

**THE IMPACT OF CONCURRENT ENGINEERING PRACTICES ON
QUALITY OF DESIGN OF NEW PRODUCTS.**

BY

MOHD YUSOFF HJ ABDULLAH

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ABSTRAK

Fokus kajian ini adalah untuk menyingkap persoalan terhadap; (1) Sejauh manakah amalan "Concurrent Engineering" (CE) terlibat di dalam rekabentuk dan pembangunan sesuatu produk di dalam Industri Perkilangan Malaysia? (2) Bagaimanakah amalan CE memberi kesan kepada kualiti rekabentuk sesuatu produk? (3) Bagaimanakah produk yang kompleks mempengaruhi hubungan antara tahap penglibatan amalan CE dan kualiti rekabentuk sesuatu produk.

Hari ini, kebanyakan syarikat sedar bahawa usaha untuk membangun sesuatu produk baru yang menepati kehendak pelanggan dan boleh terus kekal dipasaran adalah sesuatu yang amat mencabar. Pembangunan produk baru adalah melibatkan proses pengurusan yang agak rumit yang mana melibatkan penyertaan daripada pelbagai pihak dari pelbagai perspektif kepakaran. CE adalah merupakan konsep baru dalam membangunkan sesuatu produk yang menjurus kepada integrasi kepakaran daripada pelbagai disiplin semasa fasa rekabentuk sesuatu produk. CE berfokuskan kepada "right-the-first-time" berbanding dengan cara lama iaitu "redo-until-right".

Sampel kajian melibatkan maklumbalas soalselidik daripada 77 responden dari pelbagai sektor industri yang dipilih di Negeri Pulau Pinang. Industri-industri perkilangan yang terlibat di dalam sampel kajian ini adalah 'Electrical & Electronics', 'Machinery & Fabricated Metal', 'Chemical/Fertilizer & Rubber Base', 'Textile & Garments and Food & Agricultural Products processing'.

Hasil kajian ini didapati; (1) Tahap penglibatan amalan CE didalam rekabentuk sesuatu produk bagi Industri Perkilangan Malaysia masih rendah; (2) Kesan amalan

CE terhadap kualiti rekabentuk produk juga masih rendah; (3) Produk yang lebih kompleks memberi pengaruh yang lebih tinggi terhadap hubungan antara tahap penglibatan amalan CE dan kualiti rekabentuk sesuatu produk baru. Hasil kajian ini mungkin boleh ditambahbaik lagi dimasa hadapan jika beberapa faktor lain seperti gaya pengurusan, kaedah CE yang digunakan dan teknologi rekabentuk diambilkira didalam kajian ini.

ABSTRACT

The focus of this study is intends to address the questions of: (a) To what extent is CE practices involved in product Design & Development in Malaysian Manufacturing Industries? (b)How does CE practices impact the quality of product design? (c)How does complexity of products influence the relationship between extent of involvement of CE practices and design quality of products?

Today, many companies realize that the effort to develop new products that customers want and continue to purchase is crucial for their survival. New product development is a complex managerial process which involves multiple functional groups, each with different perspective. Concurrent Engineering (CE) is a new product development concept which aim to integrate expertise from various functional disciplines during the design phase. The focus of CE is on a “right-the-first-time” process, rather than on the typical “redo-until-right” process that is common in the sequential design process.

A sample of seventy seven (77) respondents in Penang Manufacturing Industries was filled in a structured questionnaire. The sample study included representation from the Electrical & Electronics, Machinery & Fabricated Metal, Chemical/Fertilizer & Rubber Base, Textile & Garments and Food & Agricultural Products processing.

The findings of this study are: (1) The extent of involvement of CE practices in product design in Malaysian Manufacturing Industries still very low; (2) The impact of CE practices on quality of product design also still very low; (3) The complexity of product shows the strong influence relationship between extent of involvement of CE

practices and quality of design of new products. The findings of this study could be improved in future research if other factors like managerial styles, CE method utilization as well as design technology were considered in the study.

