The Hong Kong Polytechnic University

Department of

Industrial and Systems Engineering

New Customizable Agile Reconfigurable Design System

by

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A thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

FEB 2005

CERTIFICATE OF ORIGINALITY

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Abstract of thesis entitled

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ABSTRACT

This research presents a Customizable, Agile, Reconfigurable Design System (CARDS), a novel holistic approach to product design which involves people from inside and outside the company working together; embracing change and handling it systematically, and providing maximum customer satisfaction. CARDS enhances the transparency of the product development process, helps staff to overcomes the traditional inertia they experience when faced with change, and helps managers to cope with the flood of information which is prevalent in the rapidly changing business environment of today.

The CARDS works through three distinct modules: the Team Transformation Module, the Process on Demand Module, and Product Specifications Enhancement Module. Each module deals with different facets of the product development cycle, and is designed to address specific needs and purposes. The ultimate goal of the modules, is to achieve agility in three areas. The Team Transformation Module aims at delivering organizational agility, the Product on Demand Module is for achieving process agility, whereas the Product Specifications Enhancing Module optimizes the feature agility of products. These three modules, while being independent are closely and dynamically integrated. One distinguishing feature of CARDS is that outside parties such as customers, vendors, or outside resources are allowed to play a role in the product development including the making of management decisions. This form of external collaboration provides the form of agility that makes this system unique and particularly effective in satisfying market needs.

In carrying out the three modules, several supporting technologies which are frequently utilized by manufacturing firms are incorporated. These supporting technologies are carefully chosen in relation to the actual business practice. However, it should be stressed that the supporting technologies used in this report do not exclude other supporting technologies. For different businesses or industries, different supporting technologies may be adopted in CARDS so as to suit the different specific needs of individual businesses or industries.

Two case studies have been conducted to test and validate the feasibility of CARDS. A review of the system was carried out with follow through studies interviewing the participants in the case studies. The significance of CARDS lies in its ability to provide a holistic and systematic approach to address the problems of handling changes in the product development stage. Also, the approach brings in a whole new paradigm shift in organizational thinking. It breaks down the departmental and organizational barriers within an enterprise and brings in a system which enables the staff to make changes with the minimum of disruption. In turn, the approach will bring in a change in corporate culture which encourages the staff to take risks. Finally the whole organization and its staff will be converted to welcoming “change” and become “customer needs” oriented. In this way, CARDS will facilitate continuous improvement of the products under development, which is the key to success for most manufacturing companies.

Publications arising from the thesis

Journal Paper

1. SAMSON TAM, WB LEE, WALTER CHUNG & HENRY LAU. 'An Object-Based Process Planning and Scheduling Model in a Product Design Environment'. Logistics Information Management, MCB University Press, vol. 13, No. 4, pp. 191-200, August (2000)

2. WB LEE, HENRY LAU, ZHUO-ZHI LIU & SAMSON TAM. 'A fuzzy analytic hierarchy process approach in modular product design'. Expert Systems, The International Journal of Knowledge Engineering and Neural Networks, Volume 18, Number 1, pp.32-40, February (2001)

3. SAMSON TAM, WB LEE & WALTER CHUNG (2001). 'Growth of a Small Manufacturing Enterprise and Critical Factors for Success'. International Journal of Manufacturing Technology and Management, Vol.3, Nos.4/5, pp. 444-455 (2001) Special Issue on: Competitive Manufacturing in small and medium enterprises

4. SAMSON TAM, WB LEE, WALTER WC CHUNG, AND ELIZABETH LY NAM. 'Design of a Re-configurable Workflow System for Rapid Product Development'. Business Process Management, Vol. 9, No. 1, pp. 33-45 (2003)

Conference Paper

5. SAMSON TAM & WB LEE, 'Quality Function Deployment for the Development of a Product Design System', TQM & Innovation – Proceedings of the 4th International Conference on ISO 9000 and TQM, Hong Kong Baptist University, School of Business, Hong Kong, pp.369-374, 7-9 April, 1999

6. SAMSON TAM, WB LEE AND HENRY LAU, 'The Decision Support Role of an Object-based Process Planning and Scheduling Scheme for Re-inventing Business Operations', The 26th International Conference on Computers & Industrial Engineering, 15-17 December 1999, Melbourne, Australia (Proc. Vol.2, pp.11-16) International Journal of Computing and Industrial Engineering, Volume 2, Non-Refereed Papers, Industrial Research Institute Swinburne

7. SAMSON TAM, WB LEE, ELIZABETH NAM, 'A Systematic Approach Product Definition Process in GSL', Proceedings of the 9th International Conference on ISO 9000 & TQM (9-ICIT) (Best sub-thesis paper award), Bangkok, Thailand, pp.467-474, 5-7 April 2004

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CHAPTER 1 INTRODUCTION

1.1 Motivation

As we enter an era of intensified global competition, radical changes are taking place reshaping the industrial landscape of all the economies in the world. The marketplace has become truly global. People are on the cusp of an information age. All these changes are ushering in new and exciting challenges for manufacturers. The dominant theme from the 50s to the 70s was the achievement of economies of scale through mass production. Large facilities built to produce huge quantities of goods required complex organizational structures in order to maintain sufficient control and efficient management. Conventional wisdom then dictated that low unit cost could only be achieved by spreading fixed costs over the largest possible volume of output. This, however, imposed inflexibility in design and customisation. In the 80s, United States manufacturers became more and more concerned about their product quality, as they had been under much pressure to match the keen competition from higher quality overseas products. Statistical process control (SPC), employee involvement in quality assurance programs (Zairi & Youssef, 1995), and improved product design were the cornerstones of improving product quality.

As markets integrated further and global competition intensified, the market emphasis shifted in the late 80s and early 90s to a general effort to upgrade manufacturing capability. This resulted in improvements in productivity, waste reduction, and greater product variety (Ahlstrom & Westbrook, 1999). Operational efficiencies embodied in just-in-time (JIT) inventory control and focused factory concepts were quickly adopted, resulting in more effective planning and improved control systems such as manufacturing resource planning (MRP II). At the same time, a new paradigm in designing products emerged. Mass customisation was introduced to provide customer satisfaction by increasing variety and customisation without a corresponding increase in cost and lead time (Ahlstrom & Westbrook, 1999).

Over the last decade, there has been development in the area of study termed “enterprise engineering” (Hewitt, 1995) which aroused significant interest worldwide. Global competition has increased the complexity of many products and has fuelled a need for organizations to work together as an integrated “networked enterprise” that is geographically widely distributed (Crutchfield, 1986; Hamel, 1993; Warnceke, 1993). The groups of people involved here are from primary partner organizations, their stakeholders, customers and other third parties. They can be brought into co-operation to design a product or develop value-added services. In some cases the company will need to seek out specific partners with special skills or attributes and create a virtual corporation from several parties to focus on meeting the needs of customers or a particular market.

Today, as international markets mature and supporting systems become more sophisticated, the manufacturing strategist needs to identify those ever-changing factors in order to lead the market and keep his/her products competitive. Flexibility, speed, and responsiveness to the customers are increasingly recognized as the critical order-winning criteria for competing in the new markets expected in the future. This is not to suggest that quality, price, and design are unimportant. These factors continue to be critical. The inability to have a competitive price or a certain level of quality that can please the customers often means that the business survival is at risk.

These attributes are still necessary for entering the market. Although quality and price remain critical to success, they are no longer the only source of unique competitive advantage in many markets. Instead, attention has been shifting to speed and flexibility, and responsiveness to the customer which is the essence of time-based competition (Carter *et al.* , 1995).

1.1.1 Importance of Product Development

Product development is a hot topic in operational research. Firms continue to spend huge amounts of time and money on unsuccessful product development projects (Page, 1993). In short, a gap seems to exist between the market need and the products offered by companies. During the past ten years, a number of authors have investigated the relationship between market orientation and business performance. Jaworski and Kohli (1993) found that "the market orientation of a business is an important determinant of its performance, including profitability, customer retention, sales growth, and new product success" (Slater & Narver, 1994). Increased market orientation resulted in improved inter-functional coordination and a higher percentage of successful new product introductions. Barclay (1992a) concludes upon a literature review of product development studies that the attribute "a good market knowledge and strategy" is identified as a success factor in 78 per cent of the studies. Examples of specific factors related to the concept of market-oriented product development can be seen in much of the literature including Cooper (1979; 1985; 1990), Johne & Snelson (1990) and Rothwell (1992). To sum up, being market orientated in product development has proven to be a highly critical factor for both new product success and company survival.

A product is something sold by an enterprise to its customers. New products and their successful developments are the lifeblood of a company. The new products provide the impetus for the organization to grow and produce profitable returns. New products can create new markets and gain market shares, which in turn, help defend against competitive pressures. A regular supply of new products can satisfy customers and meet continuously changing customer needs and market requirements. From the perspective of an investor, successful product development results in products that are producible at a profit. This economic success depends, however, on the ability of manufacturers to identify the needs of customers and to create quickly products that meet these needs and produce them at a low cost. The successful introduction of new products is essentially dependent on the skills and competencies of individuals within organizations in promoting the key success drivers for product development.

Product development (PD) is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product (Ulrich & Eppinger, 1995). The product development process includes idea generation, product development and product commercialisation. In a prior study, Ross, Eric M., (1994) propose that the new product development (NPD) process consists of five groups of activities: opportunity identification and screening, product design, testing, commercialisation, and post-launch control. Some scholars (Cooper & Kleinschmidt, 1986; Crawford, 1994) suggested that the NPD process has been characterized as consisting of marketing and technical activities. Cooper and Kleinschmidt (1986) developed a framework of the NPD process consisting of twelve activities: six marketing activities and six technical activities. Actually, all of these are consistent with the perspective of Handfield *et al*. (1999), who view the NPD process as a series of interdependent and often overlapping activities, during which a new product is brought from the "idea" stage to preparation for full-scale production or service delivery. The whole process is shown in Figure 1.1. As the product concept moves through these stages, the product design is done, prototyping and testing are finished, and preparations for full-scale operations are finalized.

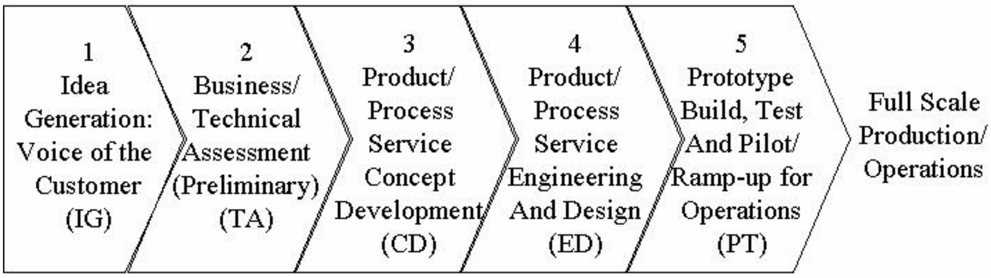

Figure 1.1 New product development process (From Handfield *et al*., 1999)

It is important to realize that the time between the introduction and the maturity of products has decreased drastically in the past few years making it possible that the window of opportunity could be missed by getting a new product into the market just a few months later than the other competitors. Competitive advantage is the dynamic interaction of product, technology and market strategies. This is contingent upon a successful product and a process development algorithm. Therefore, it is critical for enterprises to capably manage and optimise product design and development process. It requires effective actions from all major functions in the organization. Synergy in product development is achieved when all the functional activities fit well together. In brief, the efficiency and effectiveness of product development management is critical to success in business.

1.1.2 Challenges to Product Development

New product development has always been exciting, challenging, and most of all, very complex (Hainer *et.* al., 1967; Song and Montoya-Weiss 2001). Throughout the history of industrial and social development, the introduction of new products has always been a close reflection of the developments in science and technology of the time. New scientific and technological developments and discoveries are transformed into new product features and better product performances benefiting customer satisfaction. This ultimately brings more profit to an enterprise. During the last two decades, science and technology has been developed at an astonishing speed and broadness. New techniques, materials and processing methods have come up more widely and frequently than ever before. On one hand, these new techniques and materials bring about new choices and opportunities that product developers could make use of in their new product development processes so as to produce better products. On the other hand, more options inevitably mean more complexity in the related decision making processes. As a result, product development is becoming more complex and therefore more difficult nowadays.

Social and economic evolution also brings about more complexity and thus difficulty in the product development process. Customers are becoming more and more demanding. Market competition is getting more intense than ever before. Companies are under great pressure to produce better products at a faster pace than other competing companies. Or else they will lose their market. New product requirements arise from many new prospects: society, offer of competitors, external environment and so on. World class manufacturers have placed great emphasis on being close to the customers. Customer prosperity goes much further and examines how much value is added to the customer by using products and services of a company. This requires an intimate understanding of the needs of customers. This issue of becoming market/ customer oriented seems to have gained a new level of interest. Many companies are confronted with changing market conditions and announce all kinds of restructuring schemes to emphasize that they are going to be market oriented (Stump, Athaide, and Joshi, 2002). By fully integrating customers into the design process of a product, the efficiency of that design process can be significantly enhanced.

New product development has never been easy, and it is becoming more difficult than ever before. Much research effort has been made worldwide, taking different approaches to try to solve this problem. Research issues focus on different aspects to improve the profitability of a product through better development processes. They are typically represented by the concepts of concurrent engineering or simultaneous engineering, life cycle engineering, or integrated product and process development (IPPD) (Ishii, 1990; Allen, 1990; Syan & Menon, 1994).

Concurrent engineering is defined as a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support (Syan & Menon, 1994). It is intended to cause the developers, from the outset, to consider all the elements of a product life cycle from concept through to disposal, including quality, cost, schedule, and user requirements. Essential issues and techniques in concurrent engineering include quality function deployment, design for manufacture, design for assembly, and rapid prototyping (Syan & Menon, 1994).

A great diversity of research issues is carried out in this area of product and process development. Some methods and techniques are proposed and some tools developed that are efficient and successful in solving some specific problems. For example CE is encouraging the information sharing at the very beginning of product development stage. However, there are no general methods existing that could systematically and efficiently solve the general problems such as no standard language of mapping business process in different companies in this domain. Consequently, the overall approach to new product development is still more or less ad hoc and disappointing. A successful solution of one problem does not mean much for others. When new problems arise, people usually do not know how to solve them as swiftly and efficiently as they have done on the previous ones. As a result, there is an urgent and vital need to study in-depth a generic framework for smart product and process development.

1.2 Research Background

Reducing the time for the product development cycle emerged as a cardinal concern as the 1990s came to an end. According to Koufteros et al (2005), companies required an ongoing ability to respond quickly, effectively to satisfy, and be paid for meeting specific customer needs for products (new or old) faster than the competition. Veeramani and Joshi (1997) define this ability as the concept of agility. Organization agility has become a defining characteristic of competition today. Companies must quickly identify, design, manufacture, and deliver products that meet customer requirements, while maintaining stringent cost and quality standards. More specifically, greater importance is being placed on agility in terms of producing a broad range of low-cost, high-quality products with short lead times in varying lot sizes, built to individual customer specifications (Narasimhan & Das, 1999).

Several approaches are therefore proposed in many researches to achieve faster product development. Most product development strategies include a structure based on teams (Ranney & Deck, 1995; Wolff, 1992) to enhance horizontal communications and cross-functional co-operation (Kelsey, 1995). Adler *et al.* (1996) suggest that the development process should be viewed as one in which projects move through the knowledge-work equivalent of a job shop. This requires a cross-functional project team approach that is often referred to as “concurrent” or “simultaneous” engineering (Swink *et al.*, 1996). Product development consultant Himmelfarb, Philip (1992) argues that those terms are misleading in that they imply that fast product development is strictly a function of engineers. Although engineering is a vital member of the team, several interest groups are also represented – marketing, production, design, Research and Development (R&D), finance, purchasing, quality, suppliers, and customer representatives.

To be competitive from an agility standpoint, companies must not only be able to produce a product fast. Agility, for a company, is to be “capable of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities” (Goldman *et al.*, 1995). It merges the four distinctive competencies of cost, quality, dependability and flexibility as identified by Hayes and Wheelwright (1979). Companies therefore must also adapt their product development efficiently and build strong relationships with customers (Tolone, 2000). A company cannot become agile unless it can precisely and rapidly react to the voice of the customers. It must be able to provide timely and accurate feedback on the manufacturability of a new design and engineer changes smoothly. This agility is market sensitive – it is capable of reading and responding to real demand. Agility allows a company to react more quickly than in the past. An agile firm proactively anticipates customer requirements and leads the emergence of new markets.

In 1995, Goldman *et al.* (1995) identify four key dimensions of agile competition. The first dimension is enriching the customers. This entails a quick understanding of the unique requirements of each individual customer and rapidly providing what the customer needs. The second dimension entails cooperation (intra-organizational, inter-organizational cooperation such as supplier partnerships and perhaps emerging virtual relationships with competing organizations) in order to enhance competitiveness. The third dimension utilizes new organizational structures to master change and uncertainty through techniques such as concurrent engineering and cross-functional teams. The fourth dimension leverages on the impact of people, information and technology and recognizes the importance of employees as a company asset, placing greater emphasis on education, training and empowerment.

As firms have improved their operations in response to changing competitive environments, the conventional wisdom of manufacturing capability trade-offs has come into question. For example, firms cannot lower costs while achieving a higher level of quality - as identified by Skinner (1969). In a study of large European manufacturers, Ferdows and De Meyer (1990) find that the conventional wisdom of trading off one of the strategic performance capabilities for another might be false as shown in Figure 1.2. They conclude that the nature of the trade-offs among these capabilities is more complex than previously thought, and depending on the approach taken for developing each capability, the nature of the trade-offs changes. There is a need to develop a system to enrich the information and further the understanding of the trade-off between cost, time and specifications.

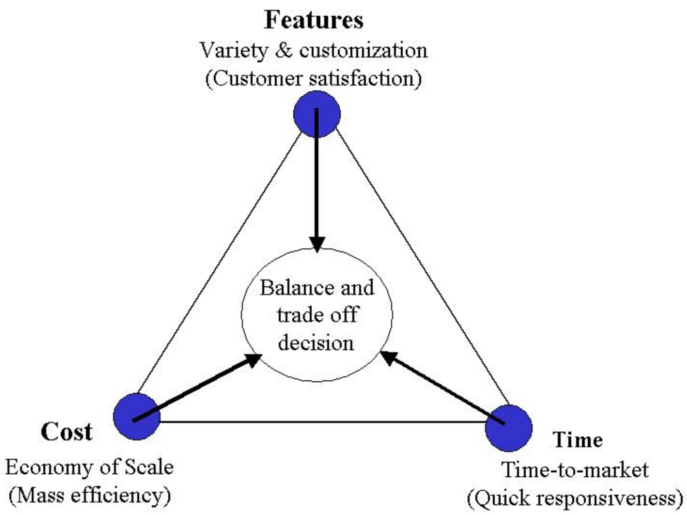

Figure 1.2 Trade-off relationships of three major design elements

(From Ferdows and De Meyer, 1990)

The Next Generation Manufacturing report (NGM 1997) has identified three major imperatives of product development in this new paradigm. These include rapid product/process realization and enterprise integration. Rapid product and process realization are required to meet the continually changing customer needs in an increasingly segmented market. The rapid development of products can only be made possible by accurately converting the voice of customers into the product designs, rapidly developing associated manufacturing capability and rapidly distributing products to end customers. Major components of an enterprise need to perform in an integrated manner to minimize any delays. The integration needs to take place at all levels of the hierarchy, from the overall enterprise level with multiple geographical locations, to within each workplace and within each project. Eliminating integration problems at all these levels can save valuable time during the product design and development stage, and enable bringing the product to market at a desired pace.

An enterprise generally deals with many projects at the same time, requiring different processing models. This makes the decision process more complicated. This also leads to continuous changes during the development processes and hence requires constant business process re-engineering. Unlike most manufacturing processes in factories or routine tasks in purchasing or procurement departments, most development processes are highly dynamic, and not well structured. They are in need of frequent modification. As a result, there is a need to conduct research into the topic and build up a new framework of product development that will enable companies to respond quickly to environmental changes, optimise the trade-off decisions and formulate a collaborative, distributed and dynamic workflow.

1.3 Research Objective and Methodology

Product development has become increasingly complex. The complexity of product development results not only from the complexity of product structure and geometry, but, more importantly, from the complexity of user requirements and resource constraints upon function, quality, reliability, safety, cost effectiveness, etc. Globally distributed enterprises need to decentralize their engineering activities. Nevertheless, the rapidly changing markets require those engineering activities to quickly, accurately and flexibly respond to market changes so as to reduce the time-to-market and production costs. Different engineering activities must work together in a coherent process to accomplish a common goal. This integration implies bringing the different components of a company together to work effectively and efficiently toward achieving its goals such as adapting the voice of customers during product design and development process (Morgan *et al.*, 1990). However, this requires multidisciplinary staffs that have to be involved in communicating and negotiating the best way to allocate the resources and to fulfil customer requirements. The challenges for product development process management include shifting from a technology-oriented to process-oriented approach, the adaptation of business logic for modularity and creating a less human dependent process.

The main aim of this research is to develop a model to define and control a whole product development process which responds better than ever before to external changes and allow the production resources to be made use of to their fullest potential. Companies without a structured model will find it difficult or impossible to maintain consistency across different projects and divisions. They will not be able to capitalize on the experience gained from other projects or to align the product development process when requirements change. However, the above targets can be achieved by developing a procedure and its associated modelling technique which can help ensure that the constructed business development process is properly structured and documented, and that the systems can be maintained continually or be developed further.

Organizational barriers such as departmental conflicts and staff interests or lack of customer involvement still cannot be solved if the companies apply best practices one by one. A question has long been asked: is there a systematic approach, which allows decision-makers to absorb information more rapidly and accurately, and react more flexibly? There is a need for a system, which can help a company to build up a set of consistent and mutually supportive business practices, which support the project team to make fair trade-off decisions.

The proposed system implies bringing the different components of a company together to work effectively and efficiently toward achieving its goals. It characterizes an agile and responsive company differentiating it from traditional organizations. Quality Function Deployment (QFD), Mass Customisation (MC) and Activity Based Costing (ABC) are three good practices selected to be embedded in the system. The system then has the potential to deliver better decisions by explicitly defining communicable organization structures that can be used for reasoning and deliberating about changed requirements. An object-oriented technique is used to provide a new way of tackling problems through models organized around real-world concepts. Since the early 90's, it has been regarded as a modelling technique to describe real world objects with their own distinct identities. It can provide a foundation for developing explicit models of organizational structures that can be used in a dynamic way (i.e. regularly, rapidly and readily) to help analyse and communicate the impact of changing relationships between enterprise processes and human resources. By using object modelling, a company can identify the elements involved in collaborative team management and their relationships. Because of the close relationship between the real-life occurrence and the objects in the model, the semantic difference between reality and the model is a small one. In the model, people can find things which are easier to understand, and thus they are able to get the optimal solution to their problems easily. This process helps promote understanding of the real-world management of different collaborative teams. The object-oriented approach promotes the ability to reuse, reduces development time, and improves analysis, design and thus quality. The introduction of object-oriented technology simplifies requirements analysis and makes it easier to understand. This leads to quicker and more logical design and also to faster actual implementation.

Research in which testing companies are used is considered to be more valuable. A critical and detailed look at the organizations, in order to develop a business model, will enable areas of incongruence to be identified and can help organizations become more streamlined and more efficient. Whether the areas of analysis are defined by function or process and whether there is any overlap is irrelevant as long as the entire organization has been examined. This will allow the companies to eliminate non-value adding activities, and identify which ones are missing, in order to achieve successful integration (Vacca, 1992). It enables the testing companies to continuously change their organization's structures and technology. This harnesses interactivity in such a way that competitive behaviours result in an ever-changing environment. Two case studies will be used as real world industrial tests for the proposed conceptual design and implementation methodology. This will help strengthen the value of this research, its applicability and contribution to the academic field. The business process model benefits firms by its ability to monitor business processes in real time and to change or redesign some or even all of the processes when dictated by change in customer requirements. In this way a business can gain considerable agility.

1.4 Thesis Layout

The thesis aims to propose a business process model that provides agility in product development. The model is called the Customizable Agile Reconfigurable Design

System (CARDS). The background of this research has been outlined in Chapter 1. In Chapter 2, the extensive literature regarding the change in the manufacturing landscape, the emergence of mass customisation, and the need to break down organizational barriers is reviewed. Different management skills and tools such as Product Data Management are reviewed, and the major features and merits of this business process modelling are introduced. In Chapter 3, a survey is conducted to find out the good business practices, which companies have found useful and beneficial to their businesses. The design of the CARDS system will be outlined in Chapter 4. Then, development of the system including its modules will then be introduced in Chapter 5. A novel approach based on a three-tiered modular structure -- Team Transformation Module, Product Specification Optimisation Module and Process on Demand module – is adopted to provide the conceptual foundation for the development of the CARDS system. In Chapter 6, the implementation of the system, in particular in the form of its four-layered structure, will be discussed. This system is to cope with the frequent changes in requirements due to ever-changing customer demands in an increasingly competitive marketplace. The implementation of such a system is further presented with two case examples to validate its practicability in an actual industrial setting in Chapter 7. The main benefits and implications of the proposed system will be fully discussed subsequently in Chapter 8. In the concluding chapter (Chapter 9), the significant findings of this thesis are highlighted, particularly the practical results of applying and implementing the CARDS system.

CHAPTER 2 LITERATURE REVIEW

2.1 Historical Development of Product Development

2.1.1 The Changing Manufacturing Landscape

In the past when mass production prevailed, controlling costs and producing a product of acceptable quality was sufficient to win the market. Economies of scale ruled the manufacturing world and everybody knew that mass production and full utilization of plant capacity was the way to make money (Utterback, 1994). This style of production resulted in inflexible plants that could not be easily reconfigured, and were associated with excess amounts of raw materials, work-in-process and finished goods inventories. One of the most promising concepts of the 1970s in enhancing manufacturing was flexible manufacturing (Crawford, 1991). Though obscured by robotics, manufacturing cells, and extremely complex automated manufacturing systems, this concept is very simple and rooted in the early days of manufacturing when a craftsman could produce different variations of a product or different products tailor made for each customer. In its strictest sense, flexible manufacturing is the ability to produce exactly what is wanted, and produce it on demand. Thus, the “instant” product would be one from a bounded set of possibilities, all of which could be readily produced. The quantity made of any given product at any given time could vary from one unit to many, with little or no cost penalty for small quantities produced. In the ideal case, change among product types would be accomplished on demand and on-the-fly, with each day’s output being a mix of products optimized for the immediate requirement.

In the late 1980s and early 1990s, the concepts of Just-in-time (JIT), total quality management (TQM), and lean production (LP) provided a new competitive advantage for many producers (Smith and Reinertsen, 1992). In pursuit of greater flexibility, elimination of excess in inventory, and advanced levels of quality in both products and customer service, industry analysts have popularized the terms “world-class manufacturing” and ‘lean production” (Brown & Eisenhardt, 1995). Lean production is regarded mainly as an enhancement of mass-production, repetitive manufacturing processes involving the elimination of inventory and other forms of waste. The result is shorter lead times, improved quality, and a higher level of customer service.

In the 1990s, industry leaders were trying to formulate a new paradigm in search of becoming successful manufacturing enterprises; even though many manufacturing firms were still struggling to implement lean production concepts. Stalk and Hout (1990) pointed out that time based competition must become the new focus. “Time-based competition is a competitive strategy that seeks to compress the time required to propose, develop, manufacture, market, and deliver products.” (Calantone et al., 2003) However, focusing on a narrow range of time-honoured concepts is not enough when competing in future markets. Speed and flexibility are becoming increasingly important. Customer responsiveness is the key to future survival. A survey of purchasing professionals found that 82 percent stated that their firms had shifted to agile manufacturing (Baumann et al, 2003). Agile manufacturing describes the “ability to thrive in a continually and unpredictably changing environment while operating profitably in a competitive climate” of producers (Moskal, 1995). The implementation of an agile manufacturing philosophy can result in a significant reduction in the time required to get products to market (Krishnan & Ulrich, 2001).

Fiorina (2000) discusses manufacturing system reconfigurability in agile manufacturing. His analysis of the reconfiguration of a manufacturing system is based on the relationship of component routes, material handling costs, and reconfiguration costs. Components with similar routes are selected in the early design stage in order to minimize the number of machines to be relocated. The variety of resources required is reduced by a proper selection of components and manufacturing processes for system reconfiguration. An algorithm for selection of components and manufacturing resources is developed. Lee's paper focuses more on selection of components than on the generation of alternative designs. The underlying approach uses similar products, but does not mention directions for dissimilar products.

Agility manufacturing was proposed as the new manufacturing paradigm replacing the lean production philosophy of JIT and TQM. It has been embraced by an increasing number of manufacturers and has resulted in dramatic reductions in production time (Vesey, 1992). The difference between the philosophies of lean production and agile manufacturing may appear subtle, but is actually significant. For many, 'lean manufacturing' and 'agile manufacturing' sound similar, but they are different. Lean manufacturing is a response to competitive pressures with limited resources. Agile manufacturing, on the other hand, is a response to complexity brought about by constant change. Lean is a collection of operational techniques focused on productive use of resources. In a similar way, some researchers contrast flexible manufacturing systems (FMS) and agile manufacturing systems (AMS) according to the type of adaptation: FMS is reactive adaptation, while AMS is proactive adaptation (Vesey, 1992). On the other hand, agile manufacturing implies a breaking out of the mass-production mould and produces much more highly customized products in an attempt to satisfy a wider spectrum of customers (Hartley et al, 1997). Ideally, it is the ability to deliver the right quantity of a unique product to the customers when and where required — all for a price appropriate to mass production conditions.

