing analysis of the design.

- Consider the possibility of standardising the evaluation chart starting from preliminary conceptual design up to final concept design for industrial designers concentrated on the same criteria all the way through.

- Generate software to include all the process within this design guideline and all the necessary information such as existing products available, human factors analysis and other information, thus reducing the lead time in design activity.

The researcher hopes that this research has made valuable contributions towards maximising the role and potential contribution of industrial design in the field of agricultural machinery for use in Malaysia. From this research it is also expected that it would be beneficial to the community especially to the designers and academia, in order to understand the contribution of industrial design in product development and the potential for improving product quality for market competitiveness.

8.5 Conference Paper

During the research one conference paper has been published in the proceedings of the National Design Seminar 2001, Johor Bahru, Malaysia, 15th January 2001, entitled:

- The Role and Potential contribution of Industrial Design in the Field of Agricultural Machinery
REFERENCES


References


270
References


273
References


148. Tovey, M., (1997) 'Styling and design: intuition and analysis in industrial design' Design Studies Vol. 18 No 1. Jan. pp 5-31


BIBLIOGRAPHY


References


275


1. Ahmad, D., (1999) Assistant Dean, Faculty of Engineering, University Putera of Malaysia, Serdang, Selangor, Malaysia, Interview, 27th September.
10. Ishak, I., (1999) Head of Dept. of Design, Faculty of Mechanical Engineering, University Technology of Malaysia, Skudal, Johor, Malaysia, Interview, 8th October.
References


Appendix I: Covering letter with postal questionnaire
To whom it may concern

May, 1999

Dear Sir or Madam:

The Role and Potential Contribution of Industrial Design in Developing Agricultural Machinery for Malaysia

I am conducting a study of how Industrial Designers can play a role and use their knowledge and skill in designing agricultural machinery and related projects. There are many predictions and many trends and in this research I want to collect the views of the people most affected (the industrial designers and the engineers) on the probability and usefulness of the various possibilities. I also want to know more about the interaction between designers involved in design related to agricultural machinery and equipment.

Just a few minutes of your time in completing the enclosed questionnaire will provide me with very valuable information to help me in my further research phases. Other phases of this research cannot be carried out until I have analysed the questionnaire data.

The views of individuals will of course remain confidential. However, if you would like a summary of the conclusions of the research please provide me with your name and address.

Please return the completed survey questionnaire using the self-addressed enveloped enclosed. I am looking forward to your reply with interest.

Thank you very much for your cooperation.

Yours sincerely,

Mohd Nasir Hussain
(Ph.D. Research Student)
Department of Mechanical Engineering
Loughborough University
Loughborough, Leicestershire
LE11 1JY.
UK.
The Role and Potential Contribution of Industrial Design in Developing Agricultural Machinery for Malaysia

Anyone who creates something original or innovative is a designer. Those who make their living by designing products of mass production and mass consumption are known as industrial designers. Industrial design is concerned with the design of manufactured products. It is a disciplinary profession, which is involved with designs that can be produced in large quantities to satisfy the needs of the buying public.

The design and development of agricultural machinery and equipment in Malaysia is currently experiencing a number of pressures. These are:

1. A long-standing reliance on imported machinery and equipment and a consequent desire to develop a sophisticated home industry to supply a growing demand.
2. A realisation that in order to successfully produce and market appropriate agricultural machinery and equipment, design capability will need to be established at the centre of research, development and production activities.
3. Many plantations face tremendous problems in planting, clearing, picking and transporting in their everyday activities. The involvement of designers is necessary to consider these problems and create products or systems to improve the situation.
4. Older people are operating most of the plantations because youngsters prefer to work in the factories rather than on the plantations.
5. Usage of imported machinery is unsuitable for certain plantations and causes major damage to the surface.

My aim in this study is to provide Industrial Designers, in Malaysia, with methods or guidelines to assist them in designing machinery appropriate to Malaysian agriculture and other agronomical factors. In this way I would like to remove the need for modification and reconstruction of imported machinery most of which are not specially designed to suit Malaysia’s needs and requirements. My interest also lies in understanding the implementation of design processes in the UK and Malaysia and the interaction between industrial and engineering designers in a design team.

Therefore, there is a need for research which will inform the development and application of industrial design to agricultural machinery and equipment within the Malaysian economy.

---

**SECTION A: BACKGROUND INFORMATION**

Please tick [ ] in the appropriate boxes.

1. Which of the following categories best fits the number of employees in your organisation?
   - Less than 50 [ ]
   - 51 – 100 [ ]
   - 101 – 200 [ ]
   - More than 200 [ ]

2. Does your organisation:
   a. Have a Design Department [ ]
   b. Have a Research and Development Department [ ]
   c. Other design-related, please specify

3. Please indicate your job function:
   - Industrial Designer [ ]
   - Design Manager [ ]
   - Engineering Designer [ ]
   - Design Consultant [ ]
   - Agricultural Designer [ ]
   - Design Director [ ]
   - Others, please specify [ ]
4. The number of years experience in the position in question 3: 

_________ years.

5. The total number of years experience in designing profession: 

_________ years.

6. Company name : ________________________________ (optional)

7. Company address : ________________________________ (optional)

8. Respondent's name : ________________________________ (optional)

9. Contact telephone number : ________________________________ (optional)

SECTION B: PERSONAL EXPERIENCE

Please tick [ ] in the appropriate boxes.

1. How long have you been involved in designing?
   - Less than 1 year [ ]
   - 1 – 2 years [ ]
   - 3 – 5 years [ ]
   - 6 – 9 years [ ]
   - More than 10 years [ ]
   - None [ ]

2. What led to your involvement in design?
   - Directed from company management [ ]
   - Research and Development project [ ]
   - Consultancy work [ ]
   - Others, please specify [ ]

3. How many agricultural machinery design projects have you been involved in?
   - 1 [ ]
   - 2 – 4 [ ]
   - 5 – 9 [ ]
   - 10 and more [ ]
   - None [ ]

4. How many design projects related to agricultural machinery have you carried out during last 5 years?
   - 1 [ ]
   - 2 – 4 [ ]
   - 5 – 9 [ ]
   - 10 and more [ ]
   - None [ ]

5. Who are the people that are involved with you during design projects?
   - Agricultural Engineers [ ]
   - Mechanical Engineers [ ]
   - Production Engineers [ ]
   - Electrical Engineers [ ]
   - Industrial Designers [ ]
SECTION C: AGRICULTURAL MACHINERY DESIGN

Please tick [] in the appropriate boxes.