Chapter 1

INTRODUCTION

1.1 INTRODUCTION

As international competition becomes more acute, the pressure for companies to improve the way they work, including the way they design new (or improved) products, also increases. Product design (PD) has become crucially important for corporate competitiveness and long-term survival. As a result of this, the broad topic of PD has been the subject of extensive research activity over the course of the last 20-30 years. The literature on engineering design, management, marketing, and research and development is now extensive, and addresses the various and complex dimensions of the subject matter (Hein 1994, Hubika 1990, Duffy 1993). Early, but still important reviews on the topic can be found in Craig and Hart (1992) and Finger and Dixon (1989). Research related to PD methods is frequently based on the simplistic assumption that the systematic use of them can be an important weapon in enhancing PD practice and that they improve the competitive edge of manufacturing companies; indeed, these are the ultimate goal of PD method developers.

During the last decade, the development of new PD methods in Europe and the US has been augmented by the 'importation' of techniques from Japan. While some of these methods seem to be more conducive to Japanese than Western industrial culture, others have been accepted by Western companies. Prescriptive information about PD methods is widely available and can be found either in publications about specific methods [Taguchi 1993, Akao 1990] or in compilations [Jones 1970]. Information is also available from general sources such as Hubika and Eder [1984], Pugh [1991],

Pahl and Beitz (1991), Andreasen and Hein (1987) and Cross (1994), where selected methods are presented in a more general framework and context. Despite the large number of available PD methods, and the importance credited to them by some researchers, it has been claimed that the adoption of methods (and of design sciences in general) by industry is not yet widespread or always successful (Gill 1991, Andreasen 1991). However, no empirical data are available describing the real extent of use of PD methods in practice.

Decisions to implement some methods could be based on the perceived benefits that they bring to accountability and traceability. Indeed, in some sectors such as automobile and aerospace, companies demand that certain methods (e.g. failure modes and effects analysis) are employed by their suppliers during the product development process.

Few will argue the benefits of concurrent engineering (CE), or dispute its inevitable acceptance as the wave of the future for new product development. As implementators have seized the opportunity to maximize their resources and synergize their companies to a new level of effectiveness, many CE success stories have been well documented. CE can enhance the performance of the design team by promoting interaction and communication among team members. This approach facilitates consideration of all of the system design issues concurrently. Several prominent companies in UK embraced the CE philosophy and have adopted the CE tools and techniques (Manoon 1998). These companies report significant productivity gains through shorter product/system development times, increased quality, lower cost and increased customer/user satisfaction. By applying a CE concept to the agile

manufacturing system design, productivity gain such as shorter design times and increased design quality can be achieved.

The focus of this study is to address the questions of: (a) To what extent is CE practices involved in product Design & Development in Malaysian Manufacturing Industries? (b) How does CE practices impact the quality of product design? (c) How does complexity of products influence the relationship between extent of involvement of CE practices and design quality of products?

1.2 Problem Statements

Design has a tremendous impact on the quality of a product or service. For example design will determine whether or not the needs of the customer will be met; and/or the cost of manufacture. Design also influence the development time and time to market. Thus allowing a competitors to introduce new products, services or features if our design does not come out on time in the market. What if, in rushing to be first to the market, our design is flawed?

An effective design process should:

- Match product or service characteristics with customer requirements;
- Ensure that customer requirements are met in the simplest and least cost by manner;
- Reduce the time required to design a new product or service, and
- Minimize the revisions necessary to make a design work able.

Design is a critical process for a firm. Strategically, it defines a firm's customers, as well as its competitors. It capitalizes on a firm's core competencies and determines what new competencies need to be developed. It is also the most obvious driver of change – new products and services often define new markets and require new process. New products can rejuvenate an organization or even an industry (Russel & Taylor, 1998). But the benefits from a newly designed product or service are more than increased revenues and market share. The design process itself is beneficial because it encourages companies to work outside their boundaries, bring in new ideas, challenge conventional thinking and experiment. Product and service design provide a natural venue for learning, breaking down barriers, working in teams and integrating across functions. The design process cuts across functional departments, requiring input, coordination, and action from marketing, engineering and production (Russell & Taylor, 1998).