Agile manufacturing requires resources that are beyond the reach of a single company so the sharing of resources and technologies among companies becomes necessary. The competitive ability of an enterprise depends on its ability to establish proper relationships among customers, suppliers and business partners (Kanji and Asher, 1993), and thus cooperation seems to be the key to possibly complementary relationships between each party. (Parthasarthy and Hammond, 2002) An agile enterprise has the organizational flexibility to adopt for each project the managerial vehicle that will yield the greatest competitive advantage. Sometimes this will take the form of an internal cross-functional team with participation from suppliers and customers. Sometimes it will take the form of collaborative ventures with other companies, and sometimes it will take the form of a virtual company (Dove, 1995), which can respond quickly to customer's requirements, cooperate closely with their global partners, and participate actively and be commercially competitive in worldwide manufacturing projects.

A virtual enterprise is a loosely coupled enterprise, which is formed by many partners (whole or parts of real companies) to fulfill a specific mission. The motivation for constructing a virtual enterprise is to enable a group of individual real enterprises to operate more efficiently and effectively as if it is a single global enterprise. As shown in Figure 2.1, Enterprise Integration is an enabling technology for developing a virtual enterprise from isolated enterprises (Hamel, 1993; Warnceke, 1993). It consists of the methodologies and technologies for virtual enterprise design and operation, as well as the enabling information and engineering technologies for supporting the design and operation of the virtual enterprise.

There is an urgent need for more effective, rapid and reusable means of designing and developing enterprises. Indeed over the last decade this line of reasoning has led to the development of an area of study termed 'enterprise integration' in which there has been significant interest worldwide. Studies of the scope of functions to be integrated

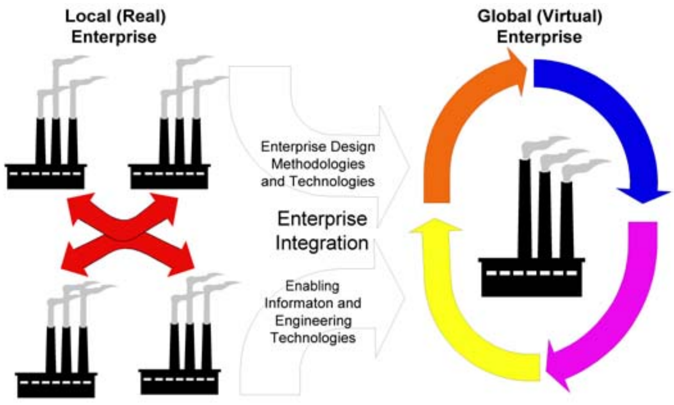

Figure 2.1 Enterprise integration for global manufacturing

(Modified after Bernus et al., 1996)

have been undertaken from the perspective of one function in relation to either one or more other functions. This is exemplified by two studies. The first examines the integration between manufacturing and marketing from the manufacturing function's vantage point (Dong and Whitney, 2001). The other is a study of the relationship among research and development function, marketing and manufacturing (Duane &

Deepa, 2002). Researchers have contributed by studying functional dyads such as the marketing function's collaboration with the R&D function and vice versa (Ragatz Handfield & Petersen 2002). Product development has been studied, as it requires cross-functional involvement (Duane & Deepa, 2002). These studies have attempted to show the relative importance of integrating combinations of functions. The studies demonstrate that significant benefits can be gained from cross-functional integration, in terms of reductions in product development times (Duane & Deepa, 2002), higher profits (Dong and Whitney, 2001), successful marketing programmes (Millson & Wilemon, 2002), better relationships with customers and suppliers and being better able to respond to industry changes. The integration of strategic business units involves the co-ordination of separate elements of each business unit so that efficiencies or market prominence can be achieved (Fuchs et al., 2000).

The literature shows that there is a conceptual framework missing that links the array of options to the purpose of the enterprise integration initiative. Product development is complicated by its dependence on many different types of expertise, which in most organizations reside in different departments, both inside and outside of engineering. Such a framework would enable managers to make decisions about structuring, managing, and implementing enterprise integration initiatives and allocating resources. Without some guidelines, senior managers are left to attempt a trial-and-error approach to enterprise integration. It is perhaps not surprising, therefore, that researchers conclude that enterprise integration remains a key capability where there seems to be very little connection between practice and theory (Chikan, 2001). A new type of business model with characteristics of reconfigurability, reusability and scalability (Dove, 1995) therefore needs to be developed. Such a model will allow flexibility not only in producing a variety of parts, but also in changing the system itself.

2.1.2 Emergence of Mass Customisation

The conventional mass-production firm is often typified as bureaucratic and hierarchical, where workers under close supervision fulfil narrowly defined, repetitive tasks, resulting in low-cost, standardized products and services (Pine, 1993) as shown in Figure 2.2. Under this mass production system, consumers are expected to accept standardized products. This acceptance by customers facilitates expansion of the market and price compression through leveraging on the economies of scale.

For more than a decade, with the emergence of the information age, intensified competition, and increasingly segmented markets, more attention has been given to

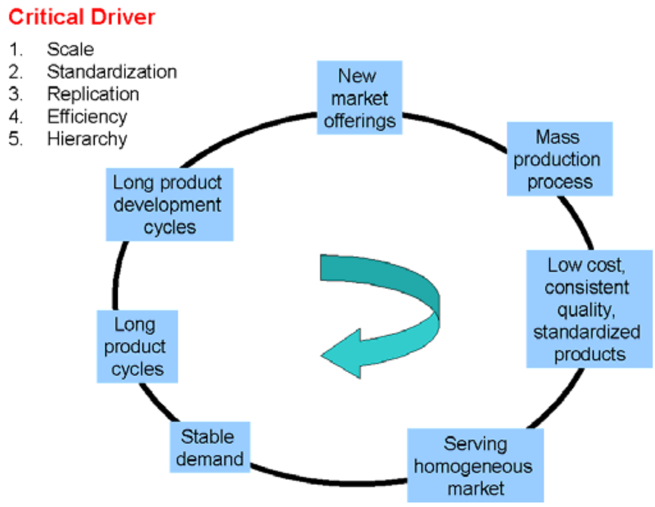

Figure 2.2 Characteristics of the mass production market

(Modified After Pine, 1993)

discussion on customizing goods and services, which in turn leads to a breakdown of the stable mass market (Wheelwright & Clark, 1992). The fragmentation of the mass market is an ongoing, inexorable trend. The individual customer's wants and needs are more and more prone to changes and shifts. In 1991, Majchrzak et al. (2000) suggested that consumer acceptance of computer technology was becoming so commonplace that the public would come to expect it to help satisfy individuals' wants. In 1998, Huang and Kusiak (1998) highlighted the increasing fragmentation of markets due to the individual selectivity of consumers.

Mass-market breakdown has been further abetted by technology (Wheelwright & Clark, 1992). Product life cycles have become shorter and shorter, while keeping up with technological change has become increasingly difficult for both manufacturers and customers. Faced with these new market realities, mass production, being the dominant business model in many industries for the past hundred years, is now challenged by the emerging paradigm - mass customisation (Colin, 2002). Historical change in production mode is shown in Figure 2.3.

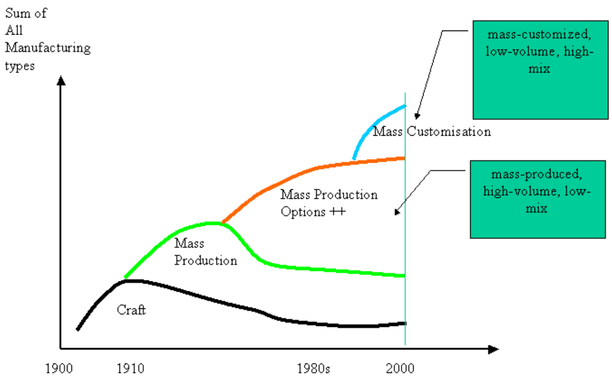

Figure 2.3 Historical change in production mode (From Colin, 2002)

The notion of mass customisation dates back to 1970 when it was first predicted by Alvin Toffler (1970) in his paper Future Shock. In 1987, Stan Davis (1987) used it to describe a trend towards the production and distribution of individually customized goods and services for a mass market. As such, mass customisation is related to the term "flexible production" as was used by Eastwood (1996). The concept of mass customisation was first fully expounded by Pine (1993), based on a survey of US firms, and elaborated by him and by others in a series of articles in the *Harvard Business Review* (Gilmore & Pine, 1997; Pine & Gilmore, 1997). They assessed the reaction to market turbulence as an indicator of the potential benefits of using mass customisation as a competitive strategy. Pine (1993) avowed that the established industrial paradigm of mass production was under challenge by a new one focusing on meeting customers' specific needs. With innovations in technology, mass customisation now makes it possible that consumers may acquire their individually specified products manufactured under the same efficiencies as that of a mass production environment, as shown in Figure 2.4. These papers all suggest that mass customisation in some sense, would inevitably be a successor to mass production historically, and would be the prime way manufacturers are to compete in the future.

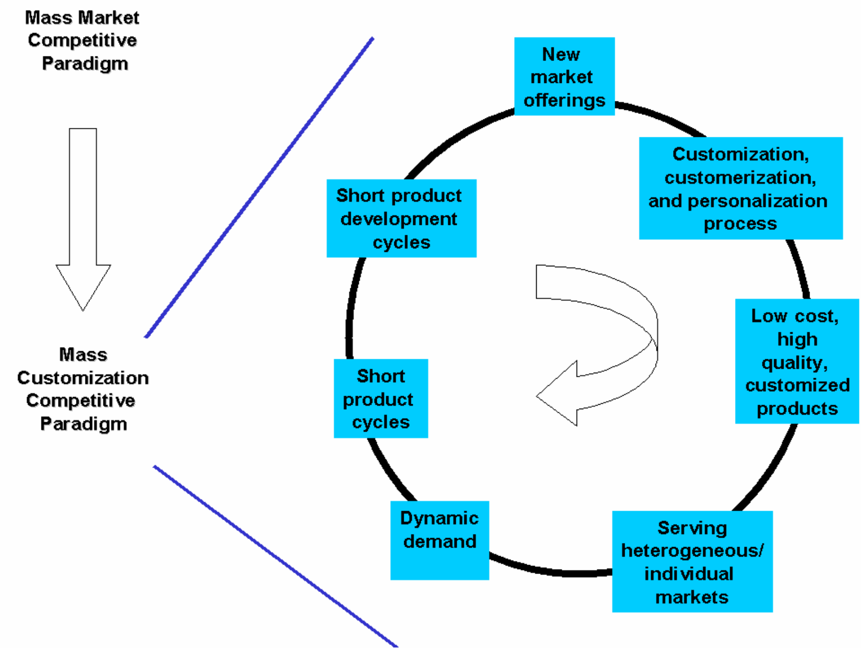

Figure 2.4 Characteristics of a mass customisation market

Pine and Gilmore, (1997) identify five progressive stages that firms can use to move from a mass production system producing standardized goods and services towards a mass customizing system, beginning with those methods which are the easiest to implement. As companies adopt broader and deeper customizing techniques, customers would receive more individualized products. In the first stage, services related to existing standardized products can be customized, such as allowing a product to take on additional features for an individual customer. Then, services or products which customers could themselves individualize could be mass produced. By the fifth stage, which marks the final stage of mass customisation, Pine foresees the use of modular components that could be assembled into different versions of products. Custom configuration of pre-designed components will minimize production costs and maximize customisation by yielding a wide variety of completed products. Economies of scale would be gained in the production of individual components, and economies of scope are achieved by the variety in end products.

Mass customisation leverages economies of scale that the businesses in the industrial age enjoyed, but at the same time, seeks to produce goods and services uniquely tailored to the needs and wants of individuals who buy them. This is shown in Figure 2.5.

Huang and Kusiak (1998) developed a methodology for determining modular products while taking into consideration the cost and performance. The modular approach promises the benefits of high volume production (by producing standard modules) while at the same time, is able to produce a wide variety of products that could be customized to individual customers. To interpret various types of modularity such as component-swapping, component-sharing, and bus modularity, a graphical representation of the product modularity was presented while the module

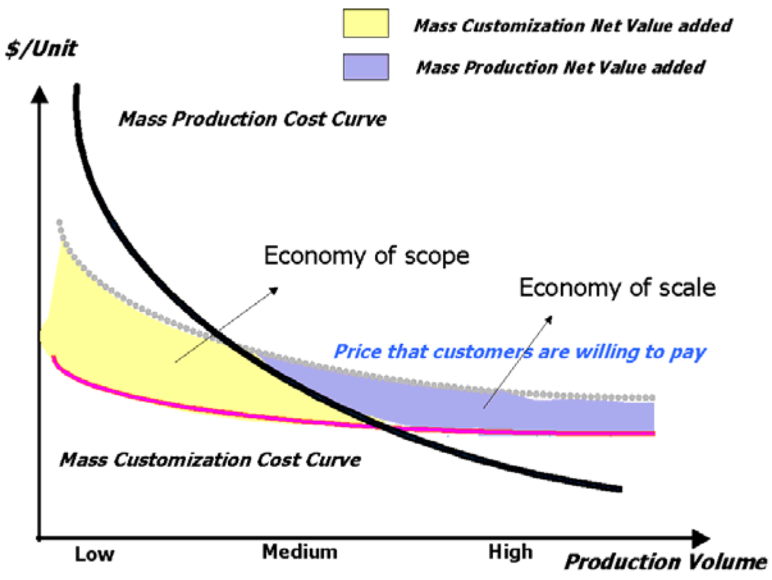

Figure 2.5 Mass customisation: economic implications

(From Jiao and Tseng, 1999)

presented of a product set are determined using a heuristic approach. With the module components known, a rule-based fuzzy representation of the module development problem is presented while the trade-off between performance and module cost is analysed using a fuzzy neural network approach. The approach is illustrated with an example of a multi-chip module.

Huang and Kusiak (1998) apply the concept of modularity to the development of modular products and product testing using modular tests. They developed the models and solution approaches to the modularity problem for mechanical, electrical and mixed process products like electro-mechanical products. They further present a module-based design approach to mechatronic products with consideration of performance criteria such as testability of electronic subsystems (Kusiak and Huang, 1996). The relationship between the design of modular products and testability, and the testing of products using modular tests are explored.

Kusiak and Huang (1996) also study the impact of modular product designs on the performance of manufacturing systems. The measurement of the performance of these product designs in transparent product of development was based on a summary span of corresponding aggregate schedule of the manufacturing system. In the case of assembly design, Boothoyd (1987) suggests the use of the minimum part count rule. Simplification of the product structure can lead to substantial savings in the cost of assembling parts. After examining some specific cases where problems have arisen from the application of the minimum part count rule, Harlou (2001) opposes rigid adherence to this rule. In several instances, the large part count facilitated significantly simpler part fabrication as well as simpler assembly operations. They suggest that the implications of design for manufacturing process rules should be examined in a broad context.

Mass customization offers numerous opportunities and advantages for both producers and consumers. The strategy of mass customization cannot, however, be followed blindly. A number of companies have already run into problems while trying to make the leap to mass customization (Pine, 1993). One example was that of Nissan, which reportedly had 87 different varieties of steering wheels, most of which were great engineering feats. But customers did not want many of them and disliked having to choose from so many options. The need for dialogue between manufacturing and marketing is crucial, especially given the often conflicting perspectives taken by these two functions (Enfield, 2000). The link between internal and external flexibility (Mortensen, 2000) needs to be strong; otherwise the mass customization offering is likely to be inadequate in market terms or too costly in operational terms.

Toyota experienced problems when they invested heavily in robots and instituted measures which deprived employees of opportunities to learn and think about processes and thus reduced their ability to improve them. Amdahl did not achieve its goal of delivering a custom-built mainframe within a week. It stocked inventory for every possible combination that customers could order and was saddled with hundreds of millions of dollars in excess inventory. Those papers have presented an overview of modular product development. However, there is not sufficient attention given in the literature to the actual implementation of mass customisation. The development of a strategy for optimally integrating different development parties is crucial and needs to be studied in the future.

2.1.3 Importance of Agile Product Development

The development and introduction of new products continues to be of critical importance to all companies, both consumer and business market-oriented (Lee and Choy, 1998). Indeed, product development has been labelled "the lifeblood"; that sustains and ensures the continuing survival of an organization (Haque et al., 2000). Most of the research (Christopher, M., 2000) assumes identical firms with only different service speeds (capacities), and found that the firm with a higher speed can usually charge a price premium and take a larger market share. In addition, it is found that the firm with the higher value of services and lower cost of waiting can also earn a price premium and a larger market share. Time-based firms compete by satisfying customers' needs as soon as possible. Successful time-based firms, as noted by Stalk and Hout (1990), provide more services and product varieties in shorter delivery times at lower costs. They can generally charge a higher price and capture a larger market share when compared to similar firms that compete on traditional, non-time-based strategies. Such time-based competition is specially important to Make-To-Order (MTO) firms, which start to work on an order only after the order is placed and all prior orders have been produced (if the first-in-first-out discipline is in place). MTO firms that can shorten the intrinsic lead time between the placement of an order and the receipt of goods or services by customers may enjoy a larger market share, a higher revenue, and a better chance of survival.

Research conducted by Booz, Allen and Hamilton (1982) is one of the most cited comprehensive researches in the NPD subject area. Booz, Allen and Hamilton have been conducting comprehensive research of the NPD process at Fortune companies, both in the U.S.A, and internationally since the 1950s. Their generalist research introduced several concepts including the “product-life cycle”, and the new product idea of a “mortality curve”. Although different results are reported in different articles about how many new products fail - ranging from 10% to 90% - Booz, Allan and Hamilton are reporting that more than 40% of new products fail. Managers cite improvement of the processes for developing new products as one of their organization’s top priorities (Day, G. S., 1994). However, the diversity, variety and complexity of new product introduction (NPI) have grown from ‘very simple’ to ‘very complex’ over the past few years. Goldman et al. (1995) iidentify the following target areas for strategic initiatives by the product introduction project management in order that this complexity may be minimized as much as possible:

(i) Market: There should be a clear definition of the key attributes of the competitive strategy for the product, within which all development should be attempted without aiming at perfection. The focus should be on incremental improvements in the product line.

(ii) Organization: All functions in the development should be treated as being of equal importance and there should be adequate communication within and between different functional teams with suitable conflict resolution mechanisms.

(iii) Vendors: Vendors should be involved from the beginning in the product development.

(iv) Technology: Technological information about new developments should be available to the product designers, manufacturing and marketing teams through free flow of such information and through interaction between the teams.

At the same time, the time-to market dimension has shrunk o. Achieving an efficient and effective product development process is not easy. Cross (2000) stated that agility enables enterprises to thrive in an environment of continuous and unanticipated change. Agility is an overall strategy focused on interactive producer-customer relationships (Goranson, 1999). What is also becoming clear is that further requirements on high variety and rapid product development are gradually being superimposed on the older requirements. For instance, the complex product markets will demand an ability to quickly deliver a high variety of customized products worldwide (Malone et al., 1999). Agile product development is critical to a company's survival today. Any company which can manage well the complex product development process and is responsive to continuous changes will be able to become a winner in today's competitive-driven market.

2.2 Various Approaches to Agile Product Development

2.2.1 Approaches for Time-to-Market

As competition intensifies, the emerging global giants are accelerating the pace of change and introducing a proliferation of niche models with ever-shortening product lifecycles. In 1985, when a new central processing unit (CPU) was introduced, it was quite innovative – but was nowhere close to today's standard in complexity. Every 18 months thereafter, a new CPU, twice as complex, was introduced at twice its performance but at roughly half the price. In 1988, a four-times-as-complex and four-times-as-fast CPU was introduced at a quarter of the previous price within a 12 month period. In 1990s, the development cycle for a new CPU (16 times faster) was only six months with price at nearly one-sixteenth of its 1985 price. The CPU example is a case in point illustrating the fast changing environment that companies are facing today. There are many other similar examples. The changing market conditions (such as the global manufacturing landscape, world economies and new innovations) and international competition are making the time-to-market a prime target for shortening. Whether making to order or making to stock, manufacturers are continually searching for ways to reduce the cycle times of their products. Verespej (2001) reports that Nissan will be able to build and deliver a custom ordered van or SUV within two weeks and General Motors wants to cut its cycle times from around 50 days to ten. According to Verespej, consumers in the USA have more than 50 brands and 200 models from which to choose. In this environment, how can companies achieve and sustain their competitive advantages? Short time-to-market is the answer. This means that a product can reach the market early, which in turn provides the corporate organization with an opportunity to enter the market during the growth phase of the product life-cycle when the profit margins and potential for growth are higher and the product has a longer remaining market life. Sherman et al., (2000) enumerates some of the advantages of achieving the objective as:

(i) Reduced time-to-market implies reduced product development time, which in turn reduces the development costs since fewer funds would be needed for late engineering changes, reworking and delays due to bureaucratic tarries.

(ii) The design related cost reductions are applied early in the development cycle.

(iii) As a consequence of being the first to introduce the product into the market, the company can be assured of a higher market share and better confidence in distribution and retail networking. This in turn increases the life-cycle of the product. Figure 2.6 compares the life cycles of products with normal and reduced development times. To manufacturers, the evidence leads to a worrying conclusion: saturation and homogeneity in the market means that brand loyalty is weakening.

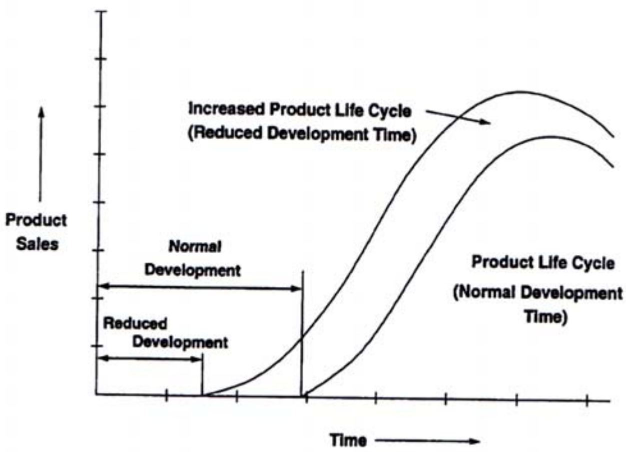

Figure 2.6 Product life-cycle curves with normal and faster time-to-market
(From Harrison et al, 2000)

(iv) Typical product delays frequently seen in new product development are reduced because of the compression of product development time. For example, competitors are quick in enhancing product features or predicating the price at the product maturity stage. Delays are mostly due to unforeseen changes in the market which necessitate changes in design or development team members and thus render a loss in the competence of the design team.

Apart from having the benefit of shrinking the product development lead time, work conducted by Smith and Reinertsen (1992) shows also the impact on the before-tax profits of different product delivery scenarios. In their work, a six months' delay in product introduction had roughly the same negative before tax profits impact as a 50% increase in development cost. The six months' delay also had a significantly greater impact than 10% higher product cost and 10% lost sales volume (Figure 2.7). Also playing a role here is the shrinking product lives of many consumer products. Figure 2.8 illustrates the sales envelope of Hewlett Packard products from 1979 to 1988 (Hennessy and Patterson, 1990). In the figure, the sales decreased by 50%. This indicates that the average life of a product in the marketplace had been roughly cut in half. Significant loss in profitability and shortened product lives together place a burden on delivering products to the marketplace on time.

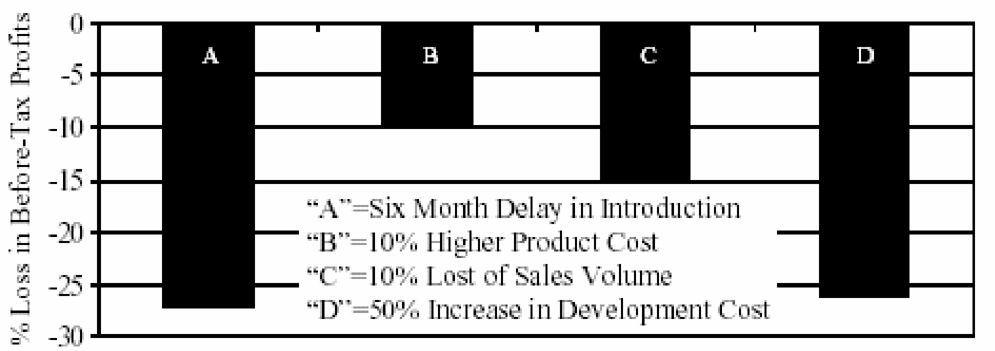

Figure 2.7 Sensitivity of Profits over Product Life (From Smith and Reinertsen, 1992)

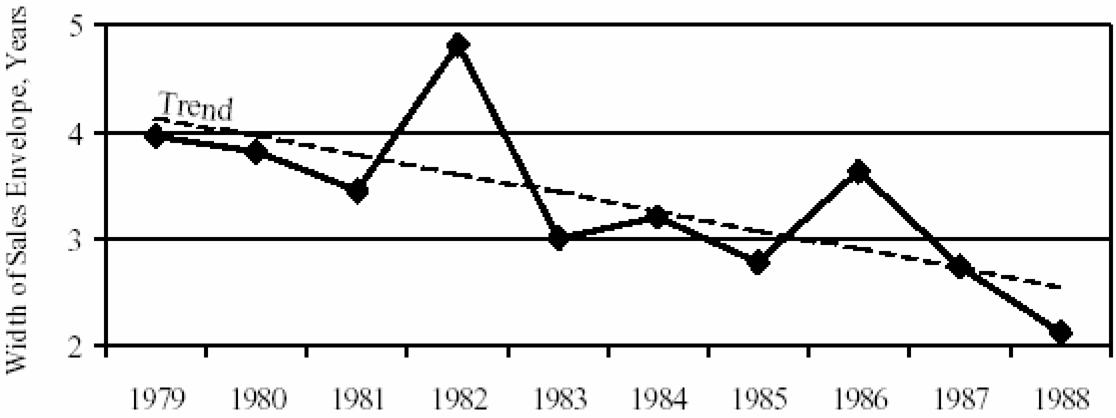

Figure 2.8 HP Sales Window by Vintage Year (From Hennessy and Patterson, 1990)

2.2.2 Reaction to Voice of Customers

According to Sherman et al.'s (2000) findings, a clear definition of the key attributes is the foremost issue to be addressed. It has been reported Hales (1994) that 70 percent of the total cost of manufacturing a product is committed by the time of conceptual formulation. It rises rapidly to 85 percent at the start of development time before any hardware is built (O'Gruin, 1990). Most people in many companies do not realize this fact. They start too late looking for the source of the problems and end up spending too much time and money in "fixing" the problems. From the cost perspective, the analysis usually is even coarser because of the complexity and uncertainty in cost estimation before actual production starts. Hence, the early determination of good alternatives, which can satisfy the performance attributes at a reasonable cost, is crucial in building products.

Cooper (1999) finds that in 74% of projects the detailed market study is graded as deficient – either done poorly or not at all. Initial screening is rated as the weakest part in the overall process, scoring lowest on the proficiency scale. Responding and listening to customer's needs is often cited as a very important part of successful product development. In an annual survey (Mason, 2003), seventy percent of the respondents listed customer needs as the primary focus of NPD strategies. After that, the next-closest factor cited was low product cost (only 13%), then followed by innovative features (11%), and then first to market (5%). This study confirms the need for effective communication with the customers. Enhancing the preciseness of product definition is a subject that has attracted much research interest in various disciplines.

Quality Function Deployment (QFD) has been recognized as an effective method for product and process development. It is a structured approach for integrating the voice of the customer into the product design or development process (Usher et al., 1998). It originated in a Japanese company called Mitsubishi, Heavy Industries Limited, in 1972, as an advanced quality system made up of an integrated set of quality tools and techniques to provide customer-driven products and services (Wang, 1997). It is considered good practice to focus on producing the products with the “needed” quality requirements suggested by customers, thus saving cost by avoiding the creation of “unwanted” product features or “over-design” (Lockamy & Khurana, 1995; Cohen 1995; Vonderembse & Fossen, 1998). It enables an organization to measure customer “wants” and map them against the engineering “how” in a way that highlights tradeoffs and drives the product’s design towards customer requirements.

In normal practice, a matrix is used to relate the variables associated with one “design phase” to the variables associated with the subsequent “design phase” and this matrix is called a “House of Quality” (HOQ). The details related to the formulation of the HOQ are covered in a number of publications (Harding et al., 1999; Zairi & Youssef, 1995). The HOQ matrix comprises score points related to various inter-relationships of different elements, thereby providing a picture of the importance and weightings of relevant factors.