1. What types of machine and equipment have you designed?
   Tractors [ ]
   Cultivators [ ]
   Sprayers [ ]
   Harvesters [ ]
   Planting machinery [ ]
   Processing machinery [ ]
   Others, please specify [ ]

2. In designing agricultural machinery and related projects, can you identify the contributions of the following disciplines in the design process:

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<tr>
<th>Clarification</th>
<th>Conceptual Design</th>
<th>Embodiment Design</th>
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   a. Marketing   | [ ]               | [ ]               | [ ]          | [ ]          |
   b. Agricultural Engineers | [ ]               | [ ]               | [ ]          | [ ]          |
   c. Mechanical Engineers | [ ]               | [ ]               | [ ]          | [ ]          |
   d. Production Engineers | [ ]               | [ ]               | [ ]          | [ ]          |
   e. Electrical Engineers | [ ]               | [ ]               | [ ]          | [ ]          |
   g. Industrial Designers | [ ]               | [ ]               | [ ]          | [ ]          |
   h. Ergonomics | [ ]               | [ ]               | [ ]          | [ ]          |
   i. Others, please specify | [ ]               | [ ]               | [ ]          | [ ]          |

3. In designing agricultural machinery and equipment, please indicate the level of importance of the following factors:

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<th>4</th>
<th>5</th>
<th>Most Important</th>
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   a. Improving product quality. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   b. Marketing information. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   c. End user input. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   d. Where the machine is to be used. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   e. Increasing sales. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   f. Company image. | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
   g. Others, please specify | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |

4. How do you rate the relative importance of the following design considerations during the process of designing agricultural machinery and equipment:
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5. How often do you use these design methods:

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</table>

6. With regard to your main area of activity, what quantities were the products to be made in?
a. Mass produced [ ]
7. What do you think the level of involvement of industrial designers in agricultural machinery and equipment design is at present (up to year 2000), and what will it be in the future (beyond 2000)?

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<th>PRESENT</th>
<th>FUTURE</th>
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<td>a. Understand design needs</td>
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<td>b. Market evaluation</td>
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<td>c. Analyse design problem</td>
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<td>d. Conducting related research</td>
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<td>e. Human factors considerations</td>
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<td>f. Preparing design specification</td>
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<td>g. Brainstorming</td>
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<td>h. Sketching</td>
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<td>i. Concept selection</td>
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<td>j. Preliminary concept drawing</td>
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<td>k. Development drawing</td>
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<td>l. Development detail drawing</td>
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<td>m. CAD modelling</td>
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<td>n. Construct mock-ups</td>
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<td>o. Construct scale models</td>
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<td>p. Constructing prototypes</td>
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<td>q. Testing prototypes</td>
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<td>r. Evaluation, final design selection</td>
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<td>s. Material selection</td>
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<td>t. Understand production capability</td>
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<td>u. Product cost reduction</td>
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<td>x. Product advertising and publicity</td>
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<td>y. Increasing sales</td>
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<td>z. Others, please specify</td>
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8. Which industrial design skills are likely to be of importance in the future of agricultural machinery and equipment design:

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<th></th>
<th>Low importance</th>
<th>High importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Working with other disciplines.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>b. Creating/generating ideas.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>c. Interaction between the multi-discipline team.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>d. Being involved from the beginning of the projects.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>e. Good basic understanding of engineering.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>f. Good basic understanding of sciences.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>g. Can communicate with other people at all levels in the company and outside company.</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
</tbody>
</table>
h. Understanding other designers' approaches.  
I. Have a good appreciation of other specialisms.  
j. Human factors/ergonomics capability.  
k. Aesthetic specialist.  
l. Others, please specify

9. How does industrial design currently make a contribution to agricultural machinery and equipment design:

<table>
<thead>
<tr>
<th>Minimal Contribution</th>
<th>Significant contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. making the products saleable</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>b. improved ergonomics aspects</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>c. reduced production cost</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>d. improving products usage</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>e. improving products quality</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
<tr>
<td>f. Others, please specify</td>
<td>[ ] [ ] [ ] [ ] [ ]</td>
</tr>
</tbody>
</table>

I would very much appreciate it if you can provide me with catalogues/ brochures/ pamphlets about your company and products to help in my research.

I am looking forward to following up some of these questionnaires with an interview and would be very grateful if you can allocate a little of your valuable time in providing more information regarding these subjects. If you are willing please tick the box. [ ]

If you would like me to send information on the findings of this survey please tick the box. [ ]

Your co-operation in completing this questionnaire is appreciated.

Please return in the pre-paid envelope to:

Mohd Nasir Hussain  
(Ph.D. Research Student)  
Department of Mechanical Engineering  
Loughborough University  
Loughborough  
Leicestershire LE11 3TU  
UK

Tel. No: 01509 210724  
Facsimile: 01509 268013  
E-mail: M.N.Hussain@lboro.ac.uk

(Note: For additional information please contact either myself or Mr. A.J.Taylor on Tel. No. 01509 223179 or e-mail address A.J.Taylor@lboro.ac.uk)
Appendix II : The UK and Malaysian variables
**LIST OF UK'S AND MALAYSIAN VARIABLES**