1.3 Objectives of Study

This study intends to investigate the impact of CE practices on quality of design of new products in the Malaysian Manufacturing Industries. The objectives of the study is to ascertain :-

- (i) The extent of involvement of CE practices in Malaysian manufacturing industries;
- (ii) The existence (if any) of any correlation between CE practices, design quality and new products development;
- (iii) Whether the CE practices will influence the quality of design of new products.

() **Research Questions**

This study hopes to answer the three major questions:

- (i) To what extent is CE practices involved in product Design & Development in Malaysian Industries?
- (ii) How does CE impact the quality of product design?
- (iii) How does complexity of products influence the relationship between extent of involvement of CE and the quality of product design?

1.5 Structure of Reports

The remaining chapter of this research report will be organized in the following manner. Chapter Two will review the literature on CE, new products development and the factors influencing the quality of design of new products. Chapter Three describes the methodology used in this research; in particular describes the theoretical framework of the study, the measuring instrument, sampling method and the method of data analysis. Chapter four report the results and statistical findings of the study, while Chapter Five the discussion, conclusion, limitation of research and suggestions for future research will be covered.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

The following literature review is divided into four sections. The first section will review the concept of concurrent engineering. The second part will review the Concurrent Engineering (CE), product development strategies and design. The third will touch a review on CE, complexity of products and design quality of new products and finally the summary of this chapter in section four.

2.2 The Concept of Concurrent Engineering (CE)

It is now widely recognised that effective new product development and introduction are central to the survival of manufacturing companies (Clausing, 1994, Rosenau, 1990, Wheelwright & Clark, 1992). In order to acquire and sustain competitiveness in an increasingly globalised and fast changing environment, manufacturers need to be able to reduce the time-to-market for new products, cut product development and introduction costs, and ensure a greater degree of customer focus. Within the field of organisation-oriented innovation research, there has been an increasing of interest over the past decade in this issue (Brown & Eisenhardt, 1995). Various studies have investigated the determinants of successful new product introduction (Cooper, 1979, Cooper & Kleinschmidt, 1987, 1994). A parallel and related development in the engineering research literature has seen the emergence of concurrent engineering (CE) as a solution to the problem of achieving more rapid and effective product innovation.

Concurrent engineering has been described as:

“... The answer to the need for shorter development cycles” (Shina, 1991)

“The product development environment for the 1990s.” (Carter & Bakert, 1992)

“A major element of many companies’ improved competitiveness.” (Clausing, 1994)

“... One of the most significant contemporary trends in new product development.”
(Gerwin & Susman, 1996).

Concurrent engineering, sometimes referred to as simultaneous engineering, is best described as :

" a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements" (Winner et al. (1988) in Jarvis 1999)

Put more simply, it is the concurrent design of products and their related processes, including manufacture and support.

According to Dean and Unal (1992 in Jarvis 1999), concurrent engineering is “designing for assembly, availability, cost, customer satisfaction, maintainability, manageability, manufacturability, operability, performance, quality, risk, safety, schedule, social acceptability, and all other attributes of the product.”

On closer examination, CE is found to mean different things to different people. It has been variously described as a design engineering philosophy, a systematic approach, a practice, a method, an environment, a competitive strategy, a new paradigm for product development and a technique. To add to the confusion, a number of synonyms are also widely used, e.g. simultaneous engineering, concurrent product and process design, integrated product and process design, and life cycle design.

A review of the engineering and design literature shows that CE is not an entirely new concept. Rather, it is part of a tradition which can be traced back to at least the 1960s (Gladman 1969 in Jarvis 1999) and which addresses the disintegrating problems associated with functional specialisation in contemporary product development. Earlier studies in this area focused on, and sought to redress, the dysfunctional consequences arising out of the professional specialisation and organisational compartmentalisation associated with separate product design and manufacturing process design (Boothroyd & Dewhurst, 1987, Dean & Susman, 1989, Ettlíe & Stoll, 1990 in Jarvis 1999).

The concept of CE may most appropriately be interpreted as a new product development and introduction philosophy which addresses the two key organisational problems identified by Tom Peters (1987):

Firstly, the process has tended to proceed in a linear sequential way with few overlapping activities. Each department would complete its work before handing this

'over the wall' to the downstream function for the next phase, a process that has been called 'a chain of hand-shaking' or 'relay races'.