Although QFD was developed to assist in analyzing the “voice of the customers” to support the specification process, it is handicapped when it is put into actual practice as the QFD process is still largely manually based. As activities involved are becoming more complex, it becomes more and more difficult to manage (Harding et al., 1999). QFD is basically deployed to generate a general view out of a lot of specific data. It does not emphasize details. Equally important is to ensure that enough time is allowed for the process and that the correct resources are available. In QFD, it becomes more difficult to change direction once a development project is underway because all of the interrelated elements of the system must be revised – one by one (Wang, 1997). QFD tools are limited regarding the types of information they can “code”. For example, the House of Quality (HOQ) permits using only a limited number of quantitative or qualitative values as inputs for evaluations or correlations. The ability of QFD tools to capture and communicate design rationale is limited when used in an asynchronous manner, whether for communication among members of the current project or for disseminating information into the organization for future reuse (Reich, 1996).

The marketplace recognizes only results and is insensitive to efforts. Among the features present, customers appreciate only what they find useful in the products; they do not care how they get there (Kidd, 1998). The reality is that if the products manufactured do not meet the market needs, demand declines and profits shrink. As the market changes, associated with this are the urgencies and pressures on the manufacturers to modify their product characteristics according to the latest requirements while the product is still being developed (Gunasekaran, 1998). This has a chilling effect on managing the complexity of such continuously varying product specifications and on handling the ongoing changes (Lee and Lau, 1999).

2.2.3 Process-based Approaches

Some researchers paid considerable attention to understanding the process of product development. Cooper and Kleinschmidt (1986) use a model of 13 sequential activities. They found that only 1.9 percent of the manufacturing firms studied used all 13 activities in the product development process, and most used just 8 or 9 activities. Rochford and Rudelius (1992) discovered similar results using a 12 activities model. Mahajan and Wind (1992) find that even a model limited to 10 activities did not accurately reflect the process followed in industry. Though these models may accurately describe the traditional product development process, the general sequential models focus on broadly defined process stages. Since the application of the models will minimize the interaction between departments, some critical departments may offer feedback only in a late stage of the product development process. Some important considerations may then be omitted from the process. These may lead to the losing of market opportunities, or difficulties in designing products that require major revision late in the development stage.

Sequential models have several limitations in that they omit the critical parts needed to address the vicissitudes of a continuously changing marketplace. This step-by-step approach is generally inflexible and it is difficult for it to accommodate any unexpected changes such as changes in certain product features so as to suit the market demand due to the lack of information sharing between departments. In particular, the lack of a universally accepted schema for information interchange among various functional divisions makes the situation even more serious when it comes to lead-time control and communication of various design activities (Lau and Jiang, 1998). However, in today's market where competition on "time-to-market" is particularly keen, the key to success is to minimize the time between product concept and product realization. Obviously, sequential models provide no means for efficient communication and offer no working mechanism to move backward as well as forward in the design and development process. The traditional sequential approach is not competitive in this market environment.

Due to the aforementioned limitations, many authors view sequential processes as obsolete and see industrial product development shifting toward a parallel or concurrent product development process model (Swink *et al.*, 1996). Concurrent involvement of product and process engineering on a cross-function product development team shortens the lead-time and improves the product performance and quality. Numbers of techniques and approaches have been suggested in the form of multi-disciplinary functional division involvement (Adler *et al*, 1996; Weatherill *et al*, 1999), requiring a special project team with the involvement of top management. Suggestions of a more responsive product development strategy, such as the team approach (Wolff, 1992; Ranney and Deck, 1995; Pena-Mora *et al*, 2000) and cross-functional co-operation (Shunk, 1992; Kelsey, 1995; Yan, 1999), have also been raised and published in a number of articles. Vokurka, and Fliedner (1998) identified the interface between R&D and marketing as critical to developing and introducing innovative products. Walker *et al* (1987) investigate the level of interaction between marketing and manufacturing, marketing and R&D, marketing and accounting. They conclude that higher levels of interaction lead to greater sharing in decision making. This will lead to effective cross-functional product development effort. Most of these proposals are concerned with the strategic approach, emphasizing concurrent engineering concepts that involve a united project group with the participation of senior management down to shop floor workers.

Erhorn and Stark (1994) model an integrated approach, where product development occurs simultaneously in multiple departments and product improvements are accomplished without hindering the process. This is shown in Figure 2.9. According to the authors, use of this model facilitates product innovation, cost management, meeting quality requirements and a shortened product development cycle. Barclay et al. (1995) also emphasize the importance of an integrated approach in discussing their wedge shaped concurrent product development model. It incorporates multiple new product options, which are narrowed into a single new product concept through a series of decision points. However, these models do not provide solutions for firms which outsource production, thus replacing the manufacturing function with sourcing as the private brand product development.

2.3 Business Process Management

The collaborative product development approach demands a multidisciplinary approach and organizations need to draw together representatives from all areas of the enterprise and also include the suppliers who are outside the enterprise. Some research has therefore been done to study ways to facilitate remote collaboration. For example, FLECSE (Flexible Environment for Collaborative Software Engineering) is a multimedia environment designed to facilitate the communication between two or more geographically dispersed software engineers (Maznevski and Chudoba, 2000). With the advent of complex, multidisciplinary, multi-site design processes, a need for managing the complicated design process emerges. The discipline of business process management (BPM) aims to develop new services that would help designers

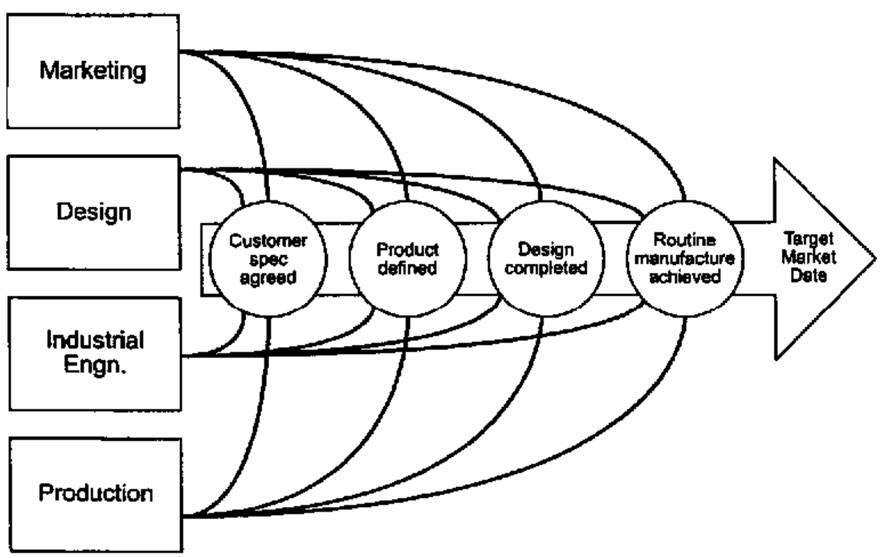

Figure 2.9 Erhorn and Stark's integrated process model (From Erhorn and Stark, 1994)

handle more complex design problems, and would facilitate effective coordination in distributed, concurrent, design teams. According to Harrington (1991), design process management covers a broad range of areas, including problem solving support, developing product and process, customer order fulfillment and so on. These macro-processes can be further disaggregated into sub-processes, activities and tasks. Understanding a company's organization by its business processes and not simply by its functional hierarchy is a very important concept in operations management (McDonough et al., 2001).

Creating a BPM approach requires carefully modelling business processes. Through business process modelling, it is possible to map activities and their interrelationships, resources and organizational units responsible for the activities, as well as the flow of information through operational and supporting processes of the internal value added chain. According to Majchrzak et al, (2000), modelling techniques should be able to represent: what should be done; when it should be done; who is responsible for the activities; and what the input and output data are. In 1996, Jacome and Director (1996) created design process formalism, which was refined by Lukas and Ferrell, (2000). This formalism provided the basic constructs used to model their Design Process Management (DPM) approach. Jacome and Director (1996) created a prototype DPM tool called Minerva that embodied her formalism. This prototype is intended to be a proof-of-concept tool, which did not provide a practical working solution. Similarly, Sutton created a new DPM tool called Minerva II that embodied his refined formalism.

Designers interact with the Minerva II manager to formulate and solve design problems by following the problem solving cycle (Figure 2.10). Designers may select any problem that is ready to be solved at any time, and then solve it with Minerva II's support. If the problem seems too complex to be addressed directly, it may be decomposed into simpler problems (Decomposition). Otherwise, designers can ask Minerva II to generate a sequence of CAD tools (called a plan) suitable for solving the problem. Minerva II consults available CAD frameworks and returns all possible sequences and this is called "plan generation". Designers choose one or more of these sequences and Minerva II executes the chosen sequences and returns a result. If the result is satisfactory, the problem is marked as solved. Otherwise, designers may backtrack or address another problem.

From the perspective of data management, existing DPM tools are helpful in that they systematically record the design history. This information can help the designers to find out the best backtracking points. However, this previous DPM work has not directly answered the problem on trade-off alternatives for management, which was identified in the introduction section. The resulting alternative is always the balance between cost, schedule and quality. Previous DPM work has not overcome this limitation due to the complexity of knowledge required to generate and evaluate these trade-off problems.

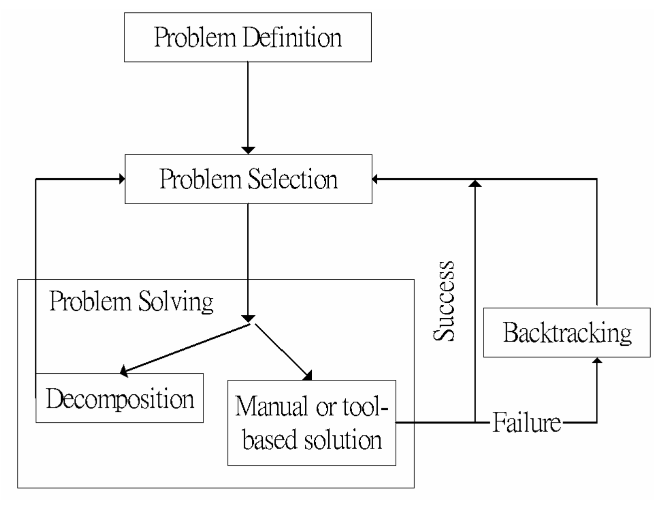

Figure 2.10 Problem solving cycle in the Minerva II design process manager

2.4 Implications from the Literature Review

Whilst there are many publications about applying best practices including Quality Function Deployment and Mass Customization, (Colin, 2002; Sullivan, 2000; Usher et al., 1998; Wang, 1997; Jacome and Director, 1996) there is a lack of literature dealing with interconnecting object technology with best practices in the product development process. In order to increase the company's competitive edge, a Customizable Agile Reconfigurable Design System (CARDS), which provides a systematic schema devised to make product design more agile and responsive to external changes, is proposed in this thesis. Some research activities have been conducted on JIT and TQM with different manufacturing strategies to reach the goal of responsiveness. (Backhouse & Burns, 1999; Vesey, 1992). These have led to an awareness of the importance of agility in an enterprise. But there are a few studies on integrating business practice with automatic information exchange, to optimize the satisfaction of customers. The proposed CARDS, which deploys information technology together with best practices in each module, helps to respond to internal and external change so as to achieve business agility.

CHAPTER 3 SYSTEM SURVEY ANALYSIS REPORT

3.1 Introduction

In this chapter, a survey which explored the current situation of product development will be discussed. We would like to find out which departments are involved in product design and development, what problems are faced by manufacturers and which technologies or tools are used in product development. We hope that we can portray a better picture about the product development issues so that the proposed system in the subsequent chapters can help the players in industry to address the issues.

Survey (Mason, 2003) mentioned in Chapter 2 finds that most of the manufacturers placed needs of customers (70%) as their primary concern in new product development, followed by lower product cost (13%) and innovative features (11%). Our survey will move one step further forward. We do not only wish to understand the manufacturers' concerns, but also wish to understand their problems and practices so we can carry out a deeper investigation into the present situation and suggest ways to overcome the problems they have.

3.2 Survey Methodology

200 questionnaires were sent to selected companies in the field of product design and development. They included software, electronics, watch, domestic products, and telecommunication industries among others. Considerable efforts were made to maximize the survey responses. The length and complexity of the questionnaire were designed to be as minimal as possible yet able to reveal important information. The

survey was conducted through mail and email. These questionnaires were then followed up by personal phone calls to ensure the highest rate of response possible. Out of the 200 questionnaires sent, 97 responses were received. This represents a response rate of 48.5% and is considered as around average.

The data were collected from corporate officers responsible for new product development programs (90% of the respondents were highly experienced). This should give a certain degree of credibility to the data obtained. These corporate officers have a unique perspective on their firms' overall new product development programmes. All respondents had more than three years of experience of being involved in the new product programmes of firms. This criterion was ascertained by a screening question in the questionnaire. In fact, many respondents have many more years working in that field. And in most cases, only the senior corporate officers were asked because they kept most of the corporate information and they probably knew the answer to the survey questions. The questionnaire is shown in Appendix I.

3.3 Result Analysis

The questionnaire contains five parts. The results of the first three parts are presented using bar charts or pie charts. Part four asks about concepts or tools applied in product design and development by the company. In order to have the respondents better understand the techniques mentioned in this survey, the definition of the tools are shown in form of footnotes put on the same page as the questions. To have the results clearly presented, a tree diagram is constructed to show all the possible responses. The corresponding response rates are also presented. Part five is about suggestions and comments, the summarized result is presented followed by discussion.

3.3.1 Department Involved in Product Design and Development

Part 1: Departments involved in product design and development (Allow multiple options)

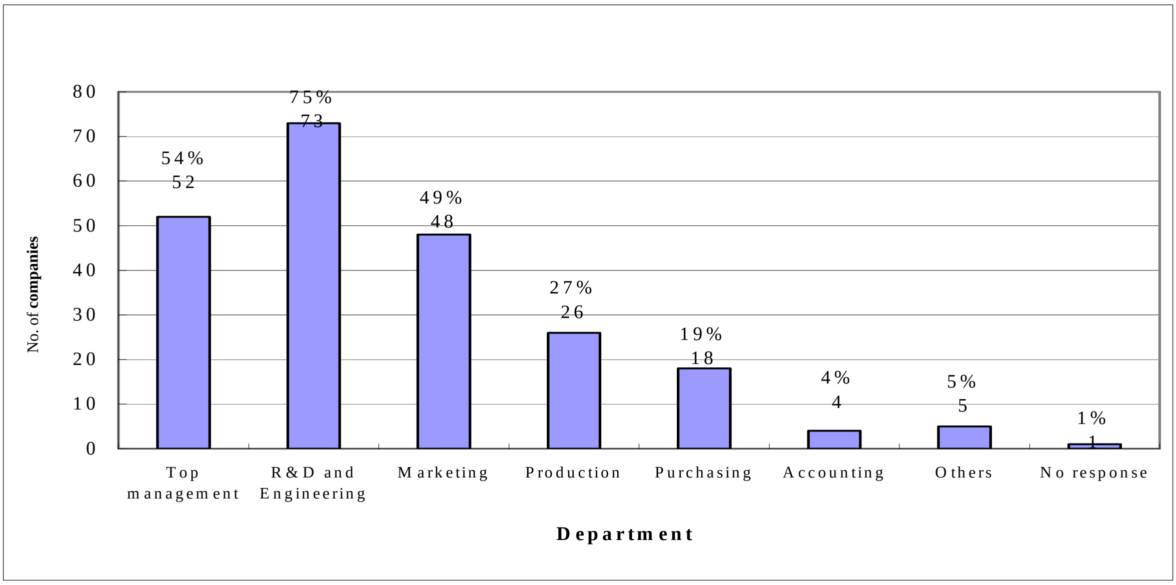

Figure 3.1 Departments involved In Product Design and Development

According to the survey, in three-quarters (75%) of the companies, R&D and engineering department were involved in the product design and development. This is quite natural as the chief function of R&D and engineering department in most companies is to generate new product ideas and features. Many mechanical and electrical experts there are responsible for product designing. About eighty percent of the design and development costs are dependent on the design of the product, and much time is spent in the designing stage in order to take into consideration as many possible aspects as possible so as to arrive at the best design. Managing product design and development is still very much complex and requires further research work.

Around half of the respondents had their top management (54%) and marketing departments (49%) involved in developing new products. This is because the strategic direction and market information provided by them is very important for designing and developing a successful product. The marketing department is involved because it has a closer relationship with the customers and thus the staff have a better understanding of customers' need and requirements. This can help develop products which can satisfy and deliver value to customers.

About one-fourth (27%) of the responding companies had their production department and about one-fifth (19%) of them had their purchasing department involved in product design and development. Production department may be involved. This depends on the nature of the company, which may be customer-focused or technology-focused. The low rate of involvement of the purchasing department may be due to the fact that management may be of the idea that the purchasing department just takes orders from other departments which supply the materials specification. Therefore it may offer little help in product design and development. However, by involving the purchasing department in the early stage of product design, useful information such as the availability of certain materials and parts, part substitutions, part cost estimates and ranges, newly developed parts and materials etc can be known earlier. This can help in the stage of design and product specification, and save time, cost and most importantly lower risks (Venkatraman & Henderson, 1998).

Only four percent of the respondents had their accounting departments involved in the design phase. This is most likely due to that the fact that management usually think that accounting work is not directly related to and thus has little contribution to offer product design and development. However, the finance and accounting department can contribute to economic analysis, good budgeting, and cost and risk estimation so as to determine whether the product is worth developing. Out of the five companies that have inter- departmental teams involved, four of them had their engineering department involved. This shows that the engineering department is a popular candidate for contributing to the product design and development process.

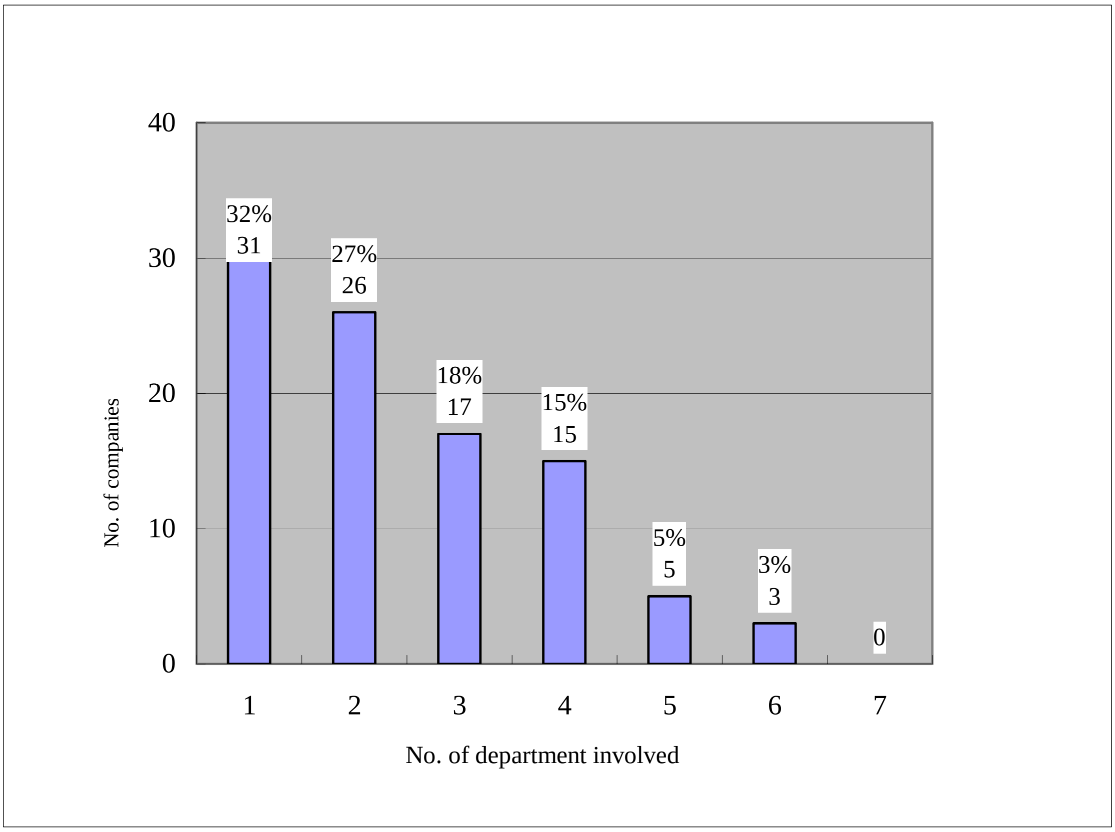

Figure 3.2 Numbers of Departments Involved in Product Design and Development

In general, all the departments can be categorized into two groups. One group includes the core departments that should be involved in product design and development. They are the R&D and engineering department, top management and marketing department. This is reflected in the survey by their high percentages of being involved in product design and development. Another group is the supplementary group, which includes departments that may not be absolutely necessary in product design and development, but their presence and involvement can help make the product design and development better. These are: the production department, purchasing department and accounting departments.. This is also shown in their lower rates of involvement as suggested by the respondents in the survey.

In Figure 3.2, the result of the survey is analysed from a project management perspective. This figure shows the total number of departments in a company involved in product design and development.

It can be seen that more than half (59%) of the companies surveyed had less than three departments involved. Very few companies (less than 8%) had more than five departments involved. The number of departments involved is regarded as very few. Some of the respondents added that they had the intention to involve more departments in product development and design in future because of increasing market competition. Product design takes place in a collaborative environment, through real time interaction with information among engineering and manufacturing teams, suppliers, customers and partners. This new paradigm has lead to tighter integration of data within the company as well as among suppliers, customers and partners (Shridhar & Ravi, 2002). For those companies which are more customer-focused, this trend is more obvious. As the use of cross-functional design teams results in improved communication, project management can become more complex.

Bringing a project to a successful conclusion requires the integration of numerous management functions such as management of technical issues; control of cost, schedule and risk; communication, team-building and conflict resolution; and precise conversion of customer requirements in the product design (New, 1996). In response to this variety of tasks, the systems approach to project management has evolved, aiming to help managers see the intricate nature of a project, and capturing it as a ‘whole’ (Kessler & Chakrabarti, 1999). Unfortunately, however, theory building has not developed at the same pace as practice and the multi-facetted, multivariable nature of modern project management has not been addressed.

3.3.2 Major Problem(s) of Product Design and Development

*Part **2**: Major problem(s) of product design and development from past experience: (Allow multiple opinions)*

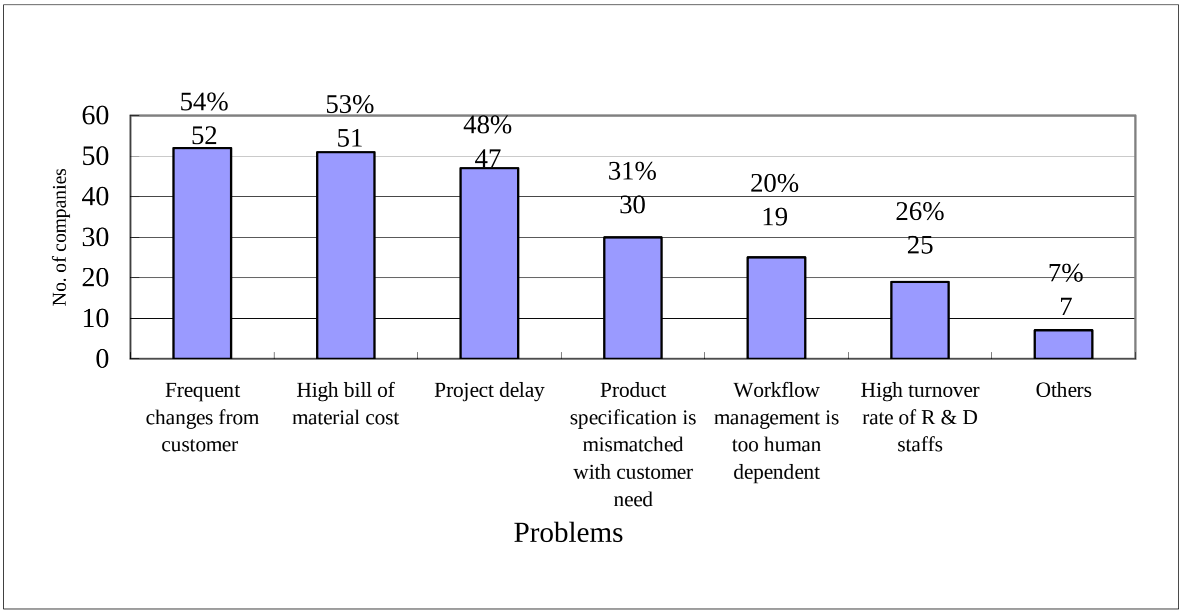

Figure 3.3 Major Problem(s) of Product Design and Development

More than half of the respondents were of the opinion that frequent customer requirement changes (54%) and high bill of material costs (53%) were their major problems in product design and development. Another major problem most commonly faced was project delay (48%). In today's increasingly competitive environment, product development lifecycles are becoming shorter with more built-in product features and functions. Companies are experiencing growing pressure to reduce the development lead-time as much as possible so as to meet market expectations. To complicate the situation further, customers are asking for more varieties of product ranges, which, preferably, can be tailor-made to suit their constantly-changing requirements (Eastwood, 1996; Lukas and Ferrell, 2000). This may account for the result that 31% respondents consider that the product specifications mismatch with the customer needs. It is obvious that a systematic approach is urgently needed in order to define the product properly so as to meet the needs of customers. In general, the earlier a product is launched into the market, the greater the opportunity the company has to gain a better market position. For companies to compete and survive in this competitive environment, it is undoubtedly essential that all functional disciplines within the companies work together concurrently to contribute to the development of products, whether it is the functional or outlook upgrade of an existing product or the design of a completely new product This is reflected in the survey results. This is particularly true in the case of New Product Development (NPD), which is considered as an activity requiring the input and concerted efforts of relevant functional disciplines covering all phases of product development - from conceptual design to actual assembly and marketing of the product.

High bills for material costs are to be expected judging from the results of Part 1, as most companies would not involve their purchasing and production departments in the product design and development process. Since material costs depend heavily on the product design, early involvement of the purchasing department can provide the management with information about the availability of certain materials, the costs and any substitutions etc. This may help determine the most appropriate material costs. Early involvement of the production department can help design a more efficient manufacturing process.

In addition, about one quarter (26%) and one-fifth (20%) respondents considered that workflow management was too manpower dependent and that there was usually a high turnover rate of the R&D staffs. These factors may lead to serious loss if companies cannot handle the problems well. Knowledge has become an important asset of a company. If a company is not aware of this importance and does not allocate resources to develop and retain its own knowledge, it will soon lose its competitiveness. With accumulated knowledge, a development team when starting a new project needs not to start from scratch. The accumulated experience derived from past projects could be reused. After the project completion, the new experience is not only shared within the project team, but also within the whole organisation. Different project teams can learn from the same experience and it thus becomes organisational knowledge. However, without a good system, this is difficult to achieve. When a project is completed, people will focus on the ensuing sales, market share and financial figures. Most often, the valuable experience in product design and development is known only to the project team members and will be lost once the project team is dismissed or its key members resign.

3.3.3 Application of Computer Supported Collaborative Work System

Part 3: System that company used: e.g. MRP for managing material schedule, ERP for managing enterprise resource, Computer Supported Collaborative Work System (CSCWS) for managing product design and development etc.

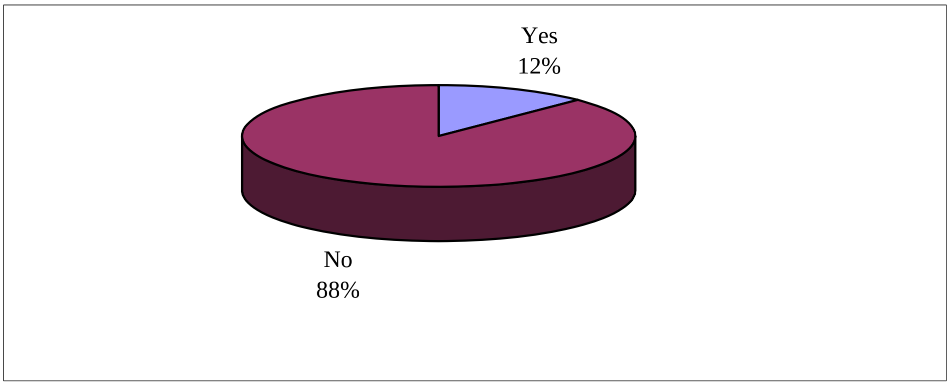

Figure 3.4 Percentage of Companies Applying CSCWS

According to the survey result, the majority (88%) of respondents did not have CSCWS in managing product design and development. The main reasons are that not only is the CSCWS technology a state-of-the-art technology, but also most SMEs cannot afford such a capital intensive investment. That may explain the results of Part 2 in that many companies are not competitive enough and thus meet various difficulties as stated in Part 2.

Basically, NPD is very much about efficient data processing. In particular, it is essential that the information associated with NPD can be shared among various divisions and even be changed efficiently. The experience and knowledge of product design and its related operations and processes is traditionally kept in relevant functional divisions tacitly or explicitly without a systematic product data repository for easy storage and retrieval.

Therefore, it will be advantageous if a low cost and generic integrated system is available to facilitate the concurrent sharing of product design information on the designing processes, costs and resources allocation. In particular, this system is able to provide a perspective and integrated view in relation to various design activities. It can facilitate better cooperation between different departments and integrate traditional applications and platforms so as to better support decision making with better information through easy and immediate access to key relevant product information that comes in from associated data sources, in a distributed manner.