1. **a1number** - No. of Employees
2. **a2orga_a** - Design Department
3. **a2orga_b** - Research, Dev. Dept.
4. **a2orga_c** - Others design related
5. **a3jobfun** - Job function
6. **a4experi** - No. years experience
7. **a5total** - Total experience
8. **b1design** - Involved in designing
9. **b2led_1** - Directed from company
10. **b2led_2** - Research, Dev. Project
11. **b2led_3** - Consultancy work
12. **b2led_4** - Others
13. **b3depro** - Agri. Mach. Design project
14. **b4last5** - Design last 5 years
15. **b5invol1** - Agricultural engineers
16. **b5invol2** - Mechanical engineers
17. **b5invol3** - Production engineers
18. **b5invol4** - Electrical engineers
19. **b5invol5** - Industrial designers
20. **b5invol6** - Marketing people
21. **b5invol7** - Ergonomists
22. **b5invol8** - Others profession
23. **c1deta1** - Design tractors
24. **c1decu12** - Design cultivators
25. **c1despr3** - Design sprayers
26. **c1dehar4** - Design harvesters
27. **c1depl5** - Design planting machinery
28. **c1depro6** - Design processing machinery
29. **c1deoth7** - Others agr. Products
30. **c2depoa1** - Marketing (Clarification)
31. **c2depoa2** - Marketing (Conceptual)
32. **c2depoa3** - Marketing (Embodiment)
33. **c2depoa4** - Marketing (Detail)
34. **c2depoa5** - Agr. Eng. (Clarification)
35. **c2depoa6** - Arg. Eng. (Conceptual)
36. **c2depoa7** - Arg. Eng. (Embodiment)
37. **c2depoa8** - Arg. Eng. (Detail)
38. **c2depoa9** - Mech. Eng. (Clarification)
41. **c2depoa12** - Mech. Eng. (Detail)
42. **c2depoa13** - Production Eng. (Clarification)
43. c2depod2   -  Production Eng. (Conceptual)
44. c2depod3   -  Production Eng. (Embodiment)
45. c2depod4   -  Production Eng. (Detail)
46. c2depoel   -  Electrical Eng. (Clarification)
47. c2depoel2  -  Electrical Eng. (Conceptual)
48. c2depoel3  -  Electrical Eng. (Embodiment)
49. c2depoel4  -  Electrical Eng. (Detail)
50. c2depol1   -  Ind. Des. (Clarification)
51. c2depol2   -  Ind. Des. (Conceptual)
52. c2depol3   -  Ind. Des. (Embodiment)
53. c2depol4   -  Ind. Des. (Detail)
54. c2depolg1  -  Ergonomics (Clarification)
55. c2depolg2  -  Ergonomics (Conceptual)
56. c2depolg3  -  Ergonomics (Embodiment)
57. c2depolg4  -  Ergonomics (Detail)
58. c2depolh1  -  Others (Clarification)
59. c2depolh2  -  Others (Conceptual)
60. c2depolh3  -  Others (Embodiment)
61. c2depolh4  -  Others (Detail)
62. c3levela   -  Improving product quality
63. c3levelb   -  Marketing information
64. c3levelc   -  End user input
65. c3leveld   -  Machine to be used
66. c3levele   -  Increasing image
67. c3levelf   -  Company image
68. c3levelg   -  Others
69. c4consia  -  Performance
70. c4consib  -  Reliability
71. c4consic  -  Functionality
72. c4consid  -  Versatility
73. c4consie  -  Easy to operate/use
74. c4consif  -  Single person operate
75. c4consig  -  Equipped with additional
76. c4consih  -  Power
77. c4consii  -  Environment
78. c4consij  -  Ergonomics
79. c4consik  -  Patents
80. c4consil  -  Safety
81. c4consim  -  Cost
82. c4consin  -  Sizes
83. c4consio  -  Weight
84. c4consip  -  Manufacturing processes
85. c4consiq  -  Material
86. c4consir  -  Maintenance
87. c4consis - Product lifetime
88. c4consit - Competition
89. c4consiu - Colour
90. c4consiv - Aesthetics
91. c4consiw - Brand identity
92. c4consix - Standard regulations
93. c4consiy - Quality
94. c4consiz - Quantity
95. c4consaa - Manufacturing capability
96. c4consbb - Need mock-ups
97. c4conscc - Need scale modelling
98. c4consdd - Product testing
99. c4conssee - Others
100. c5methoa - PDS
101. c5methob - QFD
102. c5methoc - Concurrent Eng.
103. c5method - DFMA
104. c5methoe - FMEA
105. c5methof - Hierarchical tree
106. c5methog - Morphological chart
107. c5methoh - Unstructured processes
108. c5methoi - Others
109. c6quanta - Mass produce
110. c6quantb - Large batches
111. c6quantc - Small batches
112. c6quantd - One off
113. c7presta - Understanding design needs
114. c7prestb - Market evaluation
115. c7prestc - Analyse design problem
116. c7prestd - Conducting research
117. c7preste - Human factors considerations
118. c7prestf - Preparing design spec.
119. c7prestg - Brainstorming
120. c7presth - Sketching
121. c7presti - Concept selection
122. c7prestj - Preliminary concept drawing
123. c7prestk - Development drawing
124. c7prestl - Development detail drawing
125. c7prestm - CAD modelling
126. c7prestn - Construct mock-ups
127. c7presto - Construct scale models
128. c7prestp - Constructing prototypes
129. c7prestq - Testing prototypes
130. c7prestr - Evaluation final design
Material selection
Understanding prod. capability
Product cost reduction
Production cost reduction
Product advertising
Increasing sales
Others
Understanding design needs
Market evaluation
Analyse design problem
Conducting research
Human factors considerations
Preparing design spec.
Brainstorming
Sketching
Concept selection
Preliminary concept drawing
Development drawing
Development detail drawing
CAD modelling
Construct mock-ups
Construct scale models
Constructing prototypes
Testing prototypes
Evaluation final design
Material selection
Understanding prod. capability
Product cost reduction
Production cost reduction
Product advertising
Increasing sales
Others
Working w/o disciplines
Creating ideas
Interaction multi-disp.
Early project involved
Understanding engineering
Understanding sciences
Communication
Understanding others skill
Appreciated others skill
Human factor capability
Aesthetic specialist
Others
175. c9indcoa - Making products saleable
176. c9indcob - Improved ergonomics aspect
177. c9indcoc - Reduced prod. cost
178. c9indcod - Improved products usage
179. c9indcoe - Improved product quality
180. c9indcof - Others.
Appendix III: Final version interview questions
1. What type of experience do you have in design?

2. What type of agricultural machinery design related projects have you undertaken?

3. In your opinion or experience is there any great difference between design of capital equipment and consumer products?

4. What type of design methods do you use while carrying out design projects? For example Product Design Specification, Quality Function Deployment, Concurrent Engineering etc.

5. How important are the design methods in the design process?

6. Can you think of any ways in which your design methods might be more effective?

7. Design process means from clarification of needs to product production, which do you think the most crucial stage in designing especially agricultural machinery and equipment?

8. How can we improve it?

9. If you have any ideas, what are the most significant differences between industrial design and engineering design processes?

10. What level in the design process do you think industrial design considerations should be brought in?

11. What types of skill are necessary?
12. How important are these skills in the design process?

13. How important do you think communication in design?

14. When can it been brought in during design projects?

15. Which is the most significant between verbal and visual communication during carried out design project?

16. What types of visual communication you think make the discussion between design team more meaningful?

17. Which groups of people do you think designers need to communicate with most during design project?

18. How do you find communication using 2D materials and 3D materials?

19. What do you think communicate using 2D and 3D physical models and using through computer?

20. Is there any disadvantage between these two methods?

21. How important prototyping in evaluating the design?

22. What do you think about drawing capability?

23. How importance to every designers?

24. How do the design methods differ between industrial design and engineering design?

25. Is there a need to involve multi-discipline design teams in design projects?

26. Have you got any experience working with the other type of designer?
27. How do you find the relationship between industrial designers and engineering designer working as a team in design projects?

28. How do you find the relationship between marketing, industrial designers and engineering design working as a team in design projects?

29. How important is it to involve (or get information from) the customer/client during design?

30. Do you think the industrial designer has any role in designing agricultural machinery?

31. Do you think in the future there will be more interaction between industrial designers and engineering designers in design projects?

32. What type of design elements do you think should be given a priority in designing agricultural machinery?

33. What particular problem or difficulties is the designer likely to encounter in designing agricultural machinery?

34. How do you foresee the future role of industrial designers in this area?

35. Do you have any other view regarding the design of agricultural machinery which might help me in my research?
Appendix IV: First draft interview questions
INTERVIEW

36. What type of experience do you have in design and what type of agricultural machinery design related projects have you undertaken?