Secondly, the various functional departments engaged in new product development and introduction became very compartmentalised, with the resultant goal displacement and degeneration in cross-functional communication.

The third problematic area of conventional product development processes concerns the integrative mechanisms employed to coordinate the overall effort. Often found to be inadequate, they typically involve bureaucratic drawing approval and engineering change management procedures, periodic inter-departmental manager meetings, and 'lightweight' project managers confronted by strong functional management control over resources.

Fourthly, because of a lack of consideration of downstream issues during the earlier design phases, the conventional process invariably leads to a need for post-release 'fixes' to products (in the form of engineering changes), some of which would be identified through re-design methods such as Value Engineering (Shina, 1991).

The concept of concurrent engineering is simple. It does, however, require fundamental changes in ways of working. First it requires a fundamental shift in organisation structure and culture to break down the barriers (and they do exist) between R&D, design, and manufacturing. By the very nature of the process, these people have to start working together - bringing their particular expertise to the table simultaneously rather than sequentially. They must respect each other's expertise but

attack issues and problems jointly. They must also, most importantly, address the design and manufacture process from a customer standpoint.

2.3 Concurrent Engineering (CE), Product Development Strategies and Design.

2.3.1 Product Development and Design

Recent articles in the business press and academic literature maintain that one of the primary means for achieving competitive advantage through product development is by accelerating the development process. Karagozoglou and Brown (1993), for example, state,

"There are significant economic rewards that stem from faster NPD (new product development). Earlier product introduction improves profitability by extending a product's sales life, creating an opportunity to charge a premium price, and allowing development and manufacturing cost advantages. Particularly in high-growth markets involving short product life cycles, the overall impact of NPD speed on profitability is compelling".

Claims that faster product development leads to superior performance generally have been supported by citing models developed by consulting firms (e.g., Dumaine 1989; Reinertsen 1992) or empirical studies of first-mover advantages or product introduction delays (e.g., Hendricks & Singhal 1993; Robinson & Fornell 1985). However, direct empirical evidence on whether accelerated product development increases performance is nearly nonexistent. Moreover, studies examining the factors influencing the success or failure of new product development indicate that

performance outcomes are heavily influenced by the product's quality and uniqueness and the development practices used by the organization (Zirger & Maidique 1990), suggesting that faster product development alone may not be enough to achieve higher performance.

2.3.2 CE and an Impact on Design Quality of New Products

Concurrent engineering continues to be a preferred best practice among engineering managers who are working to improve their new product design and development process. According to a recent EDMAR reader study (1997), 28.5% of the respondents indicate that they have implemented concurrent engineering concepts during the past 12 months. Far more interesting, however, are the demographics of the survey. It found that engineering leaders in both small organizations (less than 500 employees) and large entities are applying this practice in almost equal proportions. This is identical to the result found in 1996 EDMAR study.

Design project time has been reduced by up to 30% since concurrent engineering was adopted."Concurrent engineering has enabled us to do more in less time with limited resources," proclaims a product engineering manager at a midsize producer of air distribution equipment. "Before adapting concurrent engineering principles to our specific situation, we conducted a thorough review of department practices to eliminate activities that don't add value." Based on this review, the company decided to move ahead with concurrent engineering practices based on project teams and supported by new and/or upgraded engineering software. "This combination has significantly reduced the time it now takes our product development teams to

complete project," he reported. Individual project cycle times have been reduced a minimum of 10%, with the largest to date experiencing a 30% savings (EDMAR, 1997)

Too many changes, too many cost overruns leads one director to consider concurrent engineering. "We're in a market-driven industry," a director of engineering based in Pennsylvania replied, "yet we were suffering from too many changes in the middle of the program because we just weren't devoting enough time to feasibility studies and other analyses in the front end of the project." Once the company adopted concurrent engineering, the number of changes fell and the resultant cost overruns also "withered" (EDMAR, 1997).