3.3.4 Concepts and Tools Applied in Product Design and Development

Part 4: *Any concepts and tools in product design and development that have been applied in the company. <Allow multiple options>*

This part consists of various questions which allows a deeper understanding of the current business situation in adopting the different concepts or tools. For ease of reading and understanding, a general flow chart is used to present the overall results before we go into detailed discussion.

(i) Concurrent Engineering (CE)

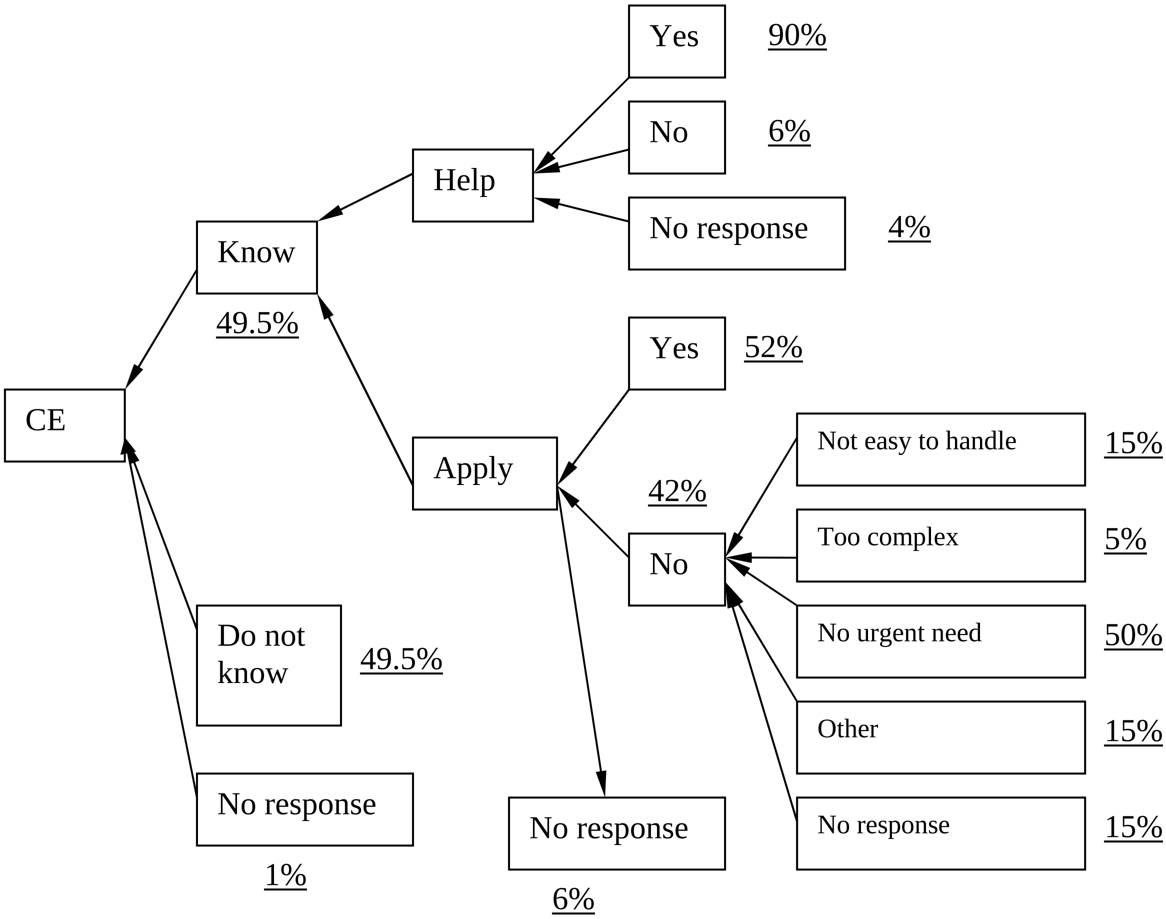

Figure 3.5 Comments towards CE

The survey findings shown in Figure 3.5 indicate that there were equal numbers of respondents who knew (49.5%) and who did not know (49.5%) about Concurrent Engineering. This shows that the concept of CE is not widespread. Among those who know about CE, 90% were of the opinion that CE could be of help in product design and development, whilst 6% of them thought otherwise. These findings are in agreement with the observation of Bal and Teo, (2000) found that CE does have practical uses and can help companies increase their competitiveness by shortening the development and implementation time, lowering costs and raising the overall quality of the end product.

Despite the high percentage of respondents suggesting that it can help, just slightly more than half (52%) of them have applied it in their operation. For those who knew CE, about half of them (42%) did not apply CE in fact. Half of these gave as a reason that there was no urgent need. About one-eighth (15%) said that it was not easy to handle. Few of them (5%) said that CE was too complex to implement, and that they did not have enough knowledge about CE. The respondents further commented that there was no widely accepted process flow or protocol to follow.

(ii) Design For Manufacturing (DFM)

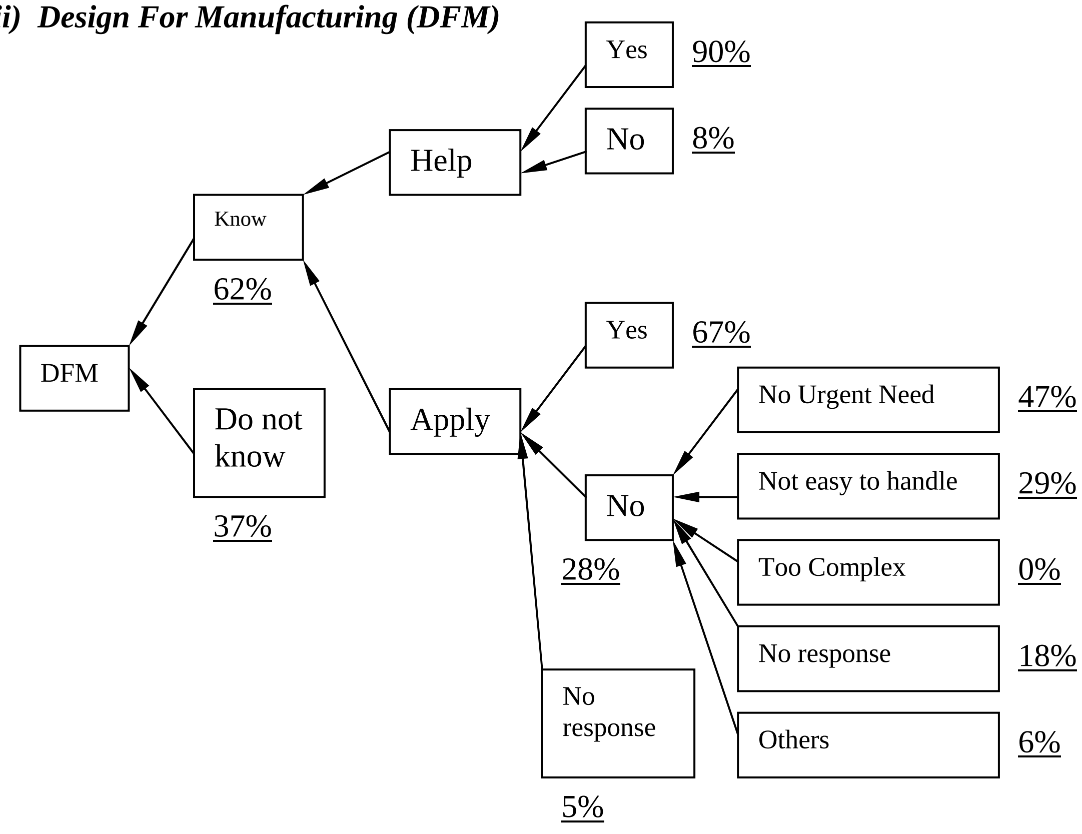

Figure 3.6 Comments towards DFM

According to Figure 3.6, more than 62% of the respondents said that they knew what DFM was, whereas 37% of the respondents said that they had no idea about DFM. Among the positive 62% respondents, most of them (90%) considered DFM to be helpful to the company, while only very few of them (8%) considered DFM as unhelpful. These companies were of the opinion that DFM can improve the quality of design and achieve greater customer satisfaction (Keys, 1990). It can also produce higher product yields in manufacturing. It increases product performance and increases greater predictability of product yields. (Bal & Foster, 1999).

Among those respondents who know DFM, 67% adopted DFM in their companies, while 28% did not. About half (47%) of the respondents who did not apply DFM in their operation claimed that there was a lack of urgent need to implement DFM. On the other hand, about thirty percent (29%) of them said it was not easy to handle the tool. They added that current DFM tools did not have sufficient reference or case studies to follow and the tools were not compatible with their current manufacturing systems. According to the respondents there is also no generic pattern or procedure to help designers using DFM make the correct design decisions. Therefore, this affirmed the opinion that DFM was not easy to handle.

(iii) Design For Manufacturing (DFM)

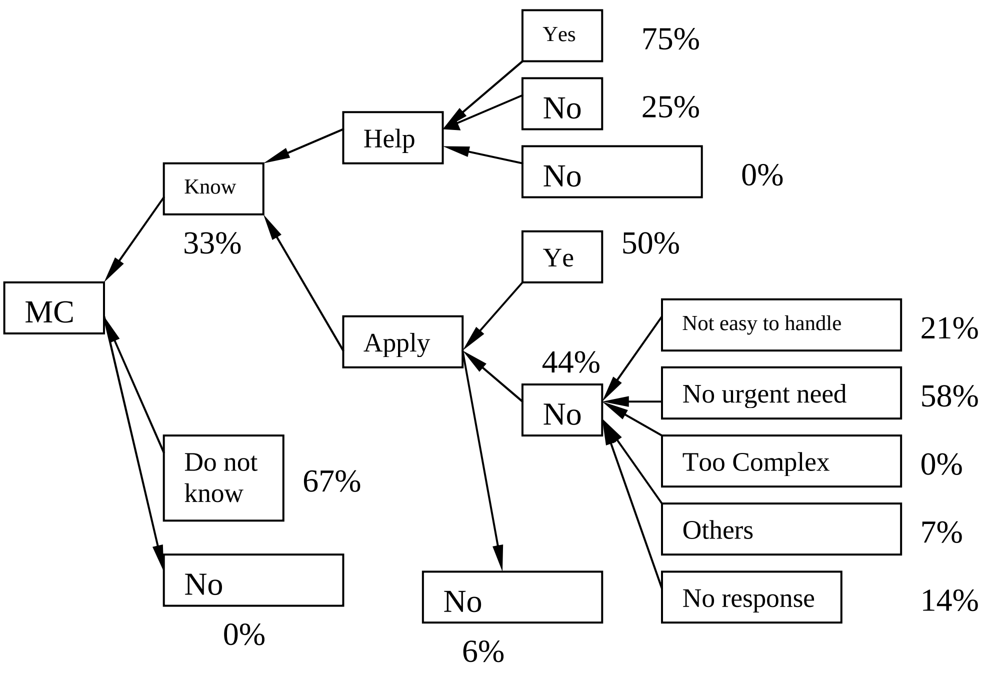

Figure 3.7 Comments towards MC

Referring to Figure 3.7, the survey results indicate that the number of respondents who did not know anything about Mass Customization (67%) is around two times as many as those who do (33%). Among the ones who knew about MC, half of them applied MC in their companies. In addition, most of the respondents (75%) who knew MC thought that was helpful to their product design and development process. Nearly half of the respondents (44%) who knew MC did not apply it in their companies. The reason was that about a quarter of (21%) of them considered that the tool was not easy to handle and more than half (58%) of them considered there was no urgent need for it.

(iv) Quality Function Deployment (QFD)

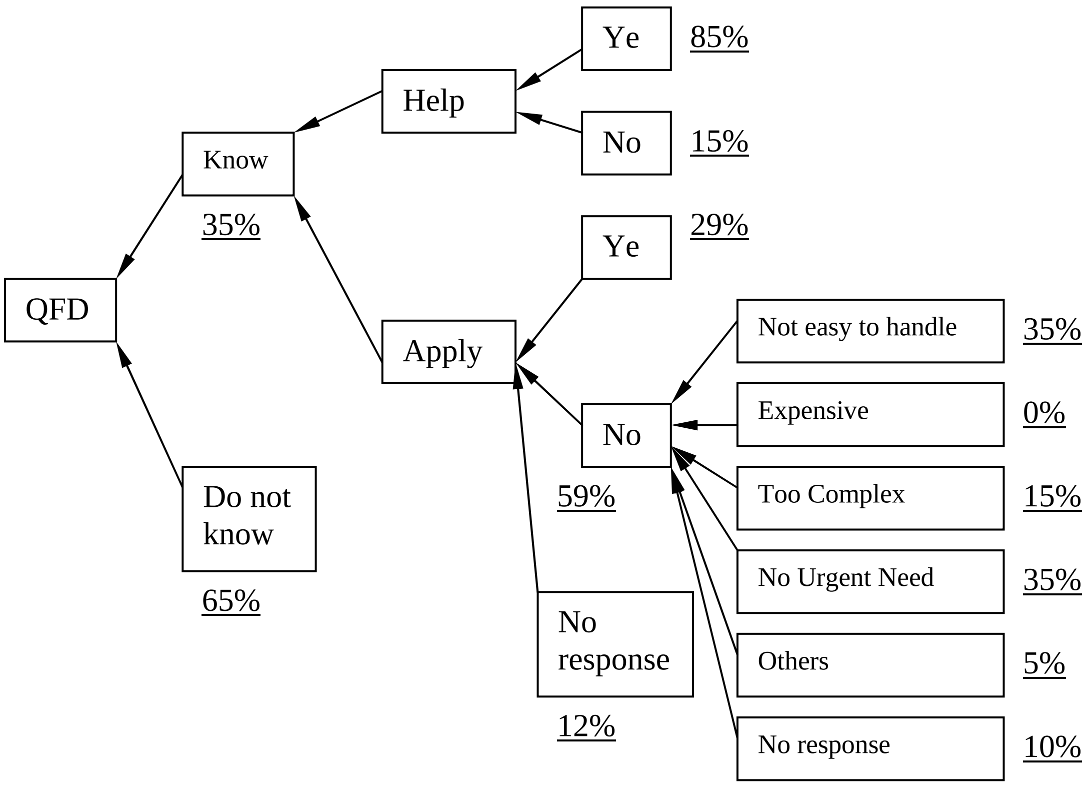

Figure 3.8 Comments on QFD

From Figure 3.8, 35% of the respondents knew what QFD was, whereas 65% of the respondents did not. The majority of (85%) the respondents who knew QFD view that QFD was helpful to the company, whereas only 15% of these respondents thought otherwise.

Not many companies applied QFD in their operation. Among those 35% respondents who knew QFD, only 29% of them applied QFD, whilst 59% did not. There are various reasons to explain why companies did not apply QFD. Among them, 35% claimed that the tool was not easy to handle and 35% of them said that they had no urgent need to use QFD in their operation. The respondents elaborated that gathering data from all external and internal parties was difficult because most people were reluctant to expose their professional secrets. In addition, not all data were well documented for QFD to further make use of. Even though the QFD matrices could be altered and tailored to fit a wide variety of projects, not every design would need the rigors of the QFD process. Furthermore, 15% of them pointed out that QFD was too complex to use. It seems that respondents did not understand the importance of the voice of customers (VOC) and did not get enough clear collaboration across various functions during the early VOC work. They focused too much on "the product" instead of "the customer".

Many companies did not adopt QFD because the technology was too difficult to handle. Any attempt to get instant results will probably result in failure (Adler et al., 1996). Other QFD mistakes most frequently committed by organizations include: making charts that are too big; mixing engineering demands with customer demands; completing QFD too late so that no changes can be implemented; and no buying-in for QFD suggested changes (Stalk & Hout, 1990).

(v) Activity Based Costing (ABC)

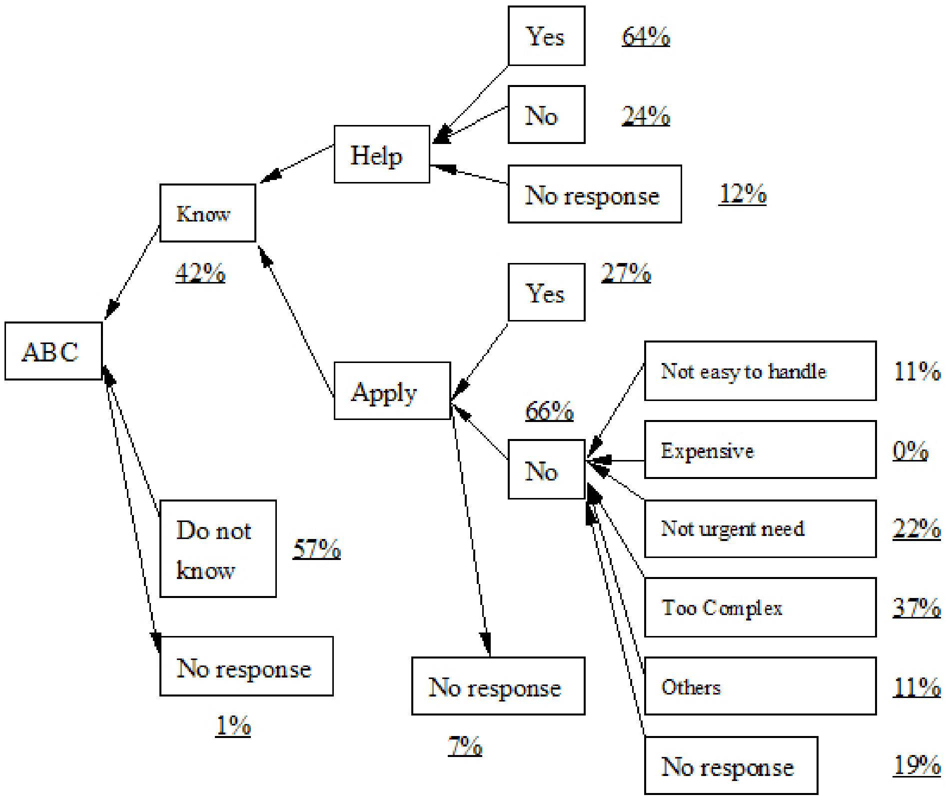

Figure 3.9 Comments on ABC

From Figure 3.9, it can be seen that close to half of the respondents (42%) knew what ABC was. It seems that the concept of ABC is quite popular. Most of the respondents (64%) who know about ABC agreed that ABC was helpful to product design and development in their companies. Twenty seven percent (27%) of those respondents who had knowledge about ABC, had adopted the technology. These respondents reported that ABC enabled them to pinpoint the sources of indirect costs and allocate the costs precisely to specific activities rather than "peanut butter" them evenly across all products or departments in a company.

Of the sixty six percent (66%) of those who knew about ABC, most did not apply ABC in their operation. This was because they thought that ABC was too complex (37%), there was no urgent need (22%) or the tool was not easy to handle (11%).

Respondents revealed that they had difficulties in making significant changes to the accounting systems for ABC. The reason (Needy *et al.*, 2000) was that any change in accounting also implied changes in both informal or formal organizational structures and in power structures. It is understandable that management accounting has faced the strongest and most vociferous challenges ever, calling for its transformation. The profession needs to embrace new initiatives without discarding all the past useful experience.

However, the change of accounting system is needed. ABC is able to reliably trace costs to activities in the value chain. Narcyz Roztocki (2004) found that evaluation of investments in information technology (IT) represents one of the greatest challenges faced by business managers (Thatcher & Oliver, 2001). Evaluating IT-related investments in emerging economies is an even more difficult task, due to generally even less predictable changes in the social, political, and economic infrastructure. One possible explanation for the difficulty of assessing IT investments may be that most evaluation techniques concentrate on inputs and outputs. This “black-box” approach disregards other complex factors that may determine performance in a manufacturing company.

3.3.5 Other Suggestions or Comments

Part 5: Other suggestions by respondents

This part consists of an open-ended question. The respondents were free to make their own suggestions and comments.

Two notable issues were observed from the respondents. First, they thought that tools for product design and development could only be affordable by large enterprises but not SMEs. Secondly, many respondents did not have much idea about the techniques or technology mentioned in the survey. They would like to have more information. For example, the companies suggested some seminars should be held or they should be sent some information about the technologies like CE, MC, ABC.

The companies had the intention to learn or to know more in order to find ways to help their business. From this, it can be seen that these companies were willing to change, only that they did not know how. The survey indicates that these companies were looking for significant changes in the manufacturing paradigm, shifting from traditional manufacturing to a new way of agile manufacturing featured by its speediness of response to ever-changing customers' needs. That is why a clear and systematic business practice needs to be developed in order to help companies to improve their businesses.

3.4 Discussion

On reviewing the survey results, it is found that most companies have inter-departmental teams involved in the product design and development process. At the same time, companies are facing the problems of frequent changes in requirements from customers, also higher material costs and project delays when they implement these changes. The survey shows that most managers believe that concepts or tools like CE, QFD, MC, ABC are helpful in addressing these problems in the design and development stage though not many managers have recognized the availability of such technologies in the market.

Despite the fact that most companies have more than one department involved in the product design and development team, the weighted average of number of departments involved is 2.3 only. That means not many companies have more than three departments participating in the process. The reason for this is that presently firms are unable to find a system that supports several departments working together. As the product design process is getting more complex nowadays, there is a need for a system which enables various departments to work together and form an inter-departmental team in the product development process.

From the survey, it transpires that most manufacturing firms want to address the problems like frequent changes from customers, project delay and high material cost. There is a need for a systematic approach which is flexible enough to support the current multi-facetted practice of modern manufacturing. The new development system should consist of proven good practices or technologies and should enable a company to satisfy the needs of customers in the shortest possible time.

Mass customization is believed to be helpful to the companies included in the survey.

It can optimize reusability and commonality, synthesize a unified product family architecture and facilitate meta-level integration throughout the design process. In this new era, customization is the key to higher competitiveness. New technologies, increasing competition, and more assertive customers are driving firms towards products customization. By applying MC, companies will gain long-term benefits of higher customer satisfaction, lower overheads and less bureaucracy. Higher production flexibility and total process efficiency may also be achieved.

QFD is also regarded by the companies included in the survey as another good technology for adoption. Having the capacity to create superior product design, QFD can focus on producing products which match the quality requirements "needed" and requested by customers. Thus, QFD will save expense by avoiding the production of "unwanted" product features or by "over-design".

Furthermore, ABC is considered as being helpful by the survey respondents. Before the advent of ABC, companies operated in the dark without knowing the true overhead costs, and always allocated the wrong resources to their products, which in turn led to a wrong pricing strategy. As mentioned in chapter 2, ABC is an accurate and precise tool to determine the logistics and distribution costs. Similar comments and feedback are also given by the respondents as well.

Concurrent engineering is also thought to be a good supporting technology in product design because it can shorten the development and implementation time so that product can be delivered to the market in a timely manner. In normal practice, NPD goes through various stages of sequential operations, from conceptual design to prototyping. This step-by-step approach is quite inflexible and finds it difficult to cope with any unexpected changes such as changes of certain product features in order to suit the market demand. In particular, the deficiency of a universally accepted schema for information interchange among various functional divisions makes the situation even more serious when it comes to lead-time control and communication among various design activities (Mason-Jones & Towill, 1999), a more flexible practice is surely helpful to product development.

It can be seen from the survey that DFM is considered helpful by more than half of the respondents. However, Garfein (1988) suggests that manufacturers need consider certain factors and make certain adjustments before implementing DFM. Firstly, DFM promotes uniaxis assembly, which may not be the best for certain companies. Secondly, DFM suggests reducing the number of parts used in an assembly line so that more functionality needs can be incorporated in one part. But Naim et al. (1995) argues that it is sometimes easier to add several simple steps rather than one complicated one. Thirdly, DFM causes a shift in decision-making power. He points out that manufacturing will have considerable influence over product design, and product design will have an even greater influence over the choice of manufacturing method. As a result, manufacturers are required to be prudent and continuously oversee the DFM process when they try to adopt it to reduce their development costs. The findings clearly indicate that firms require a dynamic business tool which allows for reconfiguration of their workflows, business models and manufacturing processes so as to meet customer demands. In order to shorten the time to market, there is a need for manufacturers to adopt some well-established good practices to transform their business operations. These practices must be able to support the transformation process in order to achieve an efficient and flexible deployment of people, resources and processes, thereby significantly improve the competitiveness of firms. With this transformation and through the assimilation of emerging practices, product innovation and shorter development lifecycles can be achieved.. In this survey, four well-accepted technologies namely: Concurrent Engineering (CE), Quality Function Deployment or QFD (Paashuis and Boer, 1997), Mass Customization or MC (Eastwood, 1996; Gilmore & Pine, 1997; Jiao, 1998) and Activity Based Costing or ABC (Needy et al., 2003) are regarded as contributive to enhancing the operational efficiency and effectiveness of the entire organization while being able to satisfy the customers at the same time.

CHAPTER 4 DESIGN OF THE CUSTOMIZABLE AGILE RECONFIGURABLE DESIGN SYSTEM (CARDS)

4.1 Introduction

This research proposes a Customizable Agile Reconfigurable Design System (CARDS), which not only handles the logistics of product design but is also easily extendable, allowing easy data maintenance, while also fulfilling several other requirements. The underlying technology for supporting the infrastructural framework of CARDS is OT which has been identified as an analysis and design method well suited for the task on hand. And due to OT's specific characteristics such as inheritance, encapsulation and polymorphism, the proposed system thus developed is expected to deliver benefits such as extendibility, and enhanced information and knowledge sharing among others.

Based on the survey and literature review as discussed, it is a necessity for manufacturers to adopt well-established, good practices to transform their business operation in order to shorten the cycle of time to market. These practices must be able to support a transformation process in order to achieve the efficient and flexible deployment of people, resources and processes, thereby significantly improving their competitiveness. With this transformation and through the assimilation of emerging practices, product innovation and a shorter development lifecycle can be achieved. In this research, it is suggested that three well-accepted practices: Quality Function Deployment or QFD (Lockamy & Khurana, 1995; Cohen, 1995; Vonderembse &

Fossen, 1998; River, 1999), Mass Customisation or MC (Eastwood, 1996; Jiao, 1998; Gilmore & Pine, 1997) and Activity Based Costing or ABC (Albright & Smith 1996; Chaffman & Talbott 1991; Cooper & Kaplan, 1987), all of which play an important role of enhancing the operational efficiency and effectiveness of the entire organisation while satisfying the customers at the same time, be incorporated as functional modules of the proposed CARDS. These practices must be able to support the transformation process in order to achieve the efficient and flexible deployment of people, resources and processes, thereby significantly improving their competitiveness.

Nowadays, global competition has created tremendous pressure on all manufacturers to achieve quick time-to-market through the shortening of the product development lifecycle. However, Small and Medium Enterprises (SMEs), who are confined by budgetary constraints and shortage of expertise, will find it difficult to sustain their competitiveness in terms of speed, innovation and flexibility. Normally, the product development cycle of consumer products, such as mobile phones, is more than a year. This has now been "compressed" to no more than 6 months, because of fierce global market competition. In order to achieve a shorter development time and quick response to market demands, relevant processes and operations must be able to be flexibly configured so as to comply with the fast changing demands of customers. Because of this, flexible assembly lines have been designed and built in companies to cope with a range of products without requiring significant set up time.

In the case of product development, this is time consuming and the cost taken for determining optimal sets of product features can be fairly high due to the reason that relevant information is needed from several functional departments, most of which are normally lacking in an efficient inter-communication system. Thus, it seems essential to break down barriers which are preventing data communication between various departments. Such barriers are now regarded as a serious problem that needs to be dealt with.

Most companies are now facing the dilemma that on one hand, customers are demanding that their orders be fulfilled ever more quickly whilst on the other hand, they are demanding highly customized products and services. The market trends of shortening the product life cycle and also meeting customers' requirements for more unique products that satisfy their exact needs and wants, call for an agile organization that is not only responsive to changes in the business environment but is also able to act proactively to market trends.

For an organization to be agile, it is important to establish the corresponding culture and have the support of responsive business processes. Companies, now, identify the product design process as one of the company's key processes. It has also been identified that the product design process needs to be re-engineered to become responsive, customizable so it is able to meet the increasingly demanding customer requirements.

4.2 Design Considerations

The design of CARDS is based on the deployment of object technology to support the information flow among the good practices including QFD, ABC and MC which have been identified through an intensive survey. In brief, QFD is considered as a good practice because it focuses on producing the products with the "needed" quality requirements voiced by customers, thus saving cost by avoiding the creation of "unwanted" product features or "over-design". MC is also a recommendable practice for rationalising parts and processes through the creation of standardised component modules, thereby reducing the proliferation of the parts and components. The ABC approach, which has been stimulated and largely influenced by the work of Cooper and Kaplan (1987), provides a more meaningful and realistic method to assess the costs required for the various activities involved. This analytical approach breaks down all the activities in an industrial plant and determines the portion of overheads required for supporting the production of the wide range of products. These three practices are essential for providing the tools for developing new products in a fast and responsive way and at the same time rationalizing the resources during the developmental stage.