37. In your opinion or experience is there any great difference between design of capital equipment and domestic products?

38. What type of design methods do you use in design or are there any specific design methods you follow while carrying out design projects?

39. Do you ever use design methods different from Q3?

40. Could you please give an example of the design methods that you used in designing?

41. Is there a need to involve multi-discipline design teams in design projects especially capital products such as agricultural machinery. What discipline or skills are necessary?

42. If you are industrial designer/engineering designer, have you got any experience working with the other type of designer? If so go to Q8 and Q9, if not go to Q10

43. How do you feel working with them?

44. How do you find the relationship between industrial designers and engineering designer working as a team in design projects?

45. As engineering designer/industrial designer do you think the industrial designer has any role in designing capital equipment such as agricultural machinery?

46. What are the most significant differences between industrial design and engineering design processes?

47. What are the advantages and disadvantages between industrial design and engineering design process in designing capital equipment?

48. How do the design methods differ between the designers?

49. What in your opinion, are the main factors for success in designing using either industrial design and engineering design process?
50. What are the effectiveness of these two design process?

51. What stage or level in the design process do you think industrial design considerations should be brought in?

52. How do you foresee the future role of industrial designers in this area?

53. Is there any way your design methods might be improved?

54. Do you expect to change your design methods in the short term or medium term?

55. How do you expect to change them and have you tried to use other type of design methods?

56. What type of design elements do you think should be given a priority in designing agricultural machinery?

57. What particular problem or difficulties is the designer likely to encounter in designing agricultural machinery?

58. Do you think in the future there will be more interaction between industrial designers and engineering designers in design projects?

59. What do you think about the research being carried out by the researcher?
Appendix V: Second draft interview questions
INTERVIEW

60. What type of experience do you have in design?

61. What type of agricultural machinery design related projects have you undertaken?

62. In your opinion or experience is there any great difference between design of capital equipment and consumer products?

63. What type of design methods do you use while carrying out design projects?

64. Could you please give an example of the design methods that you used in designing?

65. Is there any way your design methods might be improved?

66. Is there a need to involve multi-discipline design teams in design projects?

67. What discipline or skills are necessary?

68. If you are industrial designer/engineering designer, have you got any experience working with the other type of designer?

69. How do you find the relationship between industrial designers and engineering designer working as a team in design projects?

70. As engineering designer/industrial designer do you think the industrial designer has any role in designing agricultural machinery?

71. What are the most significant differences between industrial design and engineering design processes?

72. How do the design methods differ between the designers?

73. What stage or level in the design process do you think industrial design considerations should be brought in?

74. How do you foresee the future role of industrial designers in this area?
75. What type of design elements do you think should be given a priority in designing agricultural machinery?

76. What particular problem or difficulties is the designer likely to encounter in designing agricultural machinery?

77. Do you think in the future there will be more interaction between industrial designers and engineering designers in design projects?
Appendix VI : The UK interview respondents
The United Kingdom Interview Respondents

1. Dr. Ed Swain  
   Lecturer  
   Department of Mechanical and Manufacturing Engineering  
   Loughborough University  
   Loughborough  
   Leicestershire LE11 3TU

2. Mr. Paul King  
   Lecturer  
   Department of Mechanical and Manufacturing Engineering  
   Loughborough University  
   Loughborough  
   Leicestershire LE11 3TU

3. Dr. Steve Garner  
   Lecturer  
   Faculty of Industrial Design and Technology  
   Loughborough University  
   Loughborough  
   Leicestershire LE11 3TU

4. Mr. Mark Evans  
   Lecturer  
   Faculty of Industrial Design and Technology  
   Loughborough University  
   Loughborough  
   Leicestershire LE11 3TU

5. Mr. Roland Metcalfe  
   Part Time Lecturer and Consultant  
   Department of Mechanical and Manufacturing Engineering  
   Loughborough University  
   Loughborough  
   Leicestershire LE11 3TU
6. Mr. Ashley Leake  
   Industrial Designers  
   J.C. Bamford Excavators Limited (JCB)  
   Rochester,  
   Staffordshire

7. Mr. John Kilgour  
   Senior Lecturer Farm Machine Designer  
   Silsoe College  
   Cranfield University  
   Silsoe, Bedfordshire MK45 4DT

8. Mr. Paul Clapham  
   Engineer designer  
   Slingsby Engineering Ltd.  
   Slingsby Engineering Ltd. York.

9. Mr. Steven May-Russell  
   Managing Director  
   Smallfry Ltd.

10. Ms. Amanda Elliott  
    Research Associate  
    Department of Mechanical and Manufacturing Engineering  
    Loughborough University  
    Loughborough  
    Leicestershire LE11 3TU
Appendix VII: Malaysian interview respondents
Malaysian Interview Respondents

University Technology of Mara (UiTM) formerly
Institute Technology of Mara (ITM) Shah Alam, Selangor.

4. Prof. Dr Tamyez Bajuri
   Senior Lecturer
   Industrial Design Department
   Faculty of Art and Design
   University Technology of Mara (UiTM)
   Shah Alam, Selangor,
   Malaysia.

2. Asso. Prof. Alias Ahmad
   Senior Lecturer
   Industrial Design Department
   Faculty of Art and Design
   University Technology of Mara (UiTM)
   Shah Alam, Selangor,
   Malaysia.

3. Mazlan Majid
   Head Department
   Industrial Design Department
   Faculty of Art and Design
   University Technology of Mara (UiTM)
   Shah Alam, Selangor,
   Malaysia.

Discussion:

Md. Zimli Yahya
   Senior Lecturer
   Industrial Design Department
   Faculty of Art and Design
   University Technology of Mara (UiTM)
   Shah Alam, Selangor,
   Malaysia.

Anuar Sirat
   Lecturer
   Industrial Design Department
   Faculty of Art and Design
   University Technology of Mara (UiTM)
   Shah Alam, Selangor,
   Malaysia.
Standards and Industrial Research Institute of Malaysia (SIRIM)
Shah Alam, Selangor.

4. Abu Haris Hamzah
   Head of Industrial Design
   Design Centre
   SIRIM Berhad
   1, Persiaran Dato' Menteri
   P.O. Box 7035, Section 2
   40911 Shah Alam, Selangor
   Malaysia

5. Ruhaizin Sulaiman
   Industrial Designer
   Design Centre
   SIRIM Berhad
   1, Persiaran Dato' Menteri
   P.O. Box 7035, Section 2
   40911 Shah Alam, Selangor
   Malaysia.