2.3.3 Concurrent Engineering (CE), Complexity of Product (CP) and Product Design Quality (PDQ).

Project newness is a matter of how much of the product must be redesigned, independent of the complexity or technical difficulty of making that change. Project teams do not always begin from scratch to create a completely new (clean-sheet or new-to-the-firm) product. Even though Corvettes have been sold by General Motors for over 40 years, about once a decade the Corvette is redesigned from scratch, with every aspect of the car changed. This requires significant effort and time. In between these clean-sheet reintroductions, several incremental changes are taken to market to improve or "refresh" the design, which require less time to make the modifications. As obvious as this relationship is, no researcher has yet focused on how newness

affects NPD cycle time. Researchers have predominantly concentrated on new-to-the-firm products, which are inherently clean-sheet projects.

In general, many more development projects are modifications of or improvements (incremental or major) on current products or services rather than new-to-the-firm products (Kuczmarski, 1992). Because firms commercialize projects at all levels of newness, there is a need to develop an understanding of cycle time relationships that is applicable across projects that span the full range of newness, rather than just focus on relationships within one level of newness.

Previous qualitative research has indicated product complexity as affecting cycle time (Murmah, 1994). Complexity is the construct that captures the difference between developing a car rather than an electronic pager. Even when comparing cycle time across these products at the same level of newness, for example comparing the NPD cycle time required for 100% new-to-the-firm projects, cars seem inherently more complex than pagers.

As long as cycle time is defined and studied within an industry (as with Clark and Fujimoto's [1991] work in the automobile industry), accounting for the impact of complexity on cycle time may not be important. Keeping research within one industry, however, limits the generalizability of the findings. To conduct cycle time research that spans industries with products of different complexities, complexity as a construct must be quantified and then the relationship between complexity and cycle time tested. Complexity thus needed to be operationalized in a way that could be applied consistently across industries.

One way in which complexity has been operationalized is as the number of parts in products (Murmman 1994). This operationalization limits the industries from which data can be analyzed to those containing parts. Services would be difficult to interpret and include in the research, as would formulated products, such as shampoo. A different way to operationalize product complexity is as the number of functions designed into the product. The number of functions quantifies the complexity and diversity of the set of needs a product or service delivers. Cars have more functions than pagers. Pagers receive signals, let the user know they are being paged, and display appropriate information. Cars transport people and their goods from one place to another, enable them to travel comfortably, protect them from the elements, protect them in crashes, and so forth. Functions can be defined across services and products, independent of industry.

Complexity refers to the number of functions designed into a product. As products grow more complex, with more functions designed into the product and designed to work together, the task of organizing the interfaces and interactions between different functions may grow geometrically or exponentially rather than linearly, thereby increasing the need for a process. Processes do not help projects proceed efficiently through the fuzzy front end of product development. According to the findings, the length of the product development cycle is always related to the product *complexity* and newness of projects. Each function that is designed into a product requires roughly 3 1/2 to 4 1/2 months of time to develop. Each additional 10% of the design that must be changed adds 1 to 1 1/2 months to the development cycle (Griffin 1997).

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter will discuss the research design and methodology used in this research project. The questionnaire used in this study will be elaborated and explained. It will also describe the sampling, data collection technique, and statistical method used.