4.2.1 Deployment of Object Technology in CARDS

Whilst all of these practices play their own unique and distinctive part in enhancing the performance of the product development system, they are also inter-related because they share the same information In this respect, the essential task is how to integrate them to enable "seamless" multi-directional information flow in an effective manner. In general, the functionality of these three practices can be modularised to specify the internal operations and once they are broken down into smaller components (or objects), the handling of these information objects becomes more manageable, thereby allowing the possibility of an effective integration to form an object-based unified system. This modularisation lends itself to the introduction of the object technology concept which considers most of the systems to consist of reusable and inter-related modules (objects) which are themselves created and modified depending on the requirements at various stages of product and process operations (Kappel *et al.,* 1995). Whenever there are any changes of requirement, only the reusable modules are modified or slightly customized to form a new object, inheriting the features of the "parent" objects. With this approach, companies can significantly leverage their competitive advantage as a result of the reduction of development time by virtue of the reusability of previously-developed objects. More importantly, the various practices can be linked together through these objects and thus favour inter-communication via a common platform.

4.2.2 Role of Object Technology in CARDS

The object technology concept is not the latest breakthrough technology; but because of its nature and the power of the concept, its influence has been getting stronger since the early 90's. It can be regarded as a modelling technique to describe real world objects with their own distinct identities (Rumbaugh, 1991; Luo & Wong, 1997). Object technology is based on a few simple concepts that, when combined, produce significant improvements in modelling design and process activities. And of course the central concept behind object technology is that of the object itself. Briefly put, an <u>object</u> is a software program that contains related data (attributes) and procedures (behaviours).

Although objects can be used for any purpose, they are most frequently used to represent real-world objects. The basic idea is to define software objects that can interact with each other just as their real-world counterparts do, modelling the way a business works and providing a natural foundation for building systems to manage that business (Laddaga & Veitch, 1997). In particular, object technology is proving itself in the field with reassuring regularity. Developers are finding that objects allow them to create new applications with surprising speed and ease. More importantly, these applications often contain functionality that would not have been feasible with conventional technology (Anderson & Ward, 1991; Sharp & Jacqui, 1999). And the resulting applications are proving to be very flexible and extensible, reducing maintenance costs and helping companies keep pace with changing business requirements (Joablonski & Bussler, 1996; Jacobson, 1995). The following terms are regularly being used in the object technology world.

- An object (or an instance of a class) has an inner state that is aware of its own class. An object can be used by other objects. When one object uses another, it can be considered that it sends a message to the other object. The receiving object accepts the message and performs the required operation. Performing an operation means that the object inspects its values, alters its own inner state, or uses other objects.

- A class is a template for all objects, i.e. all instances can be regards as the blue print of that particular class. Moreover that particular class defines what these objects can be used for. The class also describes the operations that the object can offer, the various activities that belong to each operation, and the different attributes that each object has. A class can inherit another class. It can also inherit several other classes, which is called multiple inheritance. Inheriting another class means reusing the definition of that class, in terms of operations, relationships and attributes.

- An object model consists of a set of classes and a set of relationships.

The characteristics related to OT include:

Data abstraction

Most of what humans deal with in the real world – people, places, objects and systems – are far more complex than they can cope with. As a result, a large amount of information must be distilled down to its essentials. Applying the concept of abstraction, that is, rather than trying to comprehend the entire thing, only part of it is selected. Although humans know that it contains additional details, some details are simply not being chosen at this time. This principal is at the core of object technology and forms the basis for the primary organization of thinking and specification.

Encapsulation

Encapsulation refers to the concept of including processing or behaviour with the object defined by the class. Encapsulation allows code and data to be packaged together.

Polymorphism

This refers to the ability to take many forms. When an object receives a message that it understands, it invokes some behaviour. This behaviour is part of the definition of the object. Various kinds of objects can understand the same message, yet respond differently (Goldberg and Rubin, 1995).

Inheritance

A class can inherit another class. Inheriting another class means reusing the definition of that class, in terms of operations and attributes. Inheritance allows us to specify those common attributes and operations of a particular class *once*, then this class can be *reused* to generate other classes, if they have common attributes and operations. This can enable people to be more effective in situations like analysis and design.

Combining the concepts mentioned provides the most important properties found in various system models (Fedorowicz & Villenenve, 1999). This allows the models to be:

- <u>Comprehensive</u>

  Since it is possible to break down the classes hierarchically, an understandable overall picture of the business model can be obtained.

- <u>Understandable</u>

  The business is described in terms of objects, which often have a direct link to occurrences in the real world.

- <u>Reconfigurable</u>

  Changes are usually local to a given class. They can, therefore, be introduced without affecting other classes in the model. With major modifications, several classes may need to be changed; a good design structure, however, allows even changes of some magnitude to be kept relatively local.

- <u>Adaptable</u>

  It is possible to specialize the existing classes, with the help of the inheritance mechanism. An object model can be adapted to different situations.

- <u>Reusable</u>

  Classes can be built and handled as components.

4.3 Underlying Technology of CARDS

The CARDS primarily consists of a number of objects of different features and most important of all, they are configurable to suit the company-specific processes and operations. In particular, it is proposed that MC, ABC and QFD be modularised through the creation of a number of objects with special features, forming an integral part of the CARDS. In brief, the CARDS is based on an object-driven infrastructure, in which data in the form of modules are "inter-fertilized" to support the creation of a reconfigurable and flexible environment.

In general, a system is suggested with the incorporation of the three approaches including QFD, MC and ABC to enhance the responsiveness, reconfigurability and agility for achieving rapid product development. This combination is able to capitalize on the strengths of individual recommended practices and at the same time make up for their individual structural deficiencies. By utilizing object technology, a novel product information structure was subsequently formulated.

4.3.1 QFD as A Good Practice

QFD originated in Mitsubishi, Heavy Industries, Ltd., in Japan, in 1972, as an advanced quality system made up of an integrated set of quality tools and techniques to provide customer-driven products and services (Wang, 1997). To implement the practice of QFD, the Company uses a cross-functional team to provide a specific approach for translating the “voice of the customer” through the various stages of product planning, engineering, and manufacturing into a final product. More importantly, QFD enables an organization to measure customer “wants” and map them against the engineering “how” in a way that highlights tradeoffs and drives the design of products towards customer requirements. In particular, the main objective of QFD is to reduce the product development cycle time, while simultaneously improving the product and delivering it at a lower cost (Vonderembse & Raghunathan, 1997). A broader objective of QFD is to increase market share by gaining competitive advantage.

In brief, QFD helps companies to identify what the customer really “wants”, and translates those requirements into the appropriate technical requirements for each stage of product development (Milwaukee, 1992). Hence, the product can then be produced to fulfil the needs of customer. QFD is an integrative process which links together customer needs, product and parts design requirements, process planning, and manufacturing specifications during product development. Moreover, QFD can also help to identify consistent performance measures for the different stages in the product design-process and design-manufacturing-customer chain.

During recent years, QFD has been recognized as an effective method for product and process development. It is a structured approach for integrating the voice of the customer into the product design or development process. The purpose of QFD is to ensure that customer requirements are considered in every aspect of product development from planning to the production floor (Usher *et al.*, 1998). To realize the benefits of QFD, tools are needed to translate customer needs to technical requirement and evaluation and correlation analysis are performed by enterprises in order to distinguish the features of products from those of competitors. In general, the implementation of QFD can be divided into 4 phases. Phase One is the product concept planning which starts with consumer and market research and leads to a product plan: ideas, sketches, concept models, and marketing plans. Product design (the second phase) takes the product concepts and develops product and component specifications. Prototypes are built and tested at this stage. In phase three, manufacturing processes and production tools are designed based on the product and component specifications. Pilot runs for production processes and toolings are made to ascertain product manufacturability levels and production standards. Once problems in the pilot runs have been resolved, the product enters production (Phase Four), after which it reaches the customer. At this point, customer feedback serves as input for the next generation of the product.

In normal practice, a matrix is used to relate the variables associated with one “design phase” to the variables associated with the subsequent “design phase”. This matrix is called a “House of Quality” (HOQ). The details related to the formulation of the HOQ are covered in a number of publications (Harding *et al.*, 1999; Zairi & Youssef, 1995) and therefore are not covered in this report. In brief, the HOQ matrix comprises score points related to various inter-relationships of different elements, thereby providing a picture of the importance and weighting of relevant factors.

4.3.1.1 Pros and Cons of QFD

QFD provides a structure for benchmarking competitor designs and as a design and process planning technique; it has brought tangible benefits, ensuring that customer requirements are not misinterpreted at subsequent stages. In particular, it ensures that particular marketing strategies or sales points do not become lost or blurred during the translation process from marketing through planning and on to execution. The other benefits include (i) better monitoring of important production control points, (ii) better customer satisfaction resulting from improved quality of design, (iii) better linkages between various design and manufacturing stages, (iv) the number of product components can be reduced due to better planning, (v) an improved working atmosphere through the horizontal integration of functions, and (vi) a more efficient workflow, because planning takes place at an earlier stage and mistaken interpretations of priorities and objectives are minimized. As for the benefits within the companies, better teamwork and collaboration of marketing, design, engineering, and manufacturing divisions can also be encouraged. Thus, QFD enhances both the design process as at the same time improves the underlying organizational structure of enterprises (Dekker, 1992, Zairi & Youssef, 1995; Lockamy & Khurana, 1995).

Although QFD has been developed to assist in the process of analysing the “voice of the customer” to support the specification process, it is handicapped in relation to actual application as the QFD process is still largely manually based. As activities involved are becoming more complex, it is becoming more and more difficult to manage, (Harding *et al.*, 1999). QFD is basically deployed to produce a general view from a lot of specific data, it does not emphasize details. Equally important is to ensure that enough time is allowed for the process and that the correct resources are available. In general, implementing QFD in an organization, requires that most of the preparation work is conducted in the early planning stages. In QFD, it becomes more difficult to change direction once a development project is underway because all of the interrelated elements of the system must be revised – one by one (Wang, 1997). QFD tools are limited in the types of information that they can "code". For example, the House of Quality (HOQ) permits only a few quantitative or qualitative values to be used as evaluations or correlations. The use of manual QFD tools requires good face-to-face communication practices because they are effectively used in group settings. In such settings it may not be easy to distinguish between different but seemingly similar positions or to observe the similarities between other positions thus some design information may be unnoticed or lost. The ability of QFD tools to capture and communicate design rationale is limited when used in an asynchronous manner, whether for communication among members of the current project or for disseminating information into the organization for future reuse (Reich, 1996).

4.3.1.2 Object Technology to Support QFD

With the deployment of object technology, procedures and data of the components of HOQ can be transformed into objects. A primary advantage of the deployment of objects is that they can be conveniently reused and modified. They are normally placed in large "class libraries" that users can select from and in this respect, it is important to define accurately the data and procedures to be encapsulated into various objects. A HOQ in the form of objects can be seen as more flexible in the sense that any change in the content of its elements in terms of attributes and methods does not require the subsequent change of the affected components, all of which in fact can be updated automatically through the intrinsic property of objects, which is referred as "inheritance". Figure 4.1 shows how the HOQ is classified into 9 classes (objects are instances of classes) to represent its inherent components. However, to effectively "objectize" the HOQ, an object schema showing the inter-relationship of the objects should be formulated. With this object schema, the HOQ becomes more customisable without taking into consideration the size and complex analysis of the matrix.

Defined Classes in the HOQ:

1. **Customer Needs (CN)**
2. **Technical Descriptor (TD)**
3. **CN_TD_Relation**
4. **TD_Correlation**
5. **CP_CN Score**
6. **CN SCore**
7. **CP_TD Score**
8. **TD Score**
9. **Technical Importance**

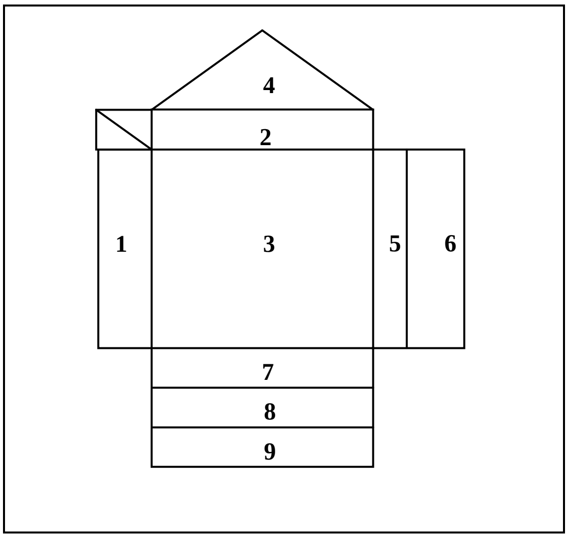

Figure 4.1: The Classification of HOQ Based on Object Technology Approach

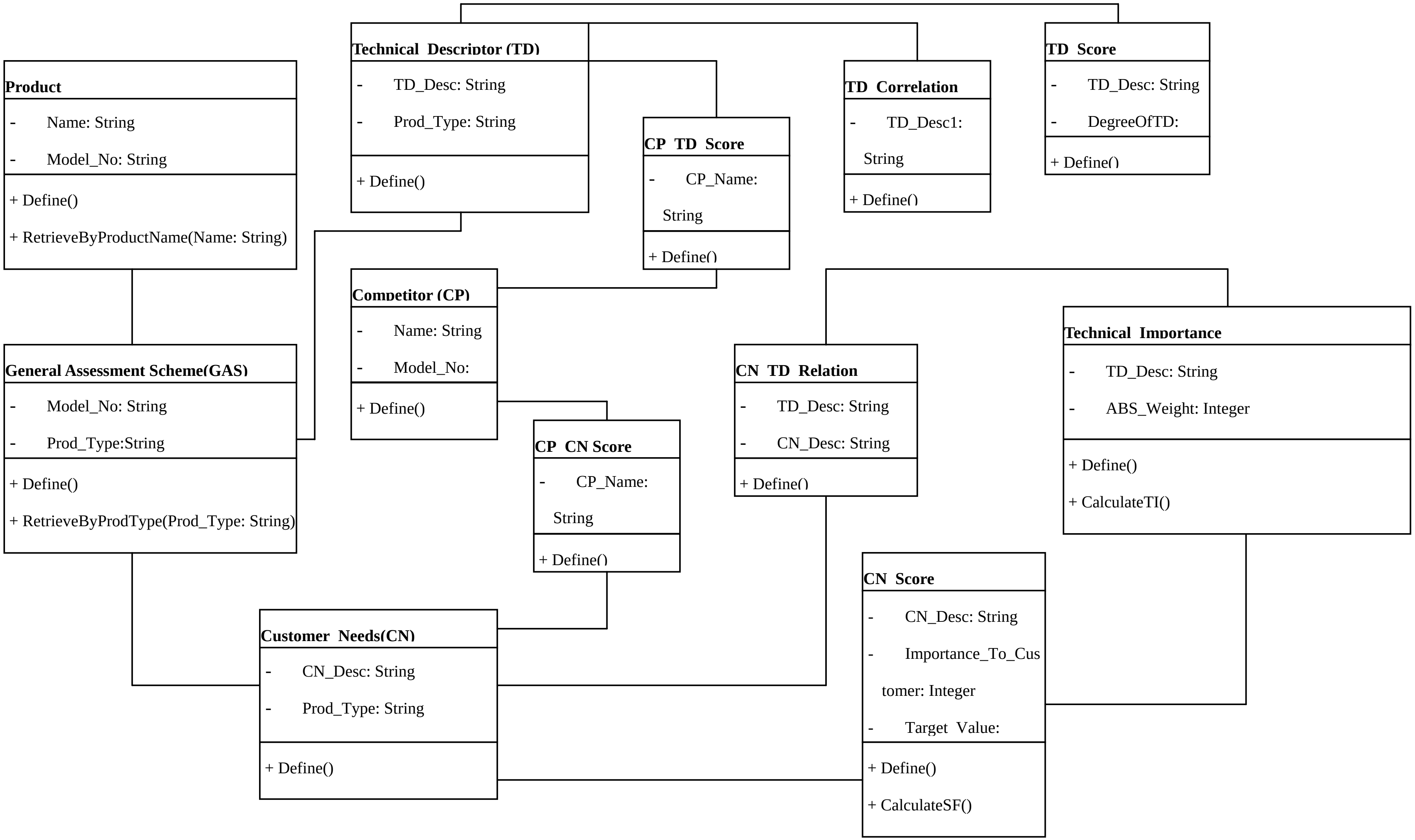

Figure 4.2: Quality Function Deployment Object Schema

Figure 4.2 shows the object schema of HOQ which illustrates the data and procedures included in each object. Basically, each object includes attributes (data) and methods (procedures), both of which can be linked with other objects by virtue of the "inheritance" feature. For example, the object *CN_Score* includes a number of attributes such as *Sales_Point*, *ScaleupFactor* as well as methods such as *calculateSP()* (for the calculation of the sales point). Based on the object schema, a clear picture of the inter-relationship of the various elements can be visualised in a better way. For example, it can be seen from the object schema that the object including *Customer_Needs* and *Technical_Descriptor* can be linked to the class *product*, through the object named *General Assessment Scheme* which evaluates the score points and weightings. Details of the relationships between the *Customer_Needs* and technical descriptors are captured in the object named *CP_TD_Score*. Information for the correlation matrix is stored within the correlation objects such as *TD_Correlation* which provides information to facilitate necessary engineering trade-offs, which need to be considered to ensure that one design feature is not improved at the expense of others. With the deployment of the object technology to capture information of the HOQ in the form of objects, a schema which is able to respond to any changes in a more effective way can be achieved by virtue of the features of objects including inheritance, encapsulation and polymorphism (Booch, 1996), all of which can contribute to the responsiveness of the system.

The objects, which encompass attributes and behaviours of various QFD components, can be produced by various software tools or languages such as Delphi (Henderson, 1998), Visual C++ or Visual Basic (Microsoft Visual Basic 1997 a & b). In this research, Visual Basic is used due to its ease of use and the vast sources of technical support available for this development tool. An example below shows the creation of the *CN_Score* (customer needs score point) class using VB.

```
' Customer_Needs_Score.cls – creation of class for CN_Score
Option Explicit
Const class_name = "Customer_Needs_Score"
' Public data members – attributes of class
        Public CN_Desc As String
        Public Importance_To_Customer As Integer
        Public Target_Value  As String
        Public Scaleup_Factor As Real
        Public Sales_Point As Real
        Public ABS_Weight As Real   'Absolute Weight
Public Function Define()  'Define Customer_Needs_Score using formula
        ………………….
End Function
Public Function CalculateSF()  As real 'Calculation of scaleup factor
        …………………..
End Function
Public Function CalculateSP()  As real 'Calculation of sales point
        …………………..
End Function
Public Function CalculateABSWeight()  As real 'Calculation of absolute weight
        …………………..
End Function
```

4.3.1.3 Methodology to Objectize HOQ

Basically, Customer Requirements, Design Characteristics, Relationship Matrix, Correlation Matrix, Competitive Analysis, Technical Importance, Technical Competitive Analysis and Target Levels are the basic elements in the HOQ. Using the concept of OT, Customer Requirements can be grouped into sets of related needs in the class of Customer Needs. Moreover, engineering characteristics can also be captured and grouped in the class of Technical Descriptor. Actually, the classes Customer Needs and Technical Descriptor can be linked to the class Product, which means a product has any many technical descriptors and is associated with any number of customer needs. Similarly, the class of Technical Descriptor can determine the class of technical descriptor correlation. Details of the relationships between the Customer Needs and Technical Descriptors are captured in instances of inter-relation class - CP_TD_Score. Information for the correlation matrix is stored within the correlation class. TD_Correlation class is an important class as it provides information to facilitate necessary engineering trade-offs, which need to be considered to ensure that one design feature is not improved at the expense of the others. The remaining information classes relate to competitor information. In order to do competitive benchmarking, it is necessary to capture customer input about competitors' products.

After creating the class diagram from the conceptual stage, a HOQ prototype can be built to test the approach. In this report, an "11 Steps Methodology" is suggested for building the HOQ prototype based on the OT approach. As the list of primary customer needs is usually vague and very general in nature, further explanation is given by defining a new, more detailed list of secondary customer needs to support the primary customer needs. Hence, Customer Primary Needs and Secondary Needs were inputted in step 1 and step 2 respectively. Now that the customer needs and expectations have been expressed, the QFD team must come up with technical descriptors that will affect one or more of the customer needs. Each technical descriptor must directly affect a customer perception and be expressed in measurable terms. These appropriate technical descriptors were defined in step 3 and step 4 and this process of refinement is continued until every item on the list is actionable. Hence, the list of technical descriptors and customer needs are divided into a hierarchy of primary, secondary, and even higher levels. The next step (step 5) in building a HOQ prototype is to compare the customer needs and technical descriptors and determine their respective relationships. It is common to use symbols to represent the degree of relationship between the customer needs and technical descriptors. For example, a solid circle represents a strong relationship (Score 9); a single circle represents a medium relationship (Score 3); a triangle represents a weak relationship (Score 1) and the box is left blank if no relationship exists. These weights are used later in determining trade-off situations for conflicting characteristics and determining an absolute weight at the bottom of the matrix. The roof of the HOQ, called the correlation matrix, is used to identify any interrelationships between each of the technical descriptors. Symbols are used to describe the strength of the interrelationships; for example, a solid circle represents a strong positive relationship; a circle represents a positive relationship; an X represents a negative relationship; an asterisk represents a strong negative relationship. Hence, the suitable rating should be inputted in step 6 to identify the relationship among different technical descriptors. Customer competitive assessment is done in step 7, the numbers 1 through 5 are listed in the competitive evaluation column to indicate a rating of 1 for worst and 5 for best.

The customer competitive assessment is a good way to determine if the customer requirements have been met and to identify areas to concentrate on in the next design. In step 8, prioritised customer requirements are developed which contains importance to customer, target value, scale-up factor, sales point and an absolute weight. The importance to customer is determined by the QFD team; numbers 1 through 10 are listed to indicate a rating of 1 for least important and 10 for very important. The target-value column is on the same scale as the customer competitive assessment (1 for worst, 5 for best can be used). The scale-up factor is the ratio of the target value to the product rating given in the customer competitive assessment. The higher the number, the more effort is needed. QFD defines how well the product design meets customer needs. The objective here is to promote the best customer needs and any remaining customer needs that will help in the sale of the product. For example, the sales point is a value between 1.0 and 2.0, with 2.0 being the highest. Finally, the absolute weight is calculated by multiplying the importance to customer, scale-up factor, and sales point. In the following step (Step 9), the technical competitive assessment is conducted, the numbers 1 through 5 are listed in the competitive evaluation column to indicate a rating of 1 for worst and 5 for best. In step 10, prioritised technical descriptors contain the degree of technical difficulty and target value. Finally, the absolute weight and the relative weight can then be defined in step 11 for judging planning. After the class diagram of QFD is generated, a development tool such as Visual Basic can be used to create a prototype.

4.3.2 Mass Customisation as a Good Practice

Over the past decade, mass production and mass distribution of standardized goods were the only way for industries to survive. At the same time, the demands of customers have been undergoing significant changes, favouring products with customized features and appearance to suit various preferences. In other words, products are made in small quantities with a wide range of built-in functions to meet specific demands. So the concept of mass production is no longer applicable or feasible. Thus, mass customisation is introduced to meet the maximum degree of customer satisfaction, focusing on varieties and customized requirements without the corresponding increases in cost and lead time. By using Design For Mass Customisation (DFMC), product designs are based on the Product Family Architecture (PFA) according to functions, geometry tooling, assembly, methods and customers' requirements. The PFA can be achieved by finding the functional requirements of the customers, mapping them with the design parameters and building physical modules which can be interchanged to customize the end products. Nevertheless, not all the products ordered by the customers can be produced solely by the existing modules. Therefore, some of the modules need to be redesigned. In such cases, the selection of modules become very important as good selection of modules can save time, cost or even provide better quality for the customers.

The design of modules includes identifying the type and characteristics of the design problem, decomposing the overall problem into sub-problems, determining the objectives of modularisation, representing the information of modules and then decomposing a product into modules. Significant research has been conducted in this domain and various methods have also been proposed to represent the modularity of a product (Kusiak and Huang, 1996) or to decompose a product into modules (Jiao & Tseng, 1999; Eppinger *et al.*, 1990; Hillstrom, 1994; Mistree *et al.*, 1994, Erixon *et al.*, 1996; Newcomb *et al.*, 1996; Kusiak & Chow, 1987; Gu & Sosale, 1999; Tsai &

Wang, 1999). Whilst most of the proposed methods are concerned with the handling of the modularisation process based on a wide range of products, the techniques to introduce responsiveness to the whole approach have not been adequately reported.

4.3.2.1 Object Technology to Support MC

Object technology is very much related to the modular approach in product design as in MC. Modular products refer to product assemblies, and components that fulfil various functions through the combination of distinct building blocks. Basic components refer to the components, subsystems, and mechanisms that interact with distinct modules resulting in different product variants. Based on the interactions within a product, six categories of modularity have been defined.

i) Component-Sharing Modularity: the same component is used across multiple products to provide economies of scope. This form of modularity is most important for putting the “mass” back into a proliferating product line whose costs are rising as fast as, if not faster than, the number of products.

ii) ii) Component-Swapping Modularity: This method is the complement of component-sharing modularity. Here, different components are paired with the same basic product, creating as many products as there are components to swap. In many cases, the distinction between component sharing and component swapping is a matter of degree.

iii) Cut-to-Fit modularity: This technique is similar to the previous two types, except that in cut-to-fit modularity one or more of the components is continually variable within preset or practical limits. The process of cut-to-fit modularity is to alter the dimension such as width, length or height of a module before assembly or combine with other modules.

iv) Mixed modularity: This type of modularity can use any of the above types, with the clear distinction that the components are so mixed together that they themselves become something different.

v) Bus modularity: This type of modularity uses a standard structure that can have a number of different kinds of components attached to it. The term comes from computers and other electronic equipment that use a bus, or back-plane, that forms the primary pathway of information transfer between processing units, memory, disk drives, and other components that can plug into the bus.

vi) Sectional modularity: The final type of modularity provides the greatest degree of variety and customisation. Sectional modularity allows the configuration of any number of different types of components in arbitrary ways, as long as each component is connected to another at standard interfaces.

The development of modular products includes the following steps:

Step 1. Clarify the task: generate specifications of the product (normally a module fulfils several main functions).

Step 2. Establish functional structure: subdivide the main functions into a minimum number of similar and recurring sub-functions based on two constraints: (a) the functional structures of the product variants considered for modularity must be logically and physically compatible; and (b) the sub-functions determined must be interchangeable.

Step 3. Determine a methodology to fulfil the sub-functions: determine solution principles for the implementation of the variant sub-functions. Precondition: Look for principles that provide variants without changing working principles and the basic design.

Step 4. Explore the feasibility between interfaces of modules and basic components (geometric, kinematics, and non-motion machine primitives).

Step 5. Review the constraints.

After the modules of components have been formed, object technology can be employed to fill the modules with the information from different parts of the company. For example, the customer requirements from the marketing department, the cost from the accounts department, the production time from the production department, the development time from R&D department and the quality from the quality department etc. The above information is saved as attributes of an object (module) and the relationship can be classified and input into the system. After the information has been captured, relevant personnel in the company are able to acquire the information about various products and make a quick response to the market.

4.3.2.2 Objectization of MC Components

It is appropriate to deploy object technology, based on its inherent properties and features as inter-related modules, in DFMC by forming part modules and by storing necessary information in attributes and methods. Figure 4.3 shows the objects of MC, illustrating the inter-relationship of technical analysis, design parameters and moduled parts.

In general, this “objectized” MC approach includes three parts; the first part is the modularisation of product parts, based on which object technology will be used to form the necessary modules in the form of object classes. These modules will be combined to form the end product as required. The second part is the formulation of the storage of required information for the modules. In object technology, attributes and procedures are created for various objects. The content of various objects are useful when it comes to the selection of suitable modules at a later stage. The third part is the selection of appropriate modules for certain specified products. It is necessary to work out which objects are required for inclusion in the design parameters and some pre-written programs are encapsulated in objects.

Figure 4.3 shows the object schema for MC. The class of Customer’s Need first provides information to the class of Design Parameters, with which it is linked. Subsequently, the attributes of Moduled Parts are also related through the object model interaction, e.g. attribute Type of product will limit the product specification of the involved Class. Besides, the class Customer's Need also contains the description of the product that customers want and this information will map with the relevant attributes of the involved Class.

The main use of the class of Design Parameters, is to act as the bridge of QFD and MC. Its use is to build the relationship between Customer's Need with the Moduled Parts as well as Technical Analysis. As such, the three main Classes of MC, all of which contain the essential information related to the modular product design approach, are inter-linked with each other.