6. Ajmain Kasim
   Co-ordinator
   Machine Design and Assembly
   National CAD/CAM Centre
   SIRIM Berhad
   1, Persiaran Dato' Menteri
   P.O. Box 7035, Section 2
   40911 Shah Alam, Selangor
   Malaysia.

7. Goh Peng San
   Co-ordinator
   Advance Manufacturing Technology Divison
   SIRIM Berhad
   1, Persiaran Dato' Menteri
   P.O. Box 7035, Section 2
   40911 Shah Alam, Selangor
   Malaysia.

Discussion:

Dr. Wan Abdul Rahman
Manager
National CAD/CAM Centre
SIRIM Berhad
1, Persiaran Dato' Menteri
P.O. Box 7035, Section 2
40911 Shah Alam, Selangor
Malaysia.
Bakri Bakar Ismail  
Research Officer  
Department of Multi Media  
Ground Floor, Block 25  
SIRIM Berhad  
1, Persiaran Dato’ Menteri  
P.O. Box 7035, Section 2  
40911 Shah Alam, Selangor  
Malaysia.

Malaysia Agricultural Research and Development Institute (MARDI)  
Serdang, Selangor.

8. Dr. Ibni Hajar Hj. Rukunudin  
Asst. Director  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia

9. Mat Akhir Hamid  
Research Officer (Engineer)  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia

10. Mohamad Isa Osman  
Research Officer (Engineer)  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia

11. Ooi Ho Seng  
Senior Research Officer (Engineer)  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia

12. Sharif Hashim Sharif Hassan  
Research Officer (Engineer)  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia
13. Tengku Ahmad Tengku Abdullah  
Research Officer (Engineer)  
Strategic, Environment and Natural Resources Research Center  
MARDI, P.O.Box 12301  
50774 Kuala Lumpur,  
Malaysia

University Putera Malaysia (UPM)  
Serdang, Selangor

14. Asso. Prof. Dr. Desa Ahmad  
Asst. Dean  
Faculty of Engineering,  
University Putera Malaysia,  
43400 UPM Serdang, Selangor,  
Malaysia.

15. Dr. Azmi Yahya  
Head Department of Agricultural Machinery Design  
Faculty of Engineering,  
University Putera Malaysia,  
43400 UPM Serdang, Selangor,  
Malaysia.

16. Asso. Prof. Dr. Jamarie Othman  
Senior Lecturer  
Department of Agricultural Machinery Design  
Faculty of Engineering,  
University Putera Malaysia,  
43400 UPM Serdang, Selangor, Malaysia.

17. Asso. Prof. Ir. Muhammad Salih Jaafar  
Senior Lecturer  
Department of Agricultural Machinery Design  
Faculty of Engineering,  
University Putera Malaysia,  
43400 UPM Serdang, Selangor, Malaysia.

Discussion:

Asso. Prof. Dr. Jamarie Othman  
Senior Lecturer  
Department of Agricultural Machinery Design  
Faculty of Engineering,  
University Putera Malaysia,  
43400 UPM Serdang, Selangor,  
Malaysia.
Dr. Rimfiel Janius
Lecturer
Department of Agricultural Machinery Design
Faculty of Engineering,
University Putera Malaysia,
43400 UPM Serdang, Selangor,
Malaysia.

Palm Oil Research Institute of Malaysia (PORIM)
Bangi, Selangor

18. Dr. Hj. Ahmad Hitam
   Head Department of Mechanisation Division
   No. 6, Persiaran Institusi
   Bandar Baru Bangi
   4300 Kajang, Selangor,
   Malaysia.

19. Ahmad Zamri Yusof
   Research Officer
   Mechanisation Division
   No. 6, Persiaran Institusi
   Bandar Baru Bangi
   4300 Kajang, Selangor,
   Malaysia.

Discussion:

Abdul Razak Jelani
Research Officer
Mechanisation Division
No. 6, Persiaran Institusi
Bandar Baru Bangi
4300 Kajang, Selangor,
Malaysia.

Salmah Jahis
Research Officer
Mechanisation Division
No. 6, Persiaran Institusi
Bandar Baru Bangi
4300 Kajang, Selangor,
Malaysia.

Ridzuan Ramli
Research Officer
No. 6, Persiaran Institusi
Bandar Baru Bangi
4300 Kajang, Selangor,
Malaysia.
Rubber Research Institute of Malaysia (RRIM), Sungai Buluh, Selangor.

20. Dr. Zainol Mohd Eusof  
Asst. Director  
Strategic, Environment and Natural Resources Research Center  
Rubber Research Institute of Malaysia  
Research Center  
Sungai Buluh, Serdang,  
Malaysia.

21. Tuan Muhammad Tuan Muda  
Head of Mechanisation Department  
Rubber Research Institute of Malaysia  
Research Center  
Sungai Buluh, Serdang,  
Malaysia.

University Technology Malaysia (UTM), Johor Bahru, Malaysia

22. Idris Ishak  
Head Department of Design  
Faculty of Mechanical Engineering  
University Technology Malaysia  
81310 UTM Skudai  
Johor, Malaysia.

23. Dr. Jamal Jamaluddin  
Lecturer  
Department of Design  
Faculty of Mechanical Engineering  
University Technology Malaysia  
81310 UTM Skudai  
Johor, Malaysia.

Discussion:

Badri Abu Ghanil  
Lecturer  
Department of Design  
Faculty of Mechanical Engineering  
University Technology Malaysia  
81310 UTM Skudai  
Johor, Malaysia.

Khairul Hanafiah  
Lecturer  
Department of Design  
Faculty of Mechanical Engineering  
University Technology Malaysia  
81310 UTM Skudai  
Johor, Malaysia.
Howard Alat Pertanian Sdn. Bhd
Selangor, Malaysia.

24. Mr. A. Nielsen
 Managing Director
 Howard Alat Pertanian Sdn. Bhd
 7482, Jalan Dua, Taman Selayang Baru,
 P.O.Box 8, 68107 Batu Caves,
 Selangor, Malaysia

25. Mr. N. Paramadevan
 Consultant Engineer
 Howard Alat Pertanian Sdn. Bhd
 7482, Jalan Dua, Taman Selayang Baru,
 P.O.Box 8, 68107 Batu Caves,
 Selangor, Malaysia

Discussion:

Mohamad Rafi Jamlus
Technical Assistant
Howard Alat Pertanian Sdn. Bhd
7482, Jalan Dua, Taman Selayang Baru,
P.O.Box 8, 68107 Batu Caves,
Selangor, Malaysia
Appendix VIII: First task from bubble diagram chart
Bubble Diagram for Manufacturing/Production
(Processes Method)