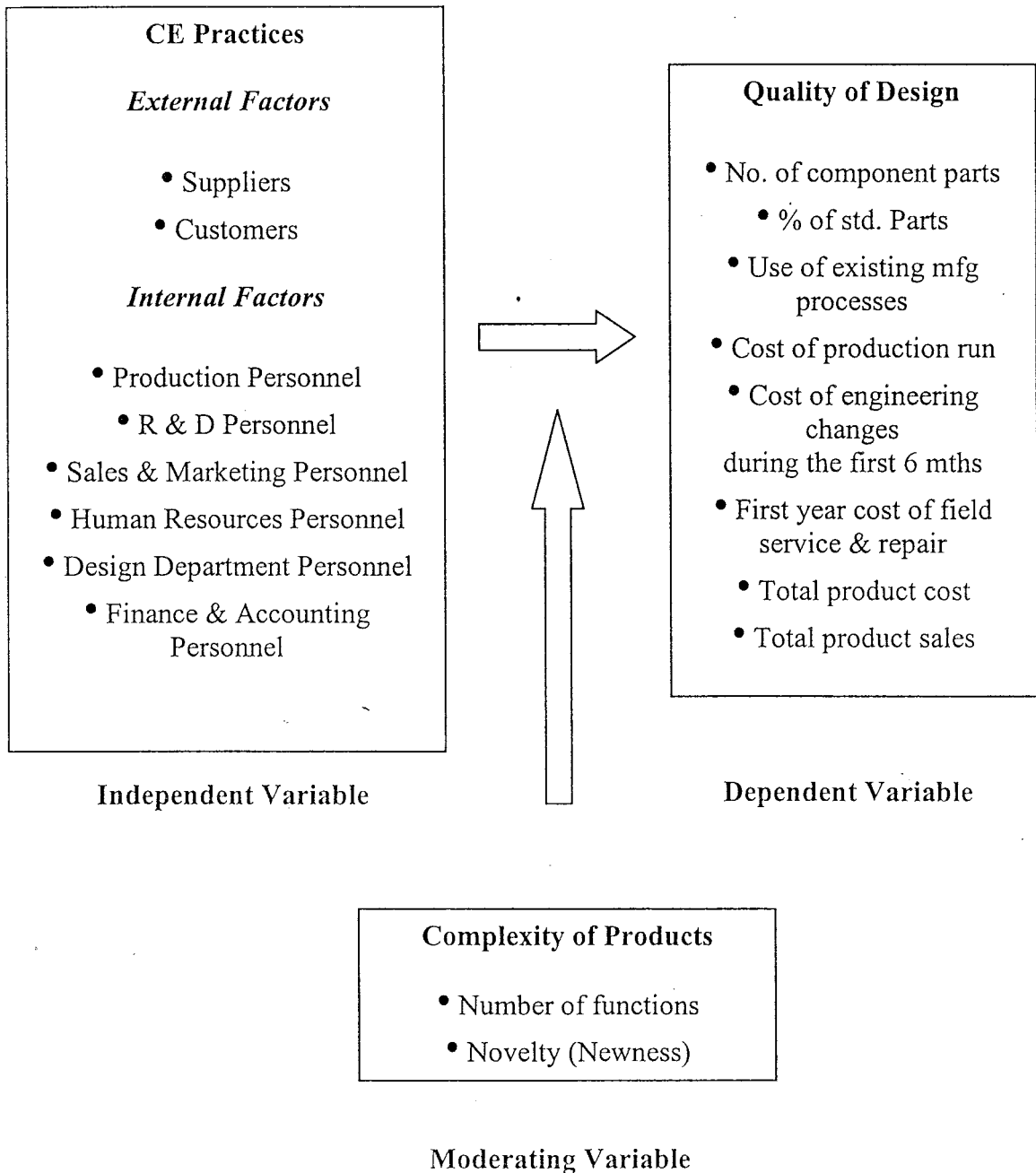
3.2 Theoretical Framework

As depicted in figure 3.1, the dependent variable is the quality of design and for the purpose of this study, eight measure were considered. They are number of component parts & product options, percentages of standard parts, use of existing manufacturing processes, cost of production run, cost of engineering changes during the first six months, first-year cost of field service and repair, total product cost and total product sales.

The important independent variable that influenced the dependent variable is Concurrent Engineering (CE) practices. The independent variable was broken down into two dimension of involvement, namely internal factors and external factors. The internal factors involved various personnel such as production personnel, R&D personnel, sale & marketing personnel, human resource personnel, design department personnel as well as finance & accounting personnel. The external factors such as customer and suppliers were considered.

The above relationship will be moderated by complexity of products which consist of the number of functions and novelty (newness).

Figure 3.1 : The theoretical framework for this study.



3.3 Hypotheses

This study is trying to explore whether there is any significant impact between level of involvement of concurrent engineering (CE) practices and quality of design of a new product. Two broad hypotheses were developed to test the associations between the independent, moderating and dependent variables. They are:-

Hypothesis 1 : The greater the involvement of CE practices the higher the quality of design.