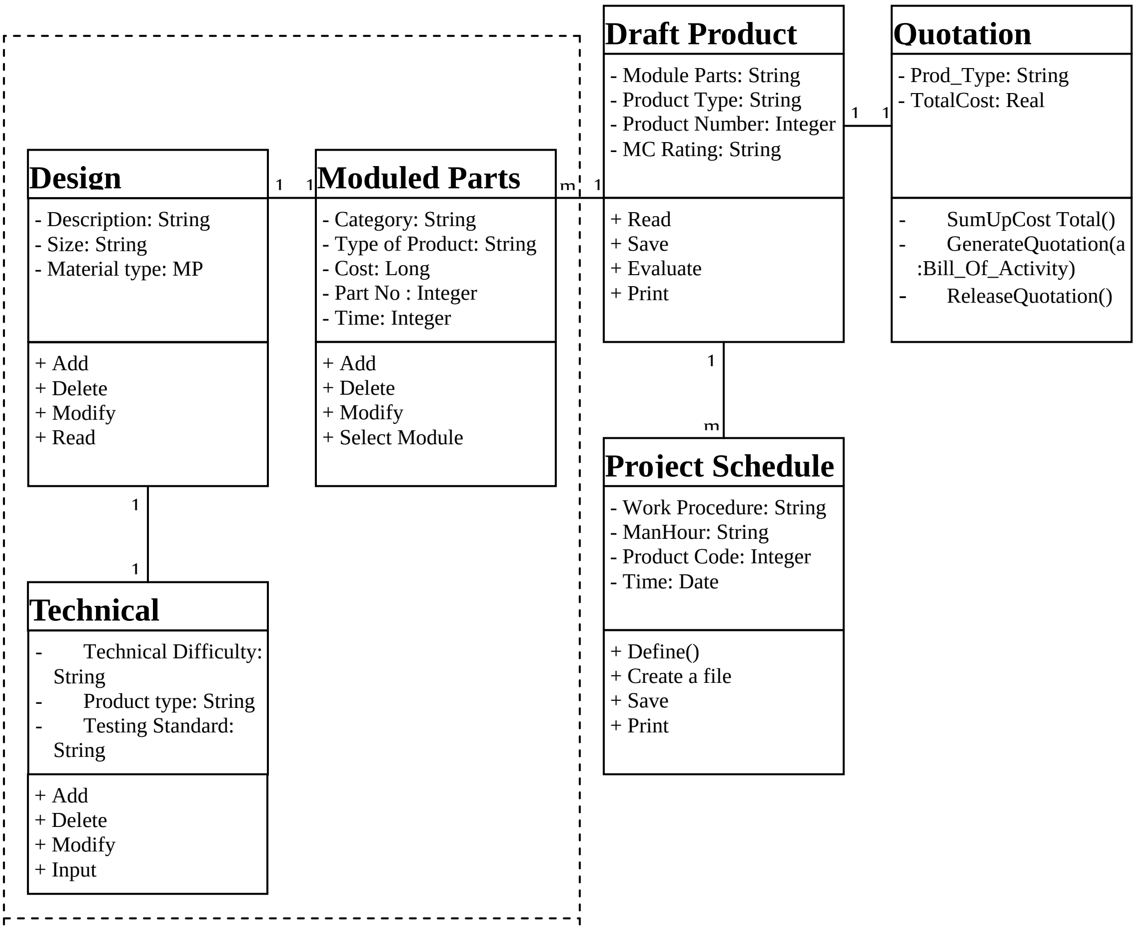

Figure 4.3 : Mass Customisation Object Schema

Moduled Parts serves many functions in the mass customisation object schema. First of all, it has included a database for storing the description of parts which is used for mapping with other relevant Class such as Draft Product Design. Besides, it stores the relationship between parts, thus providing information about which parts or modules can be combined so as to form a product. Finally, it stores other important attributes such as time and cost, which are used to calculate the lead time and product cost. Here, one of the Methods included is called “Select_Module”. The “Select_Module” chooses the right module according to the information provided. It is necessary to specify the procedures and actions in the program code in order to perform the function as specified.

The Class of “Draft Product Design” carried out search function that the appropriate modules with the existing parts are selected for fulfilling the requirements. The selection criteria will be based on part numbers, from which most of the information can be obtained such as drawings, mould number and BOM costs etc.

4.3.3 ABC as a Good Practice

ABC relies on three basic concepts to allocate costs. They are: activity, cost object and cost driver. Basically, an activity, in the context of ABC, is any task or responsibility related to a certain project. It can be a value-added task such as a designing product or a non-value added task such as an inspection. The list of activities involved in the product development cycle can be created based on the moduled parts and the existing development schedules. Cost object, which refers to the resources such as the cost of labour and materials, is the output of the task related to the project activity. Cost object is very much related to cost driver which is a measure of the amount or intensity of resource or activity that cost object has utilized. In addition, cost driver determines the portion of the total cost for an activity attributed to a particular cost object.

In general, by the means of activity-based costing, the product cost can be obtained in a more systematic way to reflect the actual tasks responsible for the cost. In order to develop the data requirements for activity-based information, it is necessary to define the terms to be used in line with the ABC terminology. As mentioned above, it is essential to ensure that the terms such as cost objects, activities, cost drivers and activity measures are clearly defined and understood.

4.3.3.1 Object Technology to Support ABC

Based on the object-based approach of ABC, an object schema can be formulated with linking to the moduled part object of the MC model. To build the ABC object schema, the costs of resources must be allocated. to individual activities or to an activity centre. Resources include the usual ledger categories for direct cost as well as administration overheads. An individual activity centre can be a task, a machine, a workstation or a process, depending on the method of cost allocation. A cost driver can also be a resource cost driver, which is used to allocate the cost of the resources to the activity.

The next step apportions the activity-centre costs to particular products or to other cost objects using another set of cost drivers, called activity cost drivers. Since costs from several activities or activity centres are allocated to each cost object, the total cost of the cost objects will then become the total product cost. After defining the above elements, a Bill of Activity (BOA) is formed. The basic concept here is that each moduled part is produced by a set of activities such as the software design of some specific functions. These activities normally require the support of company resources which are also described in the BOA. Once the activities are clearly defined and their interrelationship determined, the total cost of the product can be estimated. The delivery time of the product is also realised in a similar way. Three objects including Bill_Of_Activity, Cost-Driver_Rate and Resource are created to form the ABC object schema.

In brief, object technology, by virtue of its distinct feature of data inheritance among related groups of data, is used to enhance the performance of ABC which encapsulates data about various activities. For example, the workflow of the process plan can be reconfigured easily, based on the inherent object features which allow the automatic updating of data in various operations. Moreover, it is possible to respond rapidly to any unexpected changes due to the object inheritance behaviour which enables the automatic modification of the contents of other inter-related data objects throughout the entire value chain, to take place.

4.4 System Architecture

The system architecture of CARDS is shown in Figure 4.4. This architecture is supported by the good practices of MC, QFD and ABC, all of which can be objectized using the methodology mentioned above, taking advantage of the unique features of object technology. The essential ingredients of the CARDS are the three modules (See Figure 4.4) Team Transformation (TT) module, Product Specification

Enhancement (PSE) module, and Process on Demand (POD) module. The roles and features of these modules are described as below.

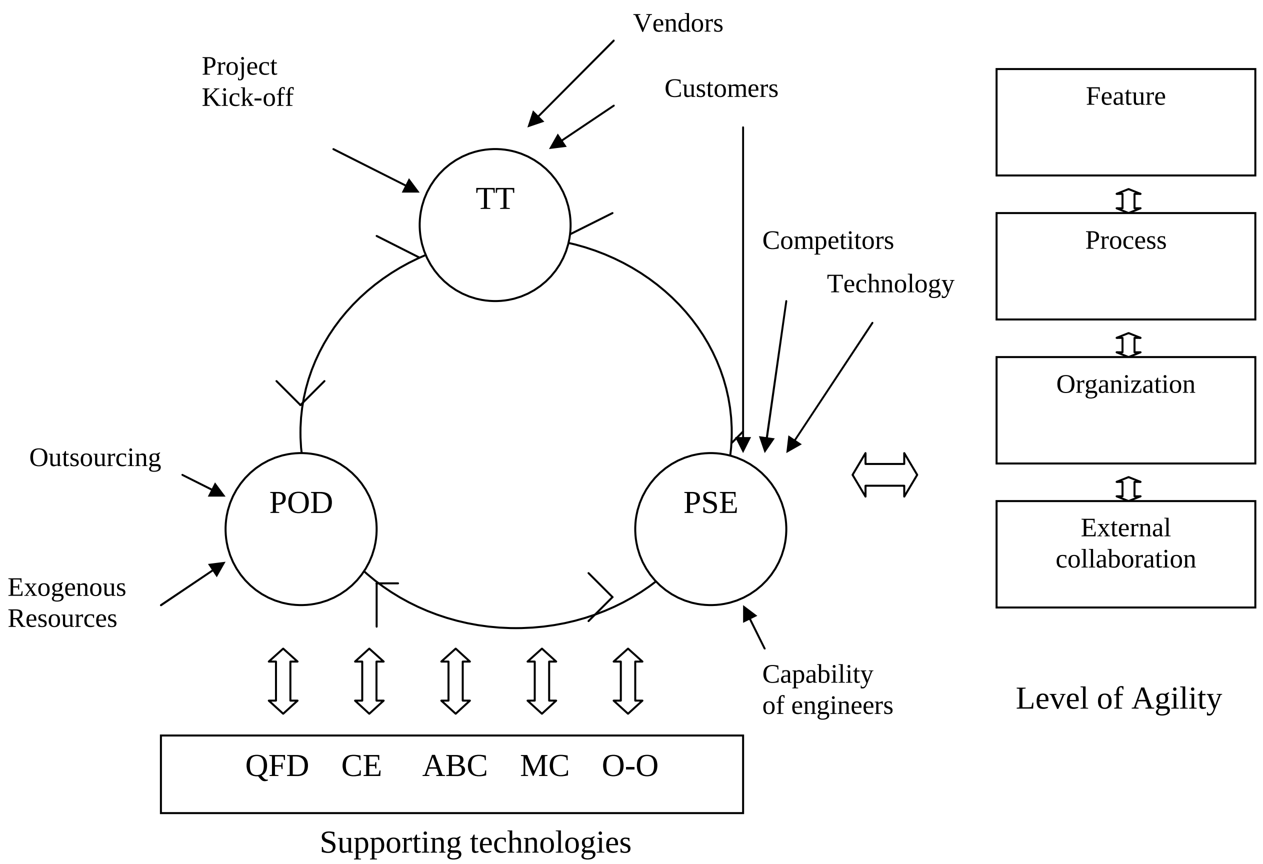

Figure 4.4 System Design of CARDS

The TT module is a novel approach used to establish the project team by identifying the core competence of each team member. Since each individual possess their own professionalism which is skill, working experience and analytical thinking, they can make use of their knowledge to face the turbulent market and business environment. As a team, it is usually expected not only to encapsulate the summation of the effort of each team member, but also to multiply the effort of each team member by creating synergy in the teamwork. Each team consists of team members (objects) who have their individual character, past experience, skills (property) and methods to cope with problems (behaviour). A rigid organizational structure usually leads to routine work which may greatly reduce the potential of individuals to innovate. As a result, TT module is designed so as to have cohesive strategy and undertake all types of innovation activity by forming an agile project team. Innovation needs breakthrough and breakthrough requires the willingness to change. The TT module allows enterprises to decompose the processes into tasks and activities so that a business analyst can discover hidden problems and invent new solutions. Simultaneously, identifying the strengths and weaknesses of each team member and assigning appropriate tasks is important in order to encourage innovation. Shortage of skill and knowledge greatly reduces productivity and competitiveness of an enterprise. The TT module is proposed to empower team members by increasing their skill and knowledge so that they actually increase productivity by making good commercial use of the innovations developed to meet the real needs of customers.

PSE module is to strive to balance supply and demand. Supply of resource is limited but the desire for a better product is unlimited. An increase in resources will lead to an increase in the cost. It is necessary to closely define the economic scope so as to fulfil customer requirements with the finite resources available. Efficient resource management carried out by the POD module helps to maximize the product competitiveness. A correlation can be seen between the POD module and the PSE module. The PSE module validates the competitiveness of the features of a product. This competitiveness is the result of the proficiency in skill and efficiency of the process carried out by TT module and POD module respectively. In order to obtain a balance between quality, cost and time, it is necessary to have a good market insight and a clear strategy and also the support of the advanced technologies which are the essential ingredients of CARDS.

The POD module helps to break down all process to sub-process by identifying each process as either dependent, independent or interdependent for optimizing resources and shortening the product development time. Having transformed the voice of the customer to technical terms, POD allows production engineers to eliminate the non-value-added processes during product development. The dynamic business environment is full of challenge. Co-operation, collaboration and competition occur among suppliers, business partners and competitors. Effective communication with internal and external customers can increase the competitive edge and enable a company to respond rapidly to changing needs in advance. POD leverages the knowledge accumulated from past experience through standardizing the way the product components or workflow are reconfigured. Apart from sustaining business performance and formulating corporate strategy, POD plays a crucial role by continuously streamlining the integrated product and process activities when engineering changes are introduced in the early stage of product development.

These three modules will interact with each other to support the effective management of product development. Management will thus achieve various kinds of agility namely:

a) Feature agility---Product features consist of: function; appearance (form); sense/feeling given by the product; texture. (i) Function is usually regarded as the major benefits obtained by the customers and those factors that are used for benchmarking the product when comparing it with products produced by competitors. These features help to define the product's market segment and position and encourage the company to make continuous improvement. (ii) Appearance refers to form, size, colour and surface finish in other words those features that usually give customers a sense of style and which may affect customers' when they use the product. Indeed, (iii) the feeling given by the service is usually stronger than that given by product. (iv) Texture is the appearance and feel of the surface of the good. Since an increasing number of manufacturers are moving up the value chain by providing post and pre-sales service to their customers, this leads to manufactures not only providing the products with excellent function, good appearance and texture, but also providing customized service that differentiates their product and service from that of their competitors. Since the taste of customers changes continuously, competitors and business partners drive the company to evolve in order to respond to these changes. The POD module makes use of QFD to analyse the actual needs of the customer and measure and rate the attributes of the product and compare them with products produced by competitors. With the novel project management approach of the TT module, project managers can steer the project team to develop a customized product.

b) Process agility--- As the features of products and services will change in accordance with the customer requirements, manufacturing processes and supply chain activities, manufacturing firms should be flexible to cope with unexpected changes and uncertain outcomes. The product development process is regarded as a cycle of activity that contains uncertainty and change. The POD module helps to assess the impact of the change request and make use of object technology to reconfigure the workflow. The request for change may lead to process rearrangement, combination, elimination and simplification. Process rearrangement can be done easily provided that the process is divided into sub-processes. However, this often results in a more complex portfolio of processes as the number of processes increases. Eliminating duplicate processes, combining the related activities and simplifying the task helps to realign the workflow so as to achieve process agility.

c) Organisation agility---CARDS adopted the essence of agile manufacturing and achieves flexibility in the design of technology and in the overall enterprise. This system reduces internal uncertainty of organization by reducing technical obstacles, adjusting project plan schedules and the scope of the work, as well as managing resources, trade-offs and improving decision-making. With CARDS, an organization is agile enough to react to changes and adjust itself accordingly. The TT module helps to achieve organisation agility by objectizing the traditional project team to a new modularised team. The newly-objectized project team becomes reactive rather than proactive to a turbulent market since TTM allows the project manger to rearrange the human resources and helps to build a flexible team for the organisation.

d) External Collaboration agility--- According to the research of Goldman (1995), the principal dimensions of external collaboration agility include enriching customers, collaboration to enhance competitiveness, mastering change and external uncertainty, as well as leveraging people and information. CARDS has been developed to help the user company to obtain up-to-date information and assemble its technology so as to achieve the ultimate goal of external collaboration agility.

4.5 Chapter Summary

This chapter has described how CARDS incorporates the three good practices: (i) quality function deployment for soliciting customer inputs, (ii) mass customisation for suggesting moduled parts for products and (iii) activity-based costing for working out the quotation as well as the associated project schedule based on values of activities. Object technology is deployed to provide a platform for easy information exchange and reusability of data among the various components (objects) of the system, thereby achieving reconfigurability of the product development procedure and operation. CARDS, is made up of three main modules namely, the Team Transformation (TT) module, the Product Specification Enhancement (PSE) module and the Process on Demand (POD) module. CARDS is a holistic systems based approach that uses various supporting technologies in each module related to the human, product and process aspects. Apart from the non-tangible benefits achieved by CARDS, such as fast responsiveness and improved productivity, quantifiable cost benefits can also be achieved through better information control with input and output from individual objects. The following chapter will exploit the development of CARDS which is a novel system for handling unanticipated changes systematically.

CHAPTER 5 DEVELOPMENT OF CARDS

5.1 Introduction

CARDS has been developed with the aim of proposing a holistic system for handling changes systematically. The system provides a means for helping enterprises to make changes to the product development process wisely, effectively and efficiently.

There are several characteristics required of this new system. Firstly, it should provide a systematic approach for companies to respond to external changes instead of responding on an ad hoc basis. In this way, personal factors may be reduced and making changes will no longer be dependent on personal experience or personal judgment.

Another important aspect of CARDS is its ability to enhance the transparency of handling changes, and facilitate information flow, so that quick and right decisions can be made. This feature echoes the concerns about project delay as expressed by the manufacturers in the survey described in Chapter Three.

In order to provide the needed agility, the CARDS system needs to break down the departmental and organizational barriers within an enterprise and bring in a system which enables the staff themselves to make change. Most importantly, it should be able to encourage the staff to take risks and initiate changes. The whole organization may be converted to become “change” and “customer needs” oriented. The success of CARDS rests on whether it can enable continuous improvement to the products to take place.

CARDS comprises three different modules, namely the Team Transformation Module, the Product Specifications Enhancement Module, and the Process on Demand Module. Each deals with different facets of the product development cycle, and addresses different specific needs and purposes. Though working differently, these three modules are closely and dynamically integrated, interconnected, and interrelated.

5.2 Team Transformation Module (TT Module)

The Team Transformation Module has been developed in order to manage the business process across different disciplines or functional units. It addresses the problem of organizational rigidity and brings in organization agility at the stage of new product development.

5.2.1 Functions of TT Module

Interaction among workflow activities is needed both within and among organizations in order to seek for an optimum combination, taking into consideration limitations on resources and project priority. Workflow interaction across organizations has additional complexity with respect to interaction among workflows of the same organization, due to the heterogeneity of the environments in which processes are executed. In fact, workflows in different organizations are typically specified in different workflow languages, which are executed on top of different vendors, and managed according to different business policies and business goals. This module is designed to encourage the creation of networked enterprises, which blur the boundaries between traditional supplier, manufacturer and customer based supply chains.

5.2.2 Building Blocks of the TT Module

Clearly, integrated efforts of multiple functional units within a business firm must be employed to develop a product and achieve the expected outcomes. When developing the Process Template Database, a review of existing models of the process of new product development was carried out. This illustrated that a diversity of processes were used in manufacturing industries. It also provided a framework for understanding the existing product development process. When the company receives any new project request or requirement change during the development process, a team can be formed or transformed by redefining the Project Flow Object Class and Humanware Object Class as shown in Figure 5.1.

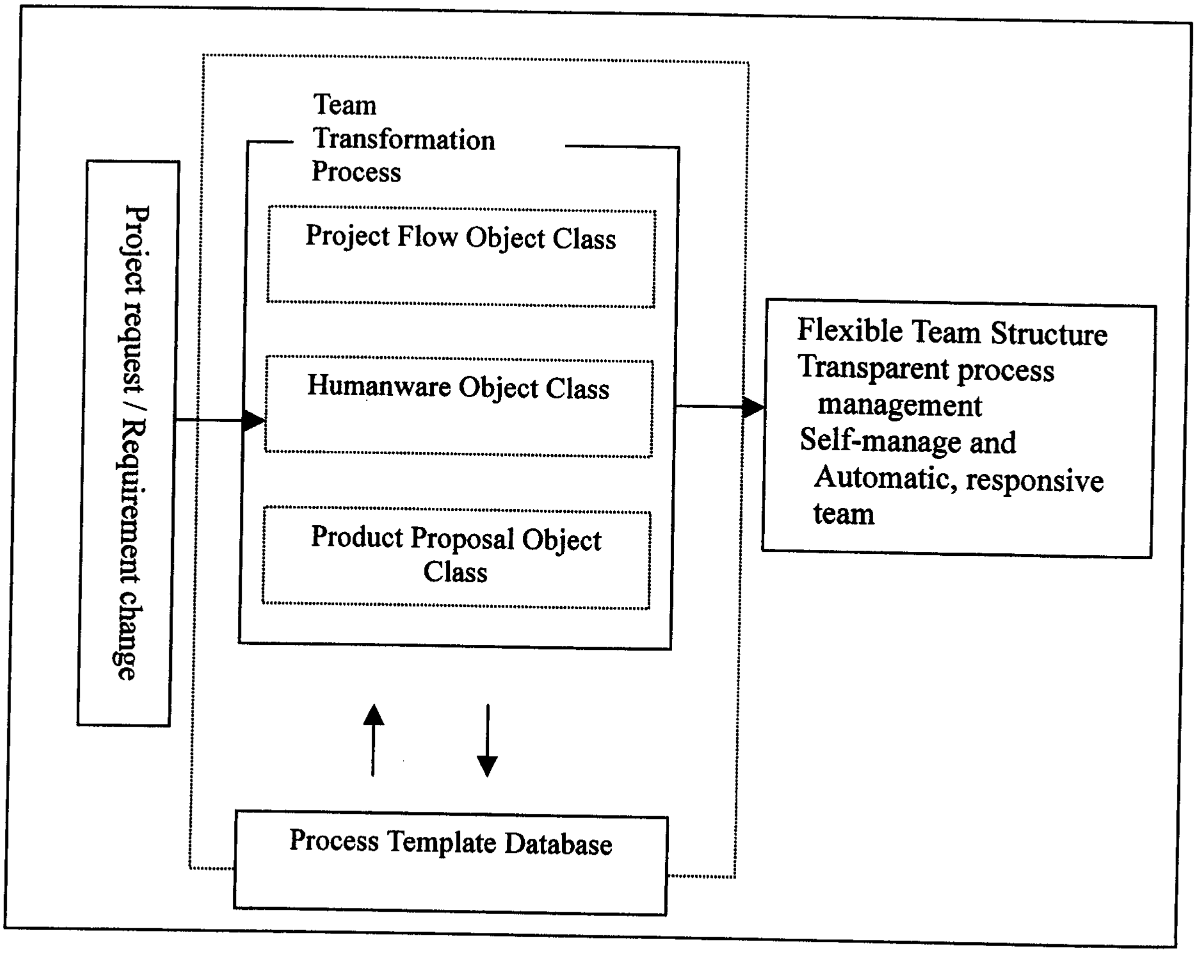

Figure 5.1 Structure of Team Transformation Module

Each object plays its own unique and distinctive role in enhancing the performance of the product development system. The objects are also inter-related and share information with each other. Operational behaviours define the actions which direct the member objects to achieve performance targets. For example, the behavior of a mechanical engineer object can facilitate design activities, which support product development. The "engineer object" can also work on the development or improvement of some common technologies or design modules that will be used in product development. A mechanical engineer object can provide related knowledge to stimulate the thinking of design engineers to encourage them to create new ideas; or help the development team to organise activities such as brainstorming in order to get ideas from many different people. If more backup from the manager is available, engineers may be willing to try new things because it becomes less risky and therefore requires less effort to achieve better results. Object modeling is used to capture the behavior and response of members. In recognizing how the work is done, the company can concentrate on making improvements which will yield the greatest returns. Understanding how these behaviours affect performance enables organizations to select and implement appropriate technologies.

After forming the objects, the next essential task is to integrate them to enable a "seamless" bi-directional information flow in an effective manner. For example, in the market segment, the marketing and sales manager is the process owner (in the super class). The R&D manager is in the subclass. In general, the handling of these information objects becomes more manageable through proper project management which facilitates efficient workflow. The introduction of the object technology concept allows modules to be reused; and inter-related modules (objects) can be created and modified depending on the requirements at various stages of product and process operations. Each pre-defined process object in the database has an inner state that is based on its own class. Each of them can be used by other objects. When one object uses another, it can be thought of as sending a message to the other objects. The receiving object accepts the message and performs the required operation. Performing an operation means that the object inspects its values, alters its own inner state, or uses other objects. Each process object can offer the various activities that belong to each operation, and the different attributes that each object has. One class can inherit another class. It can also inherit several other classes, which is called multiple inheritance. Inheriting another class means reusing the definition of that class, in terms of operations, relationships and attributes. Each object consists of a set of classes and a set of relationships. The business processes were constructed in the form of process objects with the information collected from different disciplines of the company. For example, customer requirements come from the marketing department, the cost from the accounts department, the production time from the production department, the development time from R&D department and the quality from the quality department etc. All this information is saved as attributes of an object; and the relationship will also be classified and input into the system. After the information has been input, everyone in a company will know a lot about the product and will be able to give a quick response to the market. The Product engineer will know when he/she should discuss something with a salesperson such as which part of a product can fulfill a particular requirement of the customer, and when he/she should provide a draft design to a customer with a full set of necessary information.

5.2.3 Deliverables of TT Model

When forming a management team, we need to define the behavior and relationship of objects. In this state, the automated sign-off, notification and release procedures work transparently. Interrogation of an object can reveal its relationship with other objects, its progress through the process, and any outstanding processes or signatures. Workflow processes can be pre-defined for different process types, new product development, engineering change or customization. Defining these processes makes them repeatable and consistent. Product and process knowledge can be captured in the system, and may be reused in subsequent process planning jobs or shared in other tasks. After formulating the model, ambiguous, ad hoc processes of design, development, and engineering change, can be replaced with clear, pre-defined work processes and control points. The processes and controls can remove repetitive tasks from the users, by pro-actively triggering events, updating product information, configurations, and relationships. Authorization rights and procedures can be built into the workflow to maintain release and approval integrity. There are a number of advantages in the module:

(i) Business models can help reduce risks, non-value-added tasks, and avoid avoidable errors and increase the probability of success.

(ii) It is a more systematic way to describe the business model and members' roles. This allows new thoughts and ideas to emerge, and be evaluated against those existing in the company. The company can take action based on the results of such evaluation and can change the roles or job content of staff within a short period of time.

(iii) Under the old unclear model there is a risk that people will not really understand what they are doing, or why they are doing it, or whether there is something else they might do instead. A clear business model can help them to change when facing difficulties. During the processes for developing the model, it is necessary to highlight the symptoms of poor product development management. Clear workflow in the model can then be defined to prevent missing out parts of a procedure.

In each control point, those objects can be modified. Many benefits are claimed for object modeling which can re-use and modify the standard objects and adapt them to meet changes. This module encourages companies to increase cooperation and to form networked enterprises where business processes span across organizational boundaries and are composed of cooperating workflows executed in different organizations.

5.3 Product Specification Enhancement Module (PSE Module)

5.3.1 Functions of PSE Module

Another challenge is related to the balancing of customer value and shareholder value in a world where the customer wants everything free, and the company wants to ensure the highest rate of return on investments. Product Specification Enhancement Module helps on balancing three competitive advantages namely cost, product quality and time. It consists of QFD, MC and ABC cycle, which are considered in tackling multi-criterion decision-making problems.

5.3.2 Building Blocks of PSE Module

The customer's requirements can be divided into functional requirements and performance requirements. The functional requirements include features such as with or without a back light in a pager product. The performance requirements, such as low cost, high quality, short time etc., can be used as the constraints for the optimal selection of physical modules to produce the end product. Therefore, the performance requirements can be used as the evaluation criteria. In the case of a pager, quality, cost and delivery time are often considered by customers. So they are selected as the evaluation criteria. When a product is configured from its modules, the quality, cost, delivery time are also evaluation criteria to be considered. The quality, cost, delivery time of a pager are divided into different degrees, and the three always compete with each other. For example, a high quality product usually increases production costs due to the need for a number of tests. Figure 5.2 shows the structure of the PSE module.

The House of Quality concept in this module focuses on producing products with the "needed" quality requirements as voiced by customers, thus saving cost by avoiding the creation of 'unwanted' product features or 'over-design'. MC is used to generate standardized component modules, thereby reducing the proliferation of the parts and components. The ABC approach provides a more meaningful and realistic method to assess the costs required for various activities. This analytical approach breaks down all the activities in an industrial plant and determines the portion of overhead required for supporting the production of a wide range of products.

Figure 5.2 presents the business process in the form of objects and the relationship between QFD, ABC and Mass Customization. From the mass customization point of view, the class Customer's Need -- the output of QFD is the input of mass customization. This class is shared by QFD and MC. There is a class called Design Parameter which is the buffer and between the output of QFD and MC. When the level of QFD is extended to phase 3, this class will appear in the class diagram of QFD. Thus, the existence of this class is for bridging the gap between the two practices.

Here, the class Design Parameter is used for mapping the Customer's Need with the corresponding Parts in the company. The main class of mass customization is the Moduled Part. It is basically a database for storing the information of the existing parts of the company for mapping with Customer's need. Draft_Product_Design is the output of mass customization. It is the output of a few modules which exist in the company and can be used to fulfill the customers requirements. This output will be used by ABC for identifying the Activity needed for developing the new product and estimating the cost of a product.