NEEDS

PRODUCTS/MACHINERY

Manufacturing/Production

Processes method

Design

Model construction

Quality

Material selection

Research

Information

External design consultancy

Manufacturing information

Production

Tooling

Method of production

Fabrication

Injection moulding

Compress moulding

Rotational process

Prototype

Manufacture of prototype

Testing programme

Manufacturing/Production – Task 1
Processes Method

Engineering phase

Industrial design phase

Constraints

DFME

FMEA

QFD

Ergonomics

Human factors
Bubble Diagram for Social Economy

NEEDS

PRODUCTS/MACHINERY

Social Economy

Politics

Government

Upgrade income per capital
Increase country income
Successful government for the people
Growth of manufacturing industry
Convert the country as agricultural machinery/equipment exporters
Open new land for agricultural
R & D
Development activities
Create opportunity for business
Problem solving agricultural activities
Making business
Making money
Private Sectors
Job opportunity
Social Economy - Task 1
Bubble Diagram for Task Performance

- Needs
  - Current Practise
  - Working demand
  - Working time
  - Working style
  - Time scale

- Products/Machinery
  - System operation
  - Transportation
  - Method of transport
  - Power energy
  - Physical constraint

- Task Performance
  - Objective
  - Machine
  - Problem
  - Work task
  - Skill
  - Cost
  - Handling the equipment
  - Time factor
  - Aim

- Used semi/fully auto equipment/machinery
  - Manually
  - Self belonging

- Environment
  - Type of soil
  - Drainage

Area
- Undulated area
- Plain area
- Hilly

Task Performance - Task 1
Appendix IX: Sample for questions generation from second task of the bubble diagram chart
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<th>Section</th>
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<td>1</td>
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<td>Do we know who will be using the product?</td>
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<td>2</td>
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<td>Will the equipment/machinery be suitable for the users?</td>
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<td>3</td>
<td>3</td>
<td>Will there be advantages over the current equipment/method used?</td>
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<td>4</td>
<td>4</td>
<td>Will there be disadvantages to the user in not adopting the technology?</td>
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<td>Will there be disadvantages in adopting the technology?</td>
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<td>6</td>
<td>Will the users have to maintain the equipment/machinery themselves?</td>
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<td>7</td>
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<td>Will the equipment/machinery benefit the users?</td>
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<td>Will the equipment/machinery benefit the estate?</td>
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<td>Will it benefit the smallholder’s organisation?</td>
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<td>Will the users need training to operate the machinery?</td>
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<td>11</td>
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<td>Will they be familiar with similar systems?</td>
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<td>Will they have to have qualifications to operate the equipment/machinery?</td>
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<td>Will they have to have qualifications to maintain the equipment/machinery?</td>
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<td>Will the time scale be improved by adapting from manual to mechanised systems?</td>
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<td>15</td>
<td>15</td>
<td>Are young adults attracted to the systems currently available in the plantation?</td>
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<td>16</td>
<td>16</td>
<td>Will the method of working be better with the new design?</td>
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<td>Does machinery/equipment need to be operated by a single person?</td>
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<td>Will the system be easy to be replaced/assembled by the users?</td>
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<td>Is the existing equipment/machinery safe to use?</td>
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<td>Will it be acceptable for the users/farmers to use manual hand tools in their work?</td>
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<td>Will the equipment/machinery be used by both genders?</td>
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<td>Will it be suitable to operate by elderly users?</td>
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<td>Will it be suitable to operate by children?</td>
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<td>Will they have to be fit to do the work task?</td>
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<td>Do the users have to be trained to operate the machinery?</td>
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<td>Does the current equipment/machinery met all the requirements of the users/workers?</td>
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<td>Does the users/farmers need extra awareness in handling the equipment/machinery?</td>
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<td>Will somebody monitor the safety of the users in handling the machinery?</td>
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<td>Does the work task increase stress and strain to the workers or farmers?</td>
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<td>Does the carrying method practised cause back problems?</td>
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<td>Will the workers encounter back injuries resulting from overexertion or overdoing the work task?</td>
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<td>14</td>
<td>Will they have to lift heavy things or goods in their work practise?</td>
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<td>15</td>
<td>Will they have to have lot of strength to perform work task?</td>
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<td>Will the work task require essential manual handling?</td>
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<td>Will the users/farmers have to master in controlling the equipment/machinery?</td>
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<td>18</td>
<td>Will the user's/worker's hand easily to access the equipment/machinery for replacing and repairing?</td>
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<td>19</td>
<td>Will the equipment/machinery be adjustable for user's/farmer's comfort during carry out the work task?</td>
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<td>20</td>
<td>Does the equipment/machinery meet the comfort requirement?</td>
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<tr>
<td>Effect on crops and land</td>
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<tr>
<td>1  Will the equipment/machinery safe to use on the crops/trees?</td>
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<td>2  Will it damaging the surface of the land?</td>
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<td>3  Will the weight of the equipment create a lot of problem during operating in the plantation?</td>
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<table>
<thead>
<tr>
<th>Used current equipment/machinery</th>
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<tbody>
<tr>
<td>1  Has the current product benefit to the user, owner, estate, and other smallholding organisation?</td>
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<tr>
<td>2  Has the product solve the demand?</td>
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<tr>
<td>3  Does the users produce sufficient output from current product?</td>
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<tr>
<td>4  Does the current practise make the work interesting?</td>
</tr>
<tr>
<td>5  Does the current product easily to access in the plantation?</td>
</tr>
<tr>
<td>6  Does the system improve the productivity?</td>
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<tr>
<td>7  Does the existing equipment/machinery easy to operate?</td>
</tr>
<tr>
<td>8  Does the product used manage to overcome the softness, muddy and undulated surfaces in the plantation?</td>
</tr>
<tr>
<td>9  Does the equipment/machinery suitable to any ages that used to work in the plantation?</td>
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<table>
<thead>
<tr>
<th>Current practise</th>
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<tr>
<td>1  Does the users/farmers do the work task manually?</td>
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<tr>
<td>2  Does they work individually?</td>
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<tr>
<td>3  Does team work available in the plantation?</td>
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<tr>
<td>4  Does the work task is a family activity?</td>
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<tr>
<td>5  Does the users/farmers easily to accept with new approach when it been asked to use?</td>
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<tr>
<td>6  Will the current practise make their health worst at the end of the day?</td>
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Note: If the question fall under 'not sure', please refer to the main objective of the design project.
### Understanding Nature Problem Checklist – Existing Product