This hypothesis was divided into seven specific hypothesis, namely :

- 1a : The greater the involvement of SUPPLIERS the higher the quality of design.
- 1b : The greater the involvement of CUSTOMERS the higher the quality of design.
- 1c : The greater the involvement of PRODUCTION PERSONNEL the higher the quality of design.
- 1d : The greater the involvement of R&D PERSONNEL the higher the quality of design.
- 1e : The greater the involvement of SALE & MARKETING PERSONNEL the higher the quality of design.
- 1f : The greater the involvement of HUMAN RESOURCE PERSONNEL the higher the quality of design.
- 1g : The greater the involvement of DESIGN PERSONNEL the higher the quality of design.
- 1h : The greater the involvement of FINANCE & ACCOUNTING PERSONNEL the higher the quality of design.

Hypothesis 2 : The impact of CE practices on quality of design is moderated by complexity of products being developed.

This hypothesis was divided into eight specific hypothesis, namely :

- 2a : The impact of involvement of SUPPLIERS on quality of design is greater for more complex products.
- 2b : The impact of involvement of CUSTOMERS on quality of design is greater for more complex products
- 2c : The impact of involvement of PRODUCTION PERSONNEL on quality of design is greater for more complex products
- 2d : The impact of involvement of R&D PERSONNEL on quality of design is greater for more complex products
- 2e : The impact of involvement of SALE & MARKETING PERSONNEL on quality of design is greater for more complex products
- 2f : The impact of involvement of HUMAN RESOURCE PERSONNEL on quality of design is greater for more complex products
- 2g : The impact of involvement of DESIGN PERSONNEL on quality of design is greater for more complex products
- 2h : The impact of involvement of FINANCE & ACCOUNTING PERSONNEL on quality of design is greater for more complex products

3.4 Instruments

The questionnaire used in this study comprised of six (6) parts consisting of a total of 34 items. The sections are as follow:-

Part 1: Company Profile (7 questions)

Part 2: Product Profile (4 questions)

Part 3: Concurrent Engineering Practices (9 questions)

Part 4: Quality of Design (8 questions)

Part 5: Complexity of Products (2 questions)

Part 6: Personal Detail (4 questions)

The detailed of questionnaire is appended in Appendix A.

The CE practices was design based on level of involvement of the various parties in the product design. The team approach to product design has proved to be successful worldwide. Full - time participants from marketing, manufacturing and engineering are essential to effective product design. Customers, dealers, suppliers, lawyers, accountants and others are also useful team members (Russel & Taylor, 1998). A recent study of new product launchings in high - technology firms conclude that the critical factor between success and failure was the involvement and interaction of the " create, make, and market" functions from the beginning of the design project. Ford Motor Company has been a leader in the team approach to product design in automotive industry in U.S in industry (Russel & Taylor, 1998). In this study the design team such as Supplier, Customer, Production Personnel, R&D Personnel, Sale & Marketing personnel, Human Resource Personnel, Design Personnel as well as Finance & Accounting Personnel was considered as independent variables. The customers and suppliers are considered as external factors and the rest are considered as internal factors.

The dependent variable was measured by eight (8) factors as adapted from D.A. Waliszewski (Russell & Taylor, 1998) such as:-

1. Number of component parts and product options
2. Percentage of standard parts
3. Use of existing manufacturing processes
4. Cost of first production run
5. Cost of engineering changes during the first six months

6. First year cost of field service and repair
7. Total product cost
8. Total product sales

The complexity of products as moderating variable was measured by number of functions and novelty (newness). The measuring instruments were a five Likert scale which designed accordingly based on the nature of question that to be ask.

3.5 Sampling Design.

This section addresses the part of research design process which includes the definition of the population, the sampling frame and sampling technique that have been used for this study.

3.5.1 Population of the study.

The study population consists of the manufacturing organizations operating in the State of Penang, Malaysia. The firms were further defined as being in the following manufacturing sectors; electronic and electrical (category 1), machinery and fabricated metal (category 2), chemical/fertilizer and rubber base (category 3), timber base and plastic products (category 4), textile and garments (category 5) and Food and agricultural products (category 6).