5.3.3 Deliverables of PSE Module

The Product Specification Enhancement Module provides multiple trade-off factors. The scoring method is used to represent the priorities of criteria in the decision process. The higher the score of a criterion, the more important the role it plays in the decision making process. The different requirements requested by customers regarding cost, time and quality will lead to the construction of different pictures. For example, the customer's requirements could be: low cost, relatively short time and medium quality. Or they could be: high cost, relatively short time and high quality. A

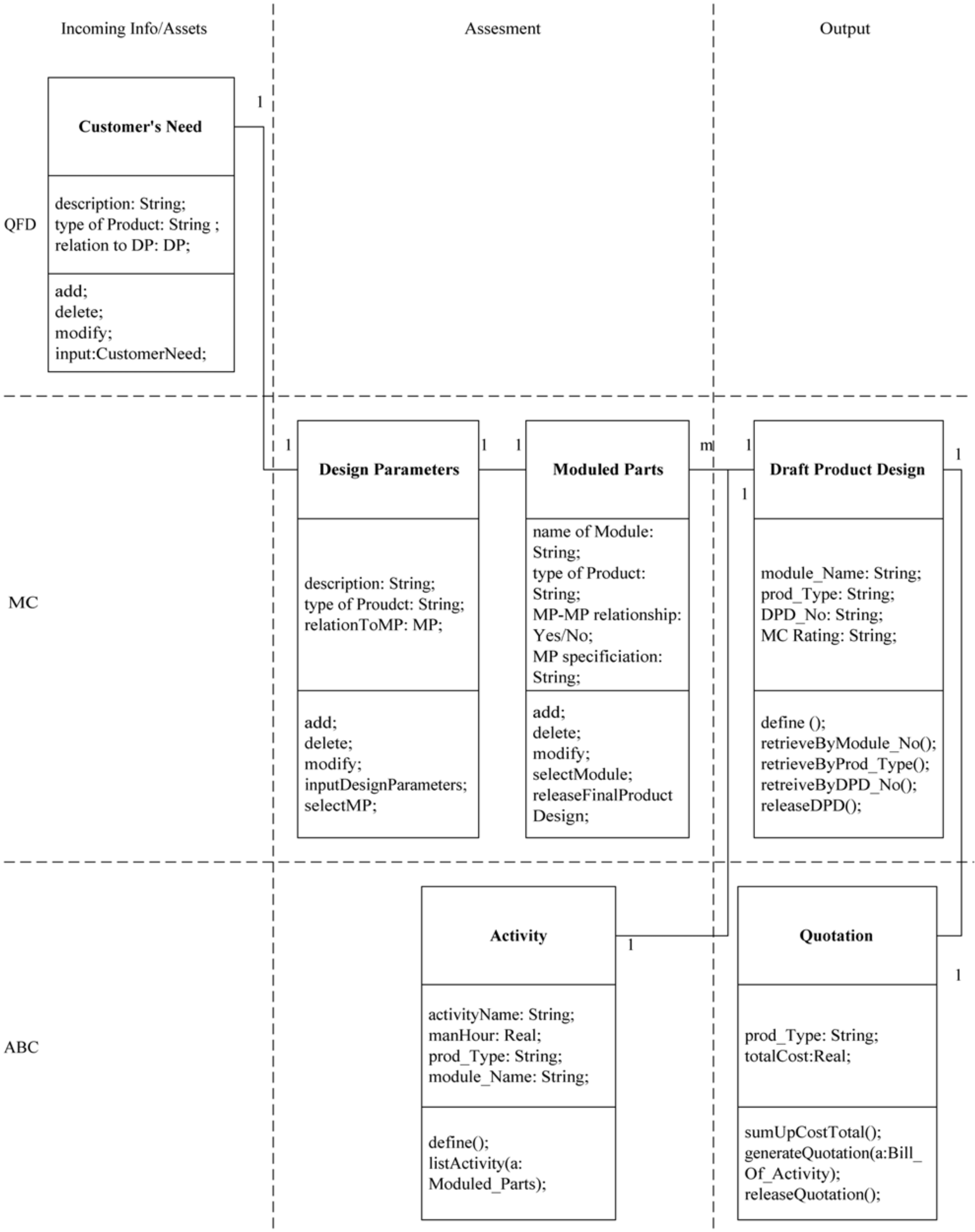

Figure 5.2 Structure of PSE Module

simulation system would be linked to the PSE module to produce a simulation of the product based on the configuration chosen by the customers. This provides real-time feedback to customers and also allows customers to re-customize the product until a satisfactory combination of product specification, time and cost is reached.

5.4 Process on Demand Module (POD Module)

5.4.1 Functions of POD Module

The Process on Demand Module (POD) applies the concept of modular product design to process management. The design of process modules includes identifying the type and characteristics of a process, the staff involved and their main tasks, decomposing the overall process into sub-processes, determining the objectives of modularization, representing the information of modules and then decomposing the whole product development into smaller process modules. By using the brick concept, the project manager can design the project plan to satisfy the customer’s multiple requirements, by selecting an optimum combination of process modules from a pool, such as good quality, short delivery time, light weight, small size and low cost. These are generated from the product specification enhancement module (PSE). The POD module plays the role of an integrator that combines data from various components (customer requirement from house of quality, cost from activity based costing) to generate process plans and schedules for product design projects.

5.4.2 Building Blocks of POD Module

Prior to the commencement of any development projects, a project schedule must be established. The Process on Demand Module shown in Figure 5.2 takes in customers’ requirements for a product design project and proposes a design process plan with time schedule, estimated cost and allocation of human resources. When ad hoc changes arise which require a change in the project schedule, the new requirements can be fed to the POD module which would propose a reconfigured schedule that caters for the new requirements.

The conceptual model of the POD module consists of building blocks of the re-configurable object repository and a data updating mechanism. Each of these building blocks is considered an object unit that interacts with other units through an inherent information exchange mechanism. The object repository can be described as the “warehouse” of the system. All information collected is stored in this object-oriented database. There are tentatively three object classes in the repository namely the Process Plan object class, the Humanware object class and the Product object class. The Process Plan object class repository is a collection of modular process plans which can be combined to form a master template for use by the planning personnel when formulating a process plan. The Humanware object class repository stores manpower information such as number of staff, their costs, locations, expertise, etc. whereas the Product object class stores information on product components products entered into the system includes product specification, time constraint, cost constraint, other situational constraints, etc. For any particular product design project, the output of the POD module would normally be a process plan and a resources allocation schedule. External to the POD module is a user interface through which users can input information into the system.

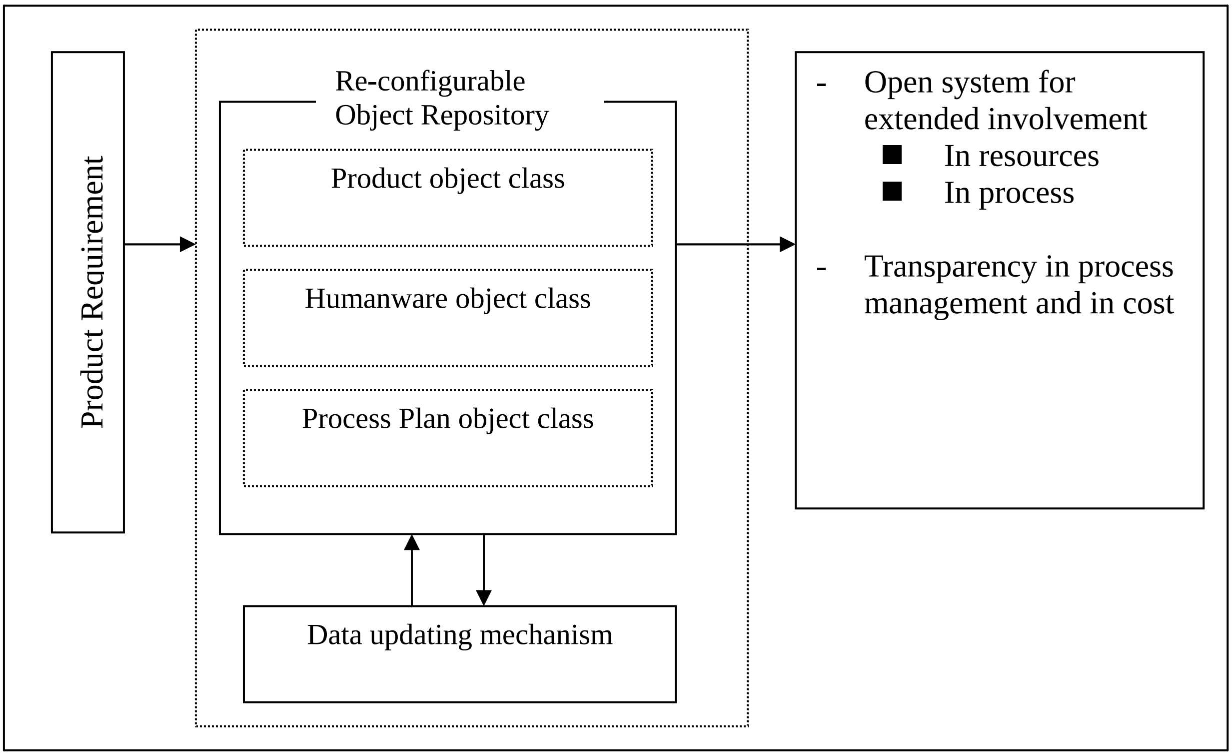

Figure 5.3 Structure of the POD Module

5.4.3 Deliverables of POD Module

The POD module operates within a Mass Customization environment in which products and processes are broken down into modules. It provides not only a product design schedule but also shows the time and cost components in relation to each design/development task module. Customers are able to adjust the time and/or cost components to suit their specific requirements. Each customization of the time and/or cost components would result in a different process and/or product configuration. Traditionally, the tasks involved in product design projects are usually processed sequentially. A task would not start until its up-line task is completed. With the advent of concurrent engineering, some tasks can be processed in a parallel manner thus reducing development time and improving the quality of the output. Modularization of products and processes provides the basic environment for design tasks to proceed in a fairly free and unrestricted manner. That is, tasks that have collected enough information can proceed first without having to wait for the completion of any up-line tasks. However, with the weakening of the inter-dependency between task modules, communication between modules must be strengthened to avoid error. The OT characteristics of polymorphism would help in this aspect. A single message is sent to the system and different objects would respond in different ways.

5.5 Chapter Summary and Discussion

This Chapter has outlined the structure and functions of the three modules which form the basis of CARDS, capitalizing on the adoption of object technology for the infrastructural design of these modules. It can be shown from the schematic diagrams of these modules that they are composed of various object classes, carrying various attributes and behaviors, thereby ensuring the seamless and flawless information exchange among themselves by virtue of the inherent features of objects, as explained in Chapter 4. As mentioned in the previous Chapter, these three modules are central to the development of CARDS which is meant to be truly flexible in dealing with different scenarios. This approach of integration of various modules is able to take advantage of the strengths and features of various classes (included in related modules) to achieve the objectives such as feature and process agility. It should be noted that for the efficient development of CARDS, the three modules also incorporate the good practices of MC, ABC and QFD so as to maximize the benefits of integration, thereby enhancing the performance of the system.

CHAPTER 6 IMPLEMENTATION OF CARDS

6.1 Introduction

In this chapter, discussion will focus on how CARDS is implemented in an enterprise. In Chapter 4, the design of CARDS and in Chapter 5, its further development, has been discussed. This chapter will deal with how to apply CARDS in enterprises for developing new products. We will explain the implementation procedures step-by-step. Furthermore, the dynamic integration and feedback loops of key modules in this holistic system will also be examined and elaborated.

From the survey of Chapter 3, it can be seen that many departments are involved in the product development process. These many stakeholders include top management as well as R&D, Engineering, Marketing, Production, Purchasing and Accounting departments, etc. One distinguished feature of the CARDS is its ability to have extended involvement of many working parties, including also outside ones, in the product development. Customers, vendors, or outside resources have a role to play. The extended involvement of parties outside enterprises makes this system unique and particularly effective in meeting market needs.

However, as the number of parties involved gets larger, sharing, translation and exchange of information between departments and between people will become more and more difficult and time consuming and less effective. Information may not pass through, or may be distorted when passing from one side to another. Also, workers may be overwhelmed by the burgeoning information coming in from all directions.

Enterprises are in need of a system for the seamless flow of information between departments, a system for departments to dispatch, exchange and collect information systematically and efficiently, so that each department may be able to collect the right kind of information for its own use. Through object technology, where people and process may be objectized, and together with UML modeling, the CARDS presents a holistic product development system where information may be processed and transferred seamlessly, so that all stakeholders can get involved closely in each stage of the development of the product.

6.2 Start-up Stage of CARDS

The start-up stage is an important initiation phase for the implementation of CARDS. This chapter presents an outline of the methodology that may be used to kick-off CARDS. A flexible team kicking-off system will be described and the issues about setting up achievable targets, identifying deliverables, building team for CARDS and its product development process overview will be illustrated in the following sections.

6.2.1 Identifying goals and deliverables

6.2.1.1 Identifying goals

The start-up stage is critical for the implementation of CARDS. Setting up clearly defined goals at the start can boost the staff's confidence to develop and effectively deploy CARDS. The goals of the CARDS implementation should match with individual company's direction and the top management's expectations. Long-term goals as well as short-term goals should be well articulated such that the staff can strive to achieve them together. Short-term goals are usually more dynamic and change according to the business environment whereas the long-term goals are usually more static in nature. Apart from identifying the long-term and short-term goals, an enterprise also needs to find out the sub-goals. As to “start from small” is easier, sub-goals should be set so that the corporate goals can be ultimately achieved. It is necessary to base the feasibility of achieving the goals on the predicted resources which can be acquired in the future. The middle management may lack confidence to achieve the goal under the predefined period so they may set goals which have already or nearly been achieved. In general, it is unwise to over-estimate the capability of enterprises and under-estimate the potential of staff.

6.2.1.2 Identifying deliverables

Having set the goals, company should consolidate functional operations and get acquainted with the exact deliverables. Similar to goal setting, deliverables should be clearly identified at the startup stage so that the staff can strive to achieve them. Then the quality of the deliverables can also act as a good performance measurement for the system. It is necessary to identify the deliverables at different stages of CARDS. The deliverables may vary from time to time as they are based on the changing requirements of customers. Since the whole product development process may take several months, technology push and customer pull may drive the enterprise to change the deliverables at different stages of product development. The deliverables of the CARDS should be allowed to be altered by the team providing such alterations are approved by top management. Staff would like to do less but top management wants to get more. As a result, deliverables should be clarified and mutually-agreed at the startup stage. Otherwise, conflicts may occur.

6.2.2 CARDS team formulation

6.2.2.1 Identifying the Champion of CARDS

The champion is similar to a Chief Operations Officer, who is responsible for motivating the project team to implement CARDS. The overall implementation schedule, budget and results should be formulated by the champion who has the authority to monitor the whole CARDS implementation process. The role of the champion is not only to steer the team to implement CARDS smoothly, but also to learn from previous mistakes and to motivate the team.

6.2.2.2 Selection of functional representative

Apart from the champion, functional representatives are needed in order to build a successful team. Usually, the departments of marketing, Research & Development and Information Technology should nominate at least one member of their staff to the team, as it helps to facilitate the working of the team to have a diversity of team members with different backgrounds, skills, functional disciplines and ways of thinking. In order to create synergy and avoid conflict in a cross-functional team, roles and responsibilities should be clearly stated and well-understood. Collaborative techniques and proper communication channels among different disciplines are necessary. Useful communication methods include regular meetings, telephone conversations, or e-mail for dispersed departments. Linking up different work done by different departments is usually the weak point and the cross-functional team should try to reach a consensus by taking into consideration others' perspectives and angles, and keeping in mind the interests of the organization as a whole instead of merely the benefits of individuals.

6.2.2.3 Enhancing background knowledge with training

Training on the CARDS concept is essential if staff is to acquire the fundamental concepts about QFD, Mass Customization, Activity Based Costing, object technology and Concurrent Engineering. Team members are also required to deploy soft skills such as authenticity listening on QFD since the initial step of QFD is to listen to the voices of customers and then translate customer requirements into technical product specifications. Training not only enhances the skills and lets team members learn the new concepts of various best practices, but also changes the mindset of team members.

6.2.2.4 Evaluation on the existing product development operation

A process map of existing designs and developments should be drawn so as to identify areas for improvement. In drawing the process map, the core process should be identified. Though a core process is important for a company it may not provide distinctive features. For instance, complying with safety regulations is important in designing a product, but a safe product may not help differentiate itself from others in the market. Only the manufacturing processes that can produce competitive products in terms of quality and service will be regarded as core processes.

Team members who are aware of the existence of problems should bring them out squarely. To identify inefficient processes, data can be collected to reflect the truth and help spot the weak areas that are in need of further improvement. Key performance indicators can be set as a quantitative measurement of quality, cost and time-to market. In order to compare the existing product development operations with those of CARDS, data should be collected prior to the implementation of CARDS so that the champion can better evaluate the achievements of CARDS.

6.3 Key Module Formulation Stage

6.3.1 Building of the Team Transformation Module

During the preparation stage of the TT Module, information should be gathered including inputs from the project proposal. Figure 6.1 shows how the TT Module is built with object-oriented analysis and design.

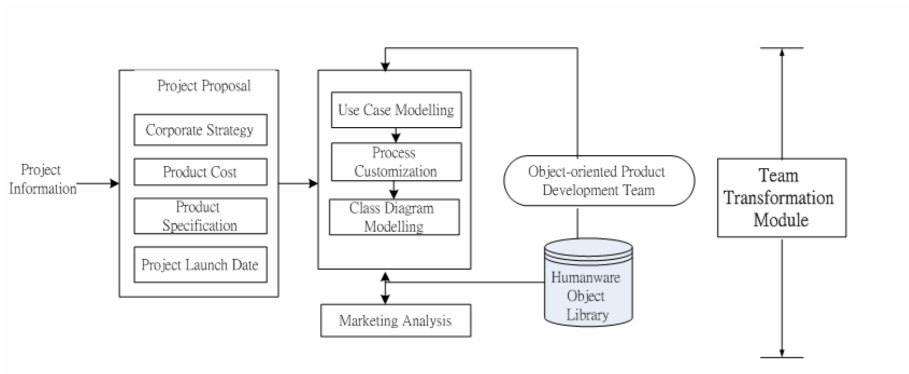

Figure 6.1 TT Module with object-oriented analysis and design

The project proposal provides basic information about corporate strategy, product cost, product specification, and project launch date. Generally, the targets on cost, quality and timing are required to satisfy the goals defined in the start-up stage. Use case modeling is focused on the usage of the system. The use cases provide an outside view of CARDS and when the services been carried out by the system. The following tasks are carried out in use cases.

(a) Authenticate the name---It is necessary to authenticate a meaningful name for the use case. That means the name should be specific enough to identify its nature and simple enough for understanding what use cases can be used for.

(b) Write a narrative description---A description should be written so as to let CARDS developers understand the inter-relationship of different actors and the responsibility of each actor, where an actor can be a person, an organization, or another system.

(c) Understand the inheritance among actors---It is found that the inheritance, which has similar attributes and properties, may be shared by a group of actors. Those objects are grouped as classes. Having identified the relationship among actors, system developers can reuse the actors according to their inherited features and behaviors.

Use case describes the initial state, procedure, final state and the involved actors. After analyzing the real interaction of the system and users, process customization is carried out in order to reengineer the process to make it fit the system and the humanware. Each process is modified to fit each actor and to co-ordinate with different sub-system/modules. This is necessary for optimizing the workforce of diverse groups in an organization. It is found that some top management does not want to customize the process but they want to ask humanware to change their working habits to adapt to the new system. However, forcing the staff to change their working habits may sometimes be counter-productive and make the situation worse. Therefore, customizing the process by aligning the working habit and staff's culture with the goals or sub-goals of the system and modules may be greatly beneficial to the organization and achieve higher organizational agility.

The class diagram is constructed by modeling the interaction between humans and process with object-oriented modeling. The noun and verb in narrative description will become the object and behavior in the class diagram. After the behaviors of the actors in the customized process are identified with the "staff skill and process description matrix" shown in Figure 6.1, the object-oriented product development team is formed and the humanware library is created by modeling the organization structure in class diagram.

Table 6.1 Staff Skill and process description matrix

	Staff 1	Staff 2	…………Staff n
Process A	B/P	B/P	
Process B	B/P	B/P	
… Process n.			

B---Behavior P---Property

The PSE Module can be built with clear goals which are specified after conducting an analysis. Strategies can then be formed to achieve the sub-goals of each module. The QFD cycle and MC cycle are two virtual cycles of activity which help management to balance innovation, production costs and time to market in an agile organization. Figure 6.2 shows the major components for implementing the PSE Module.

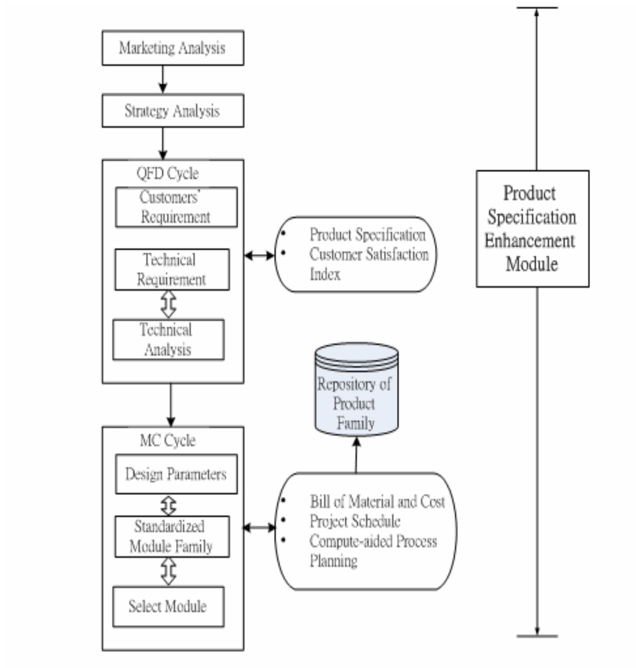

Figure 6.2 The major components for implementing the PSE module

6.3.2 Building of Product Specification Enhancement Module

6.3.2.1 Marketing Analysis and Strategy Formulation

Innovative products and breakout ideas do not come from nothing. A detailed marketing analysis is required to position products in the anticipated market segments excellent market insight, together with clear strategy, is the basic element that provides breakthrough innovation. Dr Coppendale, John (2004) stated that "Launch of breakout products generates a disproportionately high share of its total profit compared to incremental evolution".

6.3.2.2 Deployment of QFD

Three major processes are found in the QFD cycle:

(i) Collecting customer requirements

The customer requirements can be collected by reviewing the relevant documents such as requests for proposals, requests for quotations, contracts, customer specification documents, customer meetings/interviews, focus groups/clinics, user groups, surveys, observation, suggestions, and feedback from the field. That information is then sorted and ranked with ranking technique and paired comparisons so as to find out the priority of customers' needs. The inter-relationships of customer requirements are realized and organized using affinity diagrams and object models.

(ii) Transforming Technical Requirements

Technical characteristics from customer needs (Product Planning Matrix) are derived when such technical requirements are clearly understood by engineers or technicians. Technical requirements should be categorized or classified into different classes and co-related with the customers' needs. It is usual that one customers' needs will be translated to more than one technical requirement. For example, the customer requirement (low reflection) may be converted to two technical requirements/high level requirements (end finish technique and roundness). A number or a symbol is used to indicate the strength of the relationship. Typical symbols for indicating the strength is shown below:

⊙Strong relationship ○Medium Relationship ∆Weak Relationship

(iii) Conducting a Technical Analysis

A thorough technical analysis is carried out by experimental testing, rapid prototyping and simulation. Apart from scientific measurement, technical analysis can be done by the experience or intuition of experts. Reviewing the past records or failure mode analysis of the previous similar products can also give engineers some insights into how to avoid repeating past failures. For critical assemblies or parts, part characteristics are produced by appropriate process planning. A suitable manufacturing process or the route of production is determined in order to meet these assembly or part characteristics. With these process steps in mind, the necessary set-up requirements, process controls and quality controls are then determined to assure achievement of these critical assembly or part characteristics. The optimum solution is found by evaluating the proposed design concept by referring to the concept selection matrix. The system concept and architecture are then divided into subsystems and the technical characteristics are embedded into these subsystems or assemblies.

The QFD cycle is iterative in the sense that the processes within QFD do not proceed in one direction but are bi-directional. The customer requirement from the OEM subcontractor is first drafted and sent to the enterprise which transforms the client’s requirement into technical specifications. The enterprise then evaluates the feasibility of producing the products or services with its capacity of production sites and labor. If the enterprise considers that the product cannot be fabricated due to the constraints of its existing capacity or resources, it will negotiate with its customers and may provide some counter-proposals for their consideration. If customers do not agree with the product specification, the enterprise will modify the terms until the customers accept them. As both parties reach a consensus, a product specification is finalized and a related customer satisfaction index is designed. The customer satisfaction index acts as a checklist to validate the customer requirement as stated in the product specification.

(iv) Weighting considerations

There is always a trade-off between product features, cost and development time that the management needs to balance and make decisions on. This is reflected in selecting the various weightings when applying the QFD. The weighting selection has to take into account a number of important considerations. Also, the weighting selection needs to go through a working process which involves top management, customers and the whole project team. Steps need to be taken are as follows:

(a) Setting corporate strategy

The first and foremost consideration in setting the weightings would be to refer to the corporate strategy. That is - what does the company want to achieve with the new product? What competitive strategies is the company planning to adopt in marketing the new product? If the company is looking for a good brand name at all costs, then the product features would be assigned a much greater weighting than the cost and development time. On the other hand, if the competitive strategy is to reap for a large market share by venturing into the market at the earliest possible time, then development time would be of greater weighting. If competition is on cost base, cost weighting would be higher. It is therefore the corporate strategy that defines the initial weightings to be allocated in the QFD cycle.

Also, the top management needs to define the market segment and thus the targeted and potential customers. A number of these customers are then selected from different strata and different levels so that a more balanced and representative customer base may be formed. In this way, a more balanced and non-biased view may be obtained.

(b) Seeking views of the customer

The next stage would be to have the customers fully express their views and voice about what kind of new products they desire, what features they prefer most, and what price range they will take. Also, customers' view on the product's time to market may be assessed and see how much time they are willing to wait, and what the significance of that time would be.

Customers are asked to select the weightings they think will correctly reflect their preferences. Different views and weightings are sought from different customers and then an average or balance view may be assessed.

(c) Project team deliberation and consensus

After obtaining the customers voice and with the corporate strategy in mind, the weightings are carefully examined and considered by the project team. Technical difficulties and considerations such as resources available and costs constraints are putting together in deliberating if the selected weightings are appropriate and workable, and if further fine tuning of weightings is necessary. Various inputs from different departments with various expertise are carefully considered. The feasibility of the weightings must be assessed, and a conclusion is made about the tentative weightings to be assigned.

(d) Feedback loop to the top management and customers for further review and revaluation

After the initial round of weighting selection, the tentative agreed weightings will be sent back to the top management for further assessment. This is to make sure that the agreed weightings will match well with the corporate strategies, and that the weightings will not end up with products wide out of mark as far as the company's resources or the future pricing are concerned.

The customers will have another look at the concluded weightings so that they will have a second say on the result formed. In case the weightings are not satisfactory to them, the selection process will continue until a stage is reached where all parties agree on one consensus. This will then be the final weightings adopted.

6.3.2.3 Deployment of MC

Mass Customization is the new paradigm of production that provides growing product variety in the customer-oriented market. Mass production is no longer suitable for today's turbulent markets as customer's taste changes frequently and competitors are keen on introducing new products in order to get a larger market share. The implementation of MC in the PSE module includes the following steps:

Step 1: Design practitioners need to break down the product specification into various design parameters including function, appearance, form, size and material. Design parameters should truly reflect the value provided for customers and the value has a unique interpretation across various disciplines. E.g. the customers would like to have light weight product. Mechanical department may design the light weight product by reducing the padding thickness while R&D department may test the hardness weight and webbing strength of the prototype. The design parameters should be categorized systematically by examining the association (generalization and specification) of sub-classes.

Step 2: Group technology is used. In order the design features are standardized and to enhance the production efficiency the product family is fabricated together using similar production technology. Some design parameters may be reused frequently and so standard parts that fulfill those design features are designed.

Step 3: By modifying the design parameters standard components interact with other sub-assembly components and this may lead to product varieties. Selection of an appropriate module is crucial for the success of the implementation of the MC cycle. Six categories of modularity, component-sharing modularity, component-swapping modularity, cut-to-fit modularity, mix modularity, bus modularity and sectional modularity are listed and depicted in Chapter 4. Compatibility is the main concern of modularity selection.

Step 4: Careful managing of the interfaces between modules is essential; Developers should consider the interfaces and interconnections between modules.

The above procedures in MC cycle will be processed in both forward and backward directions until a feasible and clear project schedule is developed. A bill of materials, the project schedule and the estimated product development cost are obtained and the information is stored in the repository of the product family.

6.3.3 Building of the Process on Demand Module

The Process on Demand Module consists of the MC cycle and the ABC cycle. Figure

6.3 shows the major components of the Process on Demand Module which help it to achieve process agility.