**GENERAL**

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<td>Does the operating system satisfy the users? **</td>
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<td>2</td>
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<td>Does the existing product manage to perform the work task? **</td>
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<td>3</td>
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<td>Does the existing product capable to manoeuvre in any surfaces? **</td>
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<td>Does the existing product have the advantage in helping to product new system/method or equipment/machinery/devise? **</td>
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<td>Can the disadvantage factors from existing product make a change on new design? **</td>
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<td><strong>Machine</strong></td>
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<td>Will the machine perform the work task? **</td>
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<td>Does the maintenance necessary from the users/farmers? **</td>
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<td>3</td>
<td></td>
<td>Will manufacturers include maintenance in their sale?</td>
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<td>4</td>
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<td>Does suppliers support buyers in term of maintenance after sale? **</td>
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<td>5</td>
<td></td>
<td>Will the cost of the machine sufficient to the users? **</td>
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<tr>
<td><strong>Cost</strong></td>
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<td>Does the cost of the existing product enable the user to have one? **</td>
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<td>Does the estate management satisfy with the cost? **</td>
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<td>Does smallholders manipulate the cost of the product to help their member under their organisation? **</td>
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<td><strong>Fabrication</strong></td>
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<td>Does existing product been assembled locally? **</td>
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<td>Will the cost different in term of locally assemble and abroad? **</td>
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<td>Does the product brought from abroad suitable in the country? **</td>
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<td>Does existing product from abroad meet locally needs? **</td>
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**Safety**

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<tr>
<td>1</td>
<td>Does existing product meet regulation standard? **</td>
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<td>2</td>
<td>Does users require training to operate the machine? **</td>
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<tr>
<td>3</td>
<td>Does manufacturers have to give training to the buyers? **</td>
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<tr>
<td>4</td>
<td>Do users familiar with safety features on the product? **</td>
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</table>

(**) Please refer to task 3 to get more detail on the question.

Note: If the question fall under ‘not sure’, please refer to the main objective of the design project.

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* Please uses additional sheets if the column allocated not enough for further suggestion.
Appendix X: Sample for detail questions generation for designer's own references
## Understanding Nature Problem Checklist – Detailing for Palm Oil design project under ‘Use Category.’

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<tr>
<th>Section No.</th>
<th>Descriptions</th>
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<td>1a</td>
<td>Will it possible to avoid users from stepping snake or come too close to the bushes to collect goods?</td>
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<td>1b</td>
<td>Will it safe working along terrain if the surfaces are wet because of heavy rain?</td>
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<td>1c</td>
<td>Does the equipment/machinery has sharp edges which can harm the users/farmers if they hold/touch accidentally?</td>
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<td>1d</td>
<td>Will the material used affect the hand skin if they hold for longer period during carried out the work task?</td>
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<tr>
<td>1e</td>
<td>Will it be safe to the user/farmers if the equipment/machinery suddenly malfunction?</td>
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<td>1f</td>
<td>Will the equipment hurt the users/farmers if the equipment accidentally fell on their toes?</td>
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<tr>
<td>1g</td>
<td>Will the users/farmers safe in handling the equipment/machinery if it’s full with goods during moveable in the plantation?</td>
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<td>1h</td>
<td>Will the equipment/machinery easy/safe to control when they walk down the hill/terrain full with goods?</td>
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<td>1i</td>
<td>Will it be safe to the users if they fell down into the drainage or on the ground while carrying the equipment?</td>
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<td>2a</td>
<td>Will it be effective to use manual hand tools in collecting palm oil loose fruits?</td>
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<td>2b</td>
<td>Will it cause pain to user’s/farmer’s hand in using the tools for quite some time?</td>
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<td>2c</td>
<td>Will it injured user’s/farmer’s wrist?</td>
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<td>2d</td>
<td>Will holding the tool cause tiredness?</td>
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<td>3a</td>
<td>Do the equipment/machinery suitable for women?</td>
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<td>3b</td>
<td>Do the equipment/machinery suitable for children?</td>
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<tr>
<td>3c</td>
<td>Will women and children need to be fit to perform the work task?</td>
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<td>3d</td>
<td>Does the women/children have to be strong to do the work?</td>
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<tr>
<td>7a</td>
<td>Do the equipment/machinery needs to be equipped with automatic control device?</td>
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<td>7b</td>
<td>Do the equipment has to be light to enable women and children use it?</td>
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<td>7c</td>
<td>Do the machinery needs to be simple for handling especially along the terrain?</td>
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<td>7d</td>
<td>Do the equipment/machinery easy to lift and push?</td>
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<td>7e</td>
<td>Will the equipment/machinery equip with simple attachment device for different work task?</td>
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<td>7f</td>
<td>Does the equipment/machinery have minimum vibration effect to the users/farmers?</td>
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<tr>
<td>7g</td>
<td>Will sitting adjustment for different sizes of users/farmers for easy access to the control panel?</td>
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<tr>
<td>7h</td>
<td>Will using the equipment/machinery can cause backaches, neck aches, and shoulder pains etc. because the anthropometry is not calculate accurately?</td>
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<tr>
<td>7i</td>
<td>Will the sound arise from the equipment/machinery suitable for the users/farmers?</td>
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<tr>
<td>10a</td>
<td>Do the workers/farmers keen with the working condition – wet and damn environment?</td>
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<td>10b</td>
<td>Do they feel comfortable working under undesirable condition?</td>
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<td>10c</td>
<td>Do they have to work under strong heat?</td>
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<td>10d</td>
<td>Does they encounter danger for instant falling from the terrain?</td>
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<td>10e</td>
<td>Does they have to face difficulties working in the bushes which lots of dangerous animals?</td>
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<td>10f</td>
<td>Do they feel loneliness working alone in the middle of the plantation by themselves?</td>
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<tr>
<td>10g</td>
<td>Does they have to work more than they suppose to do to earn money?</td>
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<td>10h</td>
<td>Do the physical work currently practise increase their blood pressure?</td>
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<tr>
<td>11a</td>
<td>Will they have to lift or carry the goods every time during working operation?</td>
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<td>11b</td>
<td>Will double pack carrying method suitable to practise in collecting palm oil loose fruits?</td>
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<tr>
<td>11c</td>
<td>Do head carrying method normally used by women and children?</td>
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<td>11d</td>
<td>Will yoke method been practised within the workers/farmers?</td>
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<td>12a</td>
<td>Do they have to bend quite frequently to collect palm oil loose fruits?</td>
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<td>12b</td>
<td>Will they have to bend with no arm support during collecting?</td>
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<td>12c</td>
<td>Do kneeling been practised by workers especially women and children?</td>
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<td>12d</td>
<td>Does these effect them in long run?</td>
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<td>13a</td>
<td>Do lifting heavy load cause injuries to the workers/farmers?</td>
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<td>13b</td>
<td>Do they have to carry sack full with loose fruits along terrain to</td>
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<td>collection point?</td>
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<td>13c</td>
<td>Do they have to lift and push wheelbarrow to bring together all the</td>
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<td>goods in one place?</td>
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<td>13d</td>
<td>Do the have to climb terrain with heavy equipment to perform their</td>
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<td>work task?</td>
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<td>13e</td>
<td>Do women, children and elderly people have to lift heavy thing quite</td>
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<td>frequent everyday in their work?</td>
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<td>14a</td>
<td>Will collecting method currently practised require strength?</td>
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<td>14b</td>
<td>Do women perform the work task effectively?</td>
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<td>14c</td>
<td>Do the children require carrying out the work task?</td>
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<td>14d</td>
<td>Do elderly need to take part in this even?</td>
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<tr>
<td>14e</td>
<td>Do they have to push heavy load from one tree to another?</td>
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<tr>
<td>15a</td>
<td>Do the workers/farmers have to load/unload palm oil loose fruits onto</td>
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<td>transportation device to transport to the factory/collecting points?</td>
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<td>15b</td>
<td>Do they have to remove their collection every time they want to stack</td>
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<td>onto transportation device?</td>
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<td>15c</td>
<td>Do they have to shift from one to another for different type of work</td>
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<td>task?</td>
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<td>15d</td>
<td>Do manual handling cause serious pain/stress to the workers/farmers?</td>
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<td>16a</td>
<td>Do the users/farmers have to understand how the equipment/machinery work</td>
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<td>before they can operate it?</td>
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<td>16b</td>
<td>Do they have to memorise very hard all the control devices on the</td>
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<td>equipment/machinery?</td>
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<td>16c</td>
<td>Does they need to attend practical training to enable them operate the equipment/machinery?</td>
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<td>16d</td>
<td>Will the control device easily to reach by hand?</td>
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<td>16e</td>
<td>Will the control device work effectively with humidity environment in palm oil plantation?</td>
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<td>16f</td>
<td>Will the control device easily to understand and give a very simple meaning (no need long description)?</td>
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<td>16g</td>
<td>Does the control device need to be operated by foot?</td>
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<td>17a</td>
<td>Do the users/workers have to use additional tools to fix the damage?</td>
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<td>17b</td>
<td>Do they have to dismantle the equipment to enable them to reach to the cause of the problem?</td>
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<td>17c</td>
<td>Will it be easy to the users/workers at any size and height to get in touch with the maintenance problem?</td>
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<td>18a</td>
<td>Will the control be easily reached and adjusted?</td>
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<td>18b</td>
<td>Will the labels and instructions are easy to understand?</td>
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<tr>
<td>18c</td>
<td>Will the control easy to find and interpret?</td>
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<td>18d</td>
<td>Do tools necessary to adjust the position?</td>
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<td>18e</td>
<td>Will users/farmers require few motions to use the control?</td>
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<td>18f</td>
<td>Will it require one hand to adjust the position?</td>
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<tr>
<td>19a</td>
<td>Does the equipment/machinery make them feel safe when operating the product?</td>
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<td>19b</td>
<td>Does they feel comfortable using new design compare to the previous equipment/machinery?</td>
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<td>19c</td>
<td>Does new design make them feel miserable at the end of the day after using the equipment/machinery in the plantation?</td>
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<td>19d</td>
<td>Does the users have to feel suspicious all the time during operating on the equipment/machinery which they cannot fully concentrate on their work because the product does not equip with safety/alert device?</td>
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Note: If the question fall under 'not sure', please refer to the main objective of the design project.
### Understanding Nature Problem Checklist – Detailing for Palm Oil project under ‘Use Category’.