The State of Penang was selected as it provided a population almost representative of the Malaysian scenario. It has two major industrial areas of Prai Industrial Parks and

and Bayan Lepas Industrial Zones (FIZ). This industrial estates house have many multinational and local company firms as well as small and medium industries (SMI). In, addition, Penang state is also considered as the "silicon valley of Malaysia" due to the concentration of electronic firms engaged in the mass production of computer microchips. Furthermore, the majority of industry sectors in Malaysian can be found in the state per above categories, therefore increasing the study generalizability to a variety of industries. Only the organization from the above six categories were considered for the study based on the fact that these firms represent almost 70% of total factories listed in Penang (Penang Development Corporation, 1998). In addition, these firm are judged to have tendency for tangible good manufacturing and greater thrust for implementing the concurrent engineering practices incorporating customer and supplier involvement due to industry requirement and competition for product differentiation and cost leadership.

The unit analysis for this study was the product type. The key respondent was individuals who were involved in the product development and manufacturing such as R&D Manager, Engineering manager, Technical Manager, Sales & Marketing Manager, Production Manager, Industrial Designer, Mechanical Production Designer as well as Senior Engineer.

3.5.2 *Sampling Frame*

The sampling frame used was the list of all factories in Penang, Malaysia (June 1998 issue) published by Penang Development Corporation (PDC). It consists of a total of 710 factories span over 17 industry categories. However only 551 factories (84.5% of

the total firms listed) were considered for the sampling based on the rationale given in section 3.5.1.

3.5.3 Sampling Technique and Sample Size

Probability sampling was used to select the samples for the study. To be more precise, proportionate stratified random sampling was deemed to appropriate considering the facts that the population has been divided to six categories to ensure representatives from each categories. Based on random sampling, a total of 300 samples were drawn from the list of selected factories located in Penang. The proportion of sample was summarised in Table 3.1.

Table 3.1: Distribution of Targeted Sample according to Industry Types.

Industry Type	Number of factories	Targeted Samples
Electrical and Electronics	153	101
Machinery & Fabricated Metal	160	80
Chemical/Fertilizer and Rubber Base	78	39
Timber Base & Plastic Products	79	40
Textile & Garments.	29	14
Food & Agricultural Products processing	52	26
TOTAL	551	300

3.5.4 Pre - test.

A pre-test was conducted to assess the appropriateness of the questionnaire to meet the study objectives. Ten respondents from Universiti Sains Malaysia's Master in Business Administration (MBA) program with manufacturing environment working exposure participated in the pre-test. It was conducted by arranging face to face discussion pertaining to the questionnaire with each of the pre-test respondents. The overall conclusion from the pre-test exercise showed that the items were appropriate. Generally, the participants were satisfied with the language and wording of questions, meaning of words, continuity of flow and length of the questions. Based on this pre-test feedback, minor wording changes were made on question 1, question 9 and question 23 to improve the clarity of the subjects in the final revised questionnaire prior to the sampled respondents.

3.5.5 Questionnaire Administration

The questionnaire were mailed to the sampled organization during the week of December 26th, 1999 given a dateline of January 15th, 2000. One of the main problems of mail questionnaire is the low return rate. Therefore, in an attempt to increase the return rate, listed below are an efforts which were undertaken during the administration of the questionnaire as suggested by Kanuk and Berenson (1975).

- A short cover letter accompanied the questionnaire using University Sains Malaysia's School of Management letter head, explaining the purpose and objectives of the study, indicate the anonymity of the respondent, reassuring them

that the study was not meant to compare the organizations; including deadline and indicating the promise to provide a summary of the results if the returned questionnaire was accompanied by their address or business card.

- A self addressed return envelope was enclosed complete with postage to facilitate the return of the questionnaire.

Due to low response rate after the initial three weeks, the questionnaire was administered through personal contacts. The participating respondents profile is presented in Table 4.1 in Chapter 4.0.

3.6 Data Analysis

Statistical Package for Social Sciences (SPSS) software application for window was used for this analysis. Descriptive statistics was used to provide the frequency and summary of the means, median and standard deviation. Cronbach's Alpha inter - item correlation was used to look at the general reliability of instruments.

Pearson's correlation analysis was used to look at direction and inter correlation of items. Multiple regression analysis was used to determine the relationship between the dependent variable and independent variable as stated by the hypotheses.