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<th>Section</th>
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<th>Descriptions</th>
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<th>No</th>
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<th>Not Sure</th>
<th>Comments</th>
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<tr>
<td></td>
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<td><strong>Effect on crops and land</strong></td>
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<td>1a</td>
<td></td>
<td>Does the equipment/machinery/device have to have direct contact that might damage the crops/trees?</td>
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<td>1b</td>
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<td>Will the equipment/machinery/device be safe to use at any part (from young tree to mature tree) of the crops/trees?</td>
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<td>1c</td>
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<td>Will it damage the land surfaces because of its weight?</td>
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<td>1d</td>
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<td>Will it destroy the land surfaces because of its size?</td>
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<td>1e</td>
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<td>Will it injure the crops and trees trunk during manoeuvre in the plantation?</td>
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Note: If the question falls under ‘not sure’, please refer to the main objective of the design project.

Names: _____________________________________________

Department: __________________________________________

Position: _____________________________________________

Venue: _____________________________________________

Date: _____________________________________________

Time: _____________________________________________

Signature: ___________________________________________

Approved: ___________________________________________

Any further suggestion: ___________________________________________

* Please uses additional sheets if the column allocated not enough for further suggestion.
Appendix XI: Research schedule in Malaysia
RESEARCH SCHEDULE IN MALAYSIA
SEPT. - NOVEMBER 1999

Saturday (28/8/99), Sunday (29/8/99), Monday (30/8/99) or Tuesday (31/8/99)
Departure from UK to Malaysia

Monday (06/09/99) – Saturday (11/09/99) 1 week
Institut Teknologi Malaysia (ITM), Shah Alam, Selangor.
- Interview/questionnaire with lecturers.
- Interview/questionnaire with selected students.
- Literature search at ITM library.

Monday (13/09/99) – Saturday (18/09/99) 1 week
Standards and Industrial Research Institute of Malaysia (SIRIM), Shah Alam, Selangor.
- Interview/questionnaire with researchers.
- Interview/questionnaire with industrial designers.
- Literature search at SIRIM library.

Monday (20/09/99) – Saturday (02/10/99) 2 weeks
Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor.
Univerrsiti Putera Malaysia (UPM), Serdang, Selangor.
- Interview/questionnaire with staff/engineers.
- Interview/questionnaire with researchers.
- Literature search at MARDI & UPM library.

Monday (04/10/99) – Saturday (16/10/99) 2 weeks
Palm Oil Research Institute of Malaysia (PORIM), Bangi, Selangor.
- Interview/questionnaire with researchers.
- Literature search at PORIM library.

Monday (18/10/99) – Saturday (30/10/99) 2 weeks
Rubber Research Institute of Malaysia (RRIM), Sungai Buluh, Selangor and Jalan Ampang, Kuala Lumpur.
- Interview/questionnaire with researchers.
- Literature search at RRIM library.
Monday (01/11/99) – Saturday (06/11/99) 1 week

University Technology of Malaysia (UTM), Johor Bahru, Johor

- Interview/questionnaire with staff/engineers
- Interview/questionnaire with researchers
- Literature search at UTM library.

Monday (08/11/99) – Saturday (20/11/99) 2 weeks

Design Consultant and Industry visits.

- Interview/questionnaire with Industrial Designers and Engineers within Kuala Lumpur, Selangor and Johor

Monday (22/08/99) – Thursday (26/09/99) 5 days

Compiling data collection

Sunday (28/11/99), Monday (29/11/99) or Tuesday (30/11/99)

Relocate to Loughborough, United Kingdom.