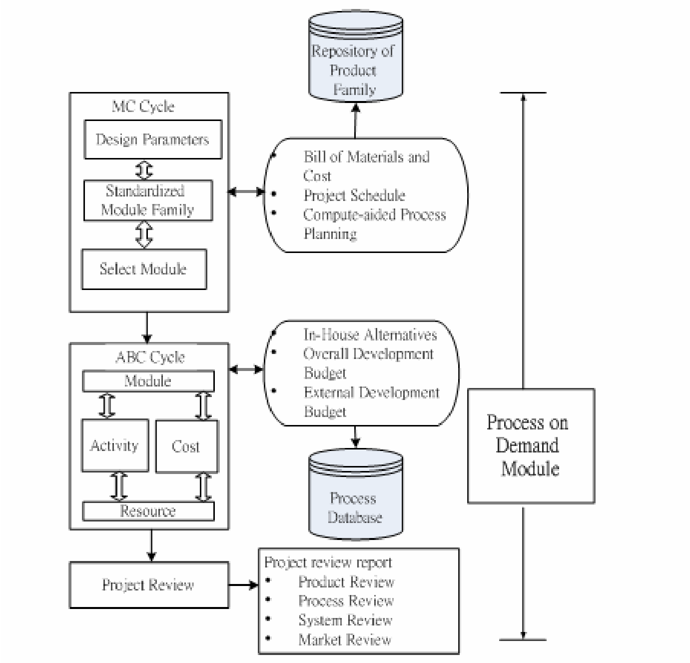

Figure 6.3 The major components of the Process on Demand Module

In applying Group Technology (GT) to the Mass Customization (MC) paradigm, design parameters or attributes should be considered first. GT is a technique for manufacturing small batches of goods with similar processes, dissimilar materials and dimensions, and which are manufactured using cells of machines grouped together physically. Therefore, similar products can be grouped together, treated as a product family and manufactured in a group of machine cells. When implementing GT, a coding system for the systematic classification of part numbers is necessary. The reason for classifying parts by their design parameters is to standardize the design of GT. Design parameters include geometric shape, dimension, material type and other environmental factors such as function and surface finish etc. Through investigating the sequence of operations and product types, process engineers should decide the design parameters in order to plan GT in the best way. Once GT is implemented, the traditional functional arrangement of equipment is changed to a machine cell arrangement. Traditionally, all the functional machines such as lathes are located together and all the milling machines are grouped together, etc. The arrangement results in a lot of complex material flow which includes backtracking. This makes the time of material flow longer and so increases the time of Work-In-Progress (WIP). Therefore manufacturers need to limit the variety of products produced, otherwise, bottlenecks of machine centers may occur and the overall throughput of production will decrease and thus the production efficiency will be reduced. On the other hand, equipment arrangements based on the use of GT concepts results in relatively smoother material flow and reduce the time of material flow. The path of material flow is clear. Therefore manufacturers can develop large variety of products in the GT layout. They can classify the products into several product families and manufacture each family in different, logical, machine cells. Moreover, as the overall efficiency of the whole production system increases, this reduces the overall production throughput time including both the productive and non-productive time (waiting time, queuing time and moving time). The overall production lead time is also reduced by the use of GT and hence the factory can achieve the objective of Mass Customization which is to manufacture a large variety of products in large quantities.

Activity-Based Costing (ABC) is a company-wide cost analysis method to evaluate the overhead costs such as water, electricity and rent etc. The fundamental principle is to use a resource driver and apply it to each overhead expense that is linked to the manufacturing process and to allocate the overhead cost to different activities. Therefore the costing engineer can make use of this data to evaluate the product cost more accurately. The costing engineer has first to establish different resource drivers for different specific overhead costs. ABC analysis, which assigns the cost based on activity rather than products or service, lets top management realize which activity has the highest cost. By allocating the overhead cost to production activities, the company can obtain cost management results and make decisions regarding in-house alternatives, the overall product or process development budget, and the external development budget. The analysis data, which is stored in a process database, can be retrieved at any time to facilitate further processing and analysis.

6.4 Integrated system implementation

There are lots of change requests triggered by customers, suppliers or sub-contractors and numerous unknown variables continuously permeate product development processes. Due to the iterative nature of product development, design practitioners and engineers may frequently get confused during project implementation and that leads to waste of engineering resources. An unambiguous implementation framework of CARDS helps engineers fully understand the status of the product development. In order to build up an integrated system and provide a clear picture about the interconnection among the three modules, Figure 6.4 shows the building blocks for CARDS implementation. Information is exchanged within the components of the three modules. The efficiency of an object-oriented product development team can be significantly enhanced by understanding the customers' needs and knowing how to respond to the dynamic market. "Doing the right thing at the right time" is the ideal; but it is almost impossible that the product development team can do the right thing the first time. So, a loop for responding to change requests is created in order to enhance the enterprise's overall agility. As mentioned in Chapter 4, organization agility, process agility and feature agility are achieved by CARDS. There are five loops found in Figure 6.4 where the first loop caters for job allocation for the experts, so as to achieve organizational agility. The second loop is used to handle feature changes; and here the QFD cycle is proposed for achieving feature agility. The third loop is used to cope with change requests where the MC cycle is used to provide for both feature and process agility. The fourth loop caters for the change requests by production engineers and in it, the ABC cycle manages the resources efficiently so as to add value without adding costs. The fifth loop is for total quality improvement. Since time is the most valuable commodity, the categorized changes are undertaken in the specified loops in order to minimize the impact and rework on other activities. The project review is carried out and four aspects (product review, process review, system review as well as market review) are studied before production is started in the manufacturing firms. To quickly respond to changes, mastering updated information can facilitate effective communication which is important for achieving the collaboration of cross-functional teams and between business partners. Information exchange across various modules not only allows team members to react to sudden changes proactively, but also lets management have a better understanding about the market trend.

6.5 System Validation and Modification

6.5.1 Evaluation of the overall performance

The first step is to evaluate the true level of effectiveness of CARDS in product design and development, by way of rapid assessment of the efficiency of information exchange, especially the data communication among various disciplines at various stages of the product development cycles. The basic product development cycle starts from project proposal and proceeds to conceptual design, detailed design and process planning and finally product launch. Different processes or design parameters may be

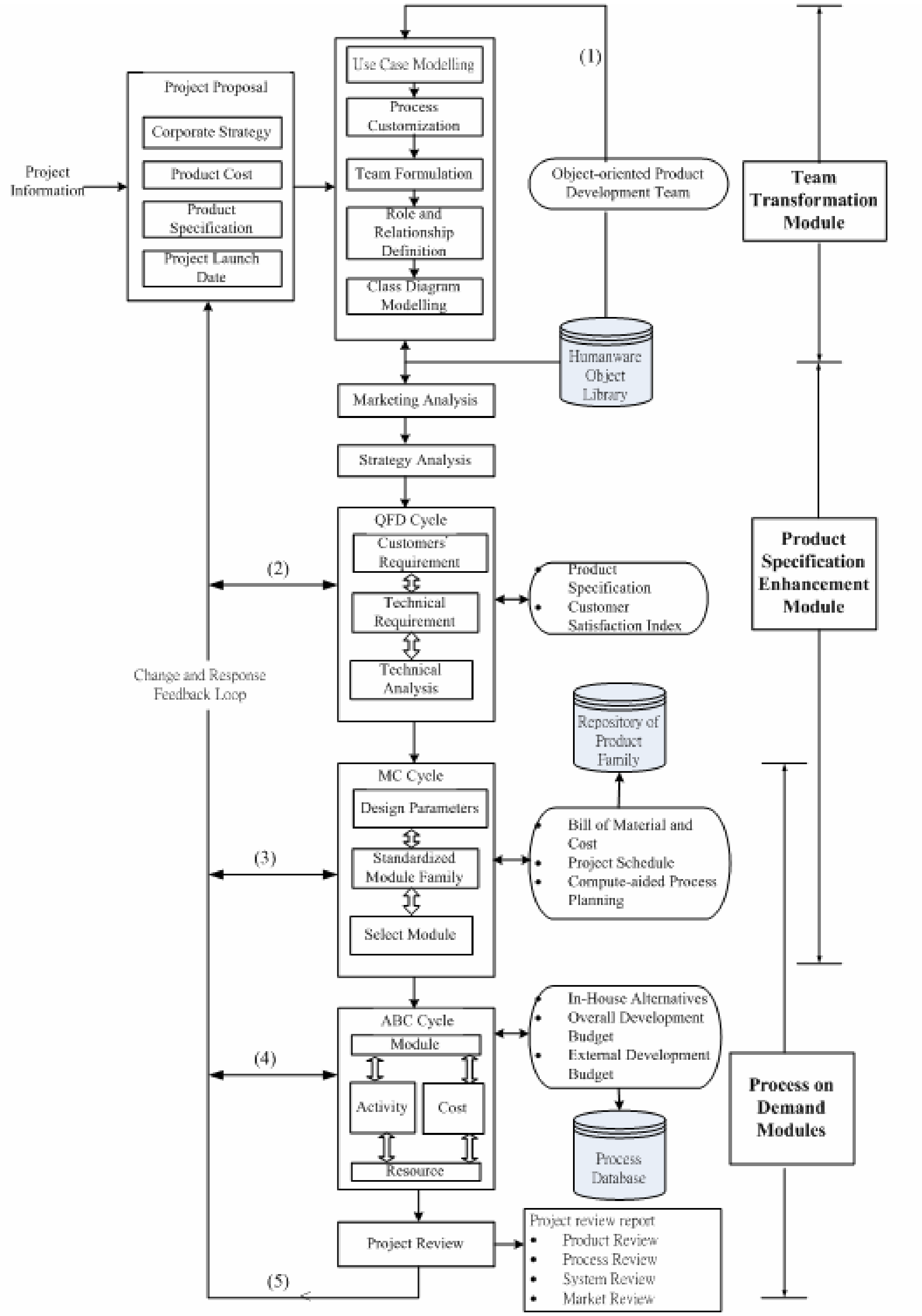

Figure 6.4 the integrated implementation approach of CARDS

tested under different assumptions or conditions. Both quantitative and qualitative analyses are conducted to evaluate the performance of CARDS. Quantitative analysis includes time work study and costs of quality study. Time study is a work measurement technique which let management clearly see the duration of each stage and how team members allocate their time on the corresponding activities. The cost of quality is also correlated with the cost of poor quality and consists of those costs which are generated as a result of producing defective material. The cost of productive, preventive as well as corrective activities can be calculated using the ABC analysis. The qualitative measurement is conducted by interviewing team members and evaluating the SWOT (Strength, Weakness, Opportunity, Threat) analysis.

The overall performance of CARDS can be measured with quantitative criteria like time to respond to market changes, product development time and duration of project delay. CARDS can reduce the time needed to respond to external market changes as well as product development time so that the company can launch a new product that adapts to more changes within a shorter period of time. In addition, the company can shorten the time of project delay and meet better the production schedule. Therefore, the new product can enjoy the advantage of being the first in the market or be launched right at the peak season And thus be able to capture a higher market share.

6.5.2 Evaluation of Customizability

A thorough assessment of the customizability of the objectized team formation is checked to find out whether the system architecture is customizable for different projects or different products. To assess the customizability of CARDS, different industries should be selected for CARDS implementation. GSL and E-Talent, which produce electronic products and software development services respectively, have been chosen for testing the customizability of CARDS. The system is tested in two different environments and three major cycles including QFD cycle, MC cycle and ABC cycle are tested for customizability. Interviews with design practitioners are conducted to validate the customizability of CARDS.

In the QFD cycle, GSL makes use of QFD to collect the opinions of customers for the purposes of product development. On the other hand, the QFD cycle is also customized to help E-Talent to provide services for customers. In the MC cycle, GSL deploys MC with standardized modules for manufacturing products, which are also suitable for customers. In the MC cycle, GSL deploys MC for enhancing production efficiency by customizing the products through adjusting the variables so as to meet the consumers' needs. Apart from parameter adjustments, products can be customized by modular customization. During software development, the programmers of E-Talent can write the code in modules (classes or objects) that can be combined into various combinations and E-Talent can customize their software development process with modular customization. In the ABC cycle, the calculation of activity costing can be applied to all industries and the costing of activities can be tailor-made for the needs of various industries.

QFD, MC and ABC are best practices, and are generic enough to apply to different industries. The case study discussed in Chapter 7 shows how CARDS is customized for deploying not only in GSL, but also in E-Talent.

6.5.3 Evaluation of Reconfiguration

Reconfiguration of a model is carried out in order to support one particular class, object or module and move it from one system unit to another unit for the purpose of providing different solutions. One unit cannot fit all. Reconfiguration is the ability to modify one unit so as to make it suitable for use in other units. Since QFD, MC and ABC have been objectized, the objectized unit has the characteristic of being reconfigurable. To evaluate the reconfiguration of CARDS, the following test is undertaken to find out whether (i) the process in the POD module can be broken down into small processes or whether (ii) the standard or rule is clearly defined in-between each sub-process so as to reduce interdependence of the sub-processes. Two main tasks are conducted to validate the reconfigurability of CARDS. Firstly, data is collected from each individual unit. Secondly, the composition of the decomposed unit is determined. The reconfiguration of different modules can be measured by using the module or objects in other system units.

6.5.4 Evaluation of Agility

Customers expectations are getting higher and higher and they would like to have more product functions or features. The customer satisfaction index can reflect the feature agility achieved by enterprises. Feature agility can be examined by finding out (i) the number of alternative features provided for customers, (ii) the number of features that can be applied to other products, (iii) the number of features that fulfill customers' needs and (iv) the number of modular parts built for each product in the repository of product family. Questionnaires and feedback forms are collected to reflect the voices of customers.

Process agility can be evaluated by the time-to-market span and the adaptability of the company to implement design changes or engineering changes as well as the number of sub-process built in the process database. Project schedule performance such as actual, versus planned checkpoint dates and schedule performance factors, can be used as an indicator for process agility.

Organizational agility can be assessed by the financial performance which is the fruitful result of an organization that has a fast response. The typical financial performance is determined by comparing the estimated budget with the actual returns and the breakeven time. In performance review, key duties and specific work objectives of each member of staff are evaluated. Assessment of achievements against planned targets helps gather information on variance and on the reasons behind discrepancies. Also a knowledge repository is created to store the domain knowledge that may provide guidance for junior staff in handling complex product portfolios. If team members are passive this usually becomes a roadblock for responding to change requests. A progressive mentality and mindset should be cultivated so as to make team members willing to face new challenges. Additionally, a kind of agile organization culture should be fostered such that all team members have a positive attitude towards responding to change requests in the development portfolio. This will help maintain the team's productivity. The organizational agility can be evaluated through the successful development of a dynamic object-oriented workforce in the humanware library.

For external collaboration agility, it can be evaluated by the number of strategic partners in the outsourcing partner library. The more potential partners in the outsourcing partner library of the company are, the better the company can source for relevant expertise to solve problems. It improves the company's agility in the end.

After system evaluation, areas for improvement are pinpointed and modifications are carried out through prioritizing opportunities and resolving problems found in the complex product development cycle.

6.6 Chapter Summary

This chapter outlines the implementation of three modules which form the basis of CARDS, capitalizing on the adoption of use case to analyze the design of these modules. Figure 6.4 shows the implementation of three modules and the human object library, repository of product family and process database. Storing the value information at different stages of product development while the seamless information is exchanged in a looping cycle of activities is also shown. As mentioned in the previous chapter, these three modules are central to the development of CARDS which is aimed at handling changes systematically. This integrated approach to the implementation of the various modules of CARD helps achieve the goals of feature agility, process agility and organizational agility. The implementation of CARDS consists of mainly three iterative cycles of MC, ABC and QFD which are carried out to cope with change requests. A method of evaluation is also introduced to validate the customizability, reconfigurability and agility of CARDS and modification can then be performed for attaining the goal of continuous improvement.

CHAPTER 7 CASE STUDIES

7.1 Introduction

This chapter presents two case studies, in which CARDS is implemented in Group Sense Limited (GSL) and in E-Talent Software Company with the aim of improving their product development processes. The system is introduced so as to allow the firms to take hold of any foreseeable business opportunities as well as to meet head-on with any challenges in the increasingly competitive global market. By implementing CARDS in the case studies, the feasibility of CARDS in a real world business setting may be tested and the system may be validated. This chapter will present step by step how CARDS is implemented in a real world setting, with the implementation steps following those laid down in Chapter Six. Certain details are simplified in this report too comply with the provisions of a confidentiality agreement with the companies concerned.

7.2 Case One – Group Sense Limited

7.2.1 Company Background

Group Sense Limited was founded in June 1988. The company grew rapidly from 6 engineers at the beginning to almost 4500 staff now (2005). The company-owned manufacturing plant is located in Dongguan in South China. It has an R&D network in HK, Singapore, Beijing and Taiwan. The company believes that customer satisfaction and product innovation are two of the key factors for a company’s success. GSL provides handheld products for different customer segments. These products are used to acquire and utilize information in a convenient and expeditious manner for education, entertainment, data storage and communication purposes. GSL creates value through continuous innovation, short time-to-market and customer-delighting products and services.

7.2.2 Goals and Expected Deliverables of GSL

The mission of GSL is to provide value-added services to its customers through continuous innovation and customer-delighting products coupled with a short time-to-market policy. In order to achieve this mission and to sustain and leverage its competitive advantage in the market, GSL focuses strongly on continuous improvement of its business operations As a result, it actively pursues and incorporates all possible kinds of organizational and operational changes that can bring about benefits to its products as well as improve its services. Apart from adopting an approach that fosters necessary and timely changes within the company, GSL also cultivates an ability to discern and to accommodate customer preference alterations in the marketplace. This rapid shift in customer tastes drives GSL to continuously review their products in progress.

The company expects the following deliverables from this project:

(i) To shorten the project time from 12 months to 6 months

(ii) To meet the expectation of customers

(iii) To build up a self-managing and self-monitoring working team

7.2.3 Formation of CARDS Team in GSL

As a means to verify the feasibility of the CARDS in an actual industrial setting, a preliminary system prototype has been developed with the support of a system implementation team, whose major job is to manage, control and monitor the progress of the whole project. Team members are composed of representatives from each of the major operating segments of the organization. This includes personnel from the following areas:

(i) Management

(ii) Purchasing

(iii) Industrial Design

(iv) Mechanical Design

(v) Electronic Design

(vi) Marketing

All members of the team are expected to participate actively. The designated champion of CARDS is the system manager. The purpose of the champion is to make it possible for each member to make a maximum contribution. One of the champion's important skills is his/her ability to chair meetings. Chairing, in a broad sense, involves more than just conducting the meetings. Some of the responsibilities are: preplanning for a successful meeting, budgeting time, starting and stopping on time, ensuring that each member is provided with agendas well in advance of each meeting, ensuring that each member participates, and ensuring that records are kept. Although this is not a full-scale test, it manages to provide some insights relating to the proposed approach. The selected reference site is the PDA Strategic Business Unit, which deals with one of the mainstream products of the company. The products are sold all over the world and new models are launched from time to time to meet market demand. This particular business unit is selected for the test.

7.2.4 Evaluation on the Existing Product Development Operation

The existing approach to handle product design may not be appropriate in the current operational environment. Currently, new product development goes through various stages of sequential operations from the conceptual design to prototyping as shown in Figure 7.1.

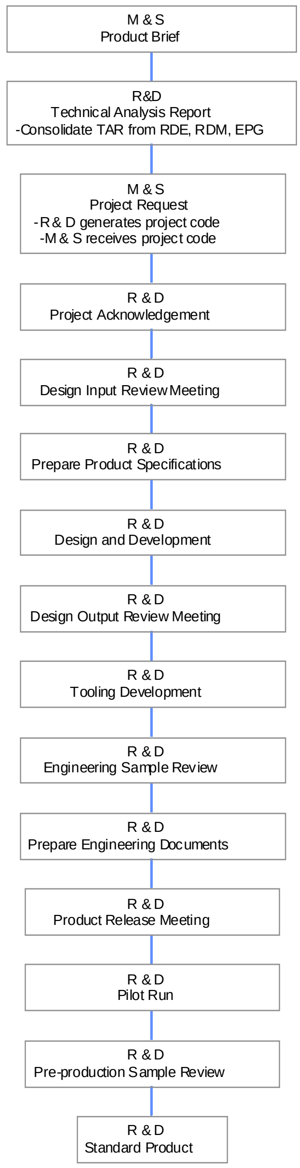

Figure 7.1 Existing Product Development Process

Normally, the product development cycle for consumer products, such as the Personal Digital Assistant (PDA), lasts more than a year using this approach. Before the implementation of CARDS in the company, projects had been seriously delayed due to a continuous need to react to changes in customers' requirements. Obviously, it is quite difficult to compress the product development cycle from 12 months to six months which is the company's target.. The previous functional departments are inflexible and it is difficult to accommodate any unexpected changes because each department can start its new work only after the completion of its previous project. As a result, changes in say product features, are difficult to cater for though they are in accordance with the market's demand. In order to speed up the project process, CARDS is therefore designed to handle increasingly varying customer demands in a cost-effective way.

7.2.5 Key Modules Formulation Stage

7.2.5.1 Building of Team Transformation Module

The first stage in product design and development is product definition. There are two main steps – project team formulation and preparation of the product specifications. This team has to work extensively with many business partners, including several world-class technology companies, on technology co-operation and alliances. Therefore, the product types are not only limited to their own brand ones, but also include some OEMs. Each customer has different requirements and has different levels of involvement in the project development stage. Also, each product has a unique project schedule and plan resulting in differentiation in resources and in staff involvement. To align with different project processes, the team will be formed by using varieties of object combinations tailor-made to suit their constantly-changing requirements. Examples of different project team structures are shown in Figures 7.2 and 7.3. Figure 7.2 shows the staffs working relationship and tasks involved in developing an own brand product for GSL company. V88 is a Personal Date Assistant (PDA) Device, which is designed and developed by PDA Strategic Business Unit (SBU). Figure 7.3 shows the staffs working relationship and tasks involved in developing an OEM product for Sharp Company. This OEM product is manufactured by OEM Strategic Business Unit (SBU) of GSL. The industrial design, mechanical design and software design are provided by Sharp (Japan) Limited Company. Referring to the diagrams, the different workflows of different product structures can be formed and understood easily. With the business unit modelling technique, the knowledge information kept in the data repository can be reused and reconfigured to cope with the rapid change of customer demands.

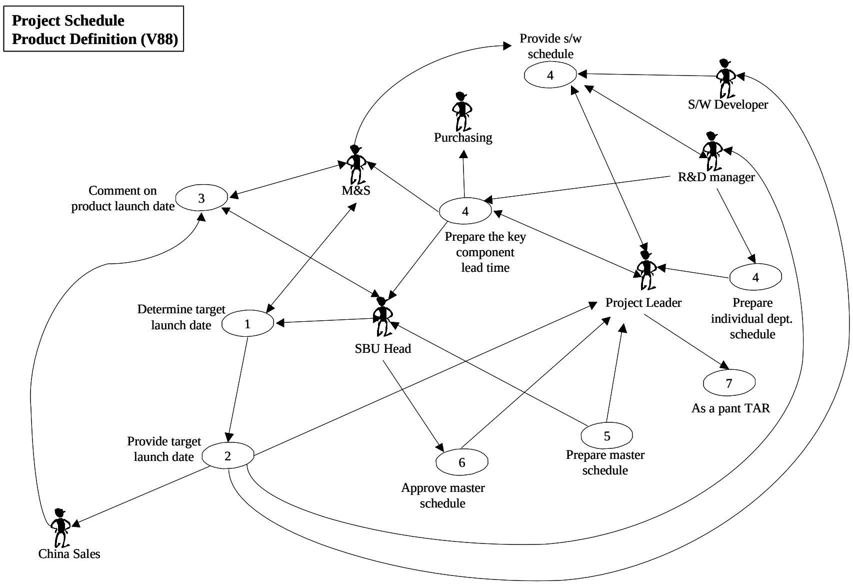

Figure 7.2 “Use Case” Diagram of Own Brand Product (V88)

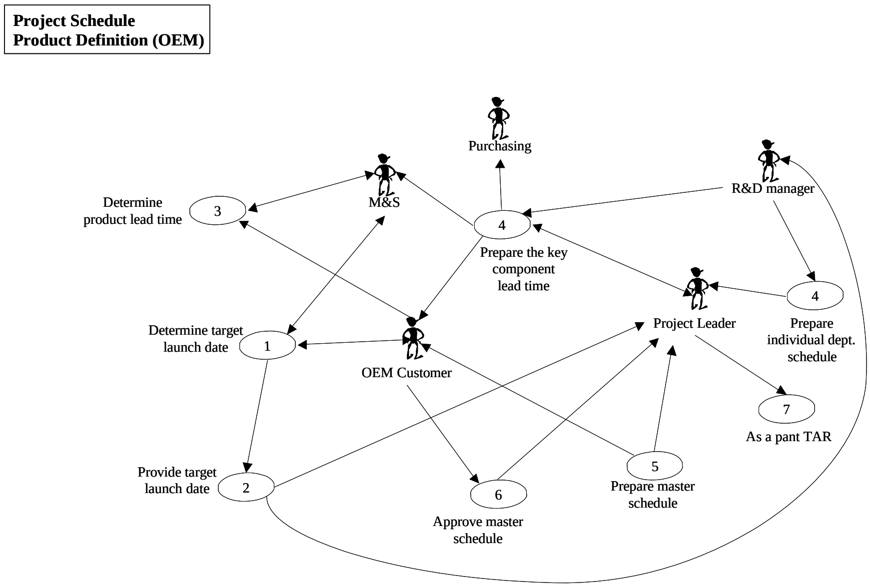

Figure 7.3 “Use Case” Diagram of OEM Product

7.2.5.2 Building of Product Specification Enhancement Module

From time to time, GSL receives product specification requests from customers, and these include important product information like customer wants, technological innovations and competition analysis. The Product Specification Enhancement module is developed to handle and manage all this important product information in a systematic way. Here, Quality Function Deployment (QFD) can be deployed to define and confirm these needs, which should be converted into appropriate technical or functional requirements for each stage of product development and production (i.e. market strategies, product design and engineering, product evaluation). The product requirement defined by QFD provides a graphical means of relating customer requirements to attributes that the project engineer understands. Each functional requirement defines the minimum acceptable durability and ideal durability.

Users are required to follow the 11 steps of Methodology as mentioned in Chapter 4, and to build the HOQ prototype with the relevant display data. As shown in Figure

7.4, the highest Absolute Weight and Relative Weight for Design Requirements go to aluminium with scores of 252 and 340 respectively. The top three highest Absolute Weight for Customer Requirements go to Reasonable Cost, Aerodynamic Look and Light Weight with scores of 12, 16 and 10 respectively. After forming the HOQ matrix, related information regarding the customer feedback and product characteristics is collected. These are customer requirements, design requirements, relationship matrix, correlation matrix, customer importance, absolute importance, competitor analysis, technical competitive analysis and ranking. And then, staff organize everything prior to the review. Some extra parts, such as the card box package, may then be deleted, simplifying the work of the graphic designer. As a result, the customer can get their custom designed PDA at a reasonable price. The company can produce exactly what customers want, within the limits of the availability of corporate resources.

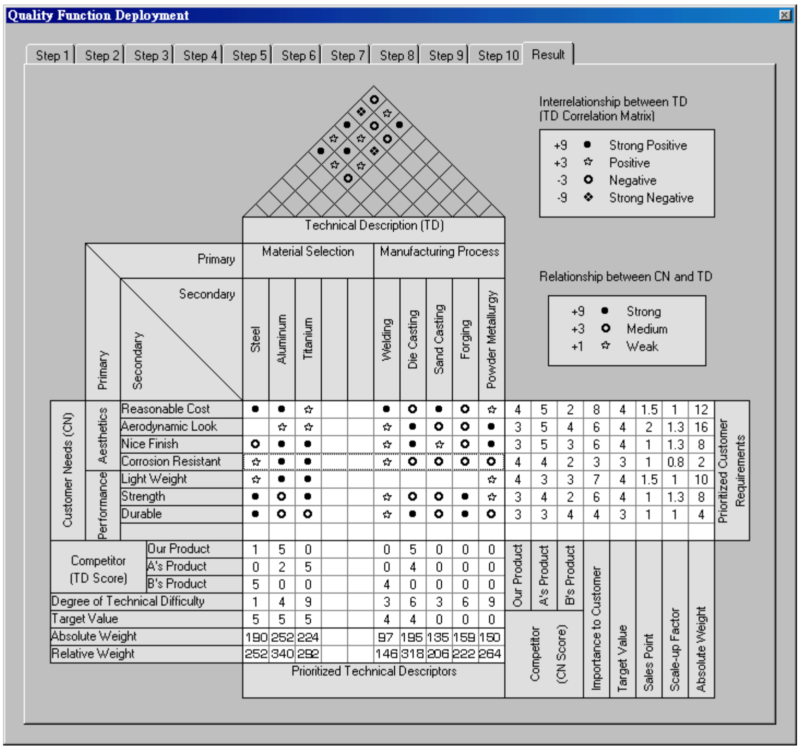

Figure 7.4 Result of HOQ Analysis

Product requirements describe and record all explicit requirements for batteries, which are defined by QFD. The MC model is then performed providing customer satisfaction with increasing variety and customisation without a corresponding increase in cost and lead time. The key concept of Design For Mass Customisation (DFMC) is the use of a family-based design approach. In this approach similar designs and production processes with past products are identified and exploited For production of the PDA product, five basic modules are identified including LCD module, Top Cabinet module, Bottom Cabinet module, Battery module and Docking module. The modules are shown in table 6.1 and an example of the MC list is shown in Figure 7.5.

Table 7.1 Module List of PDA Product

Module 1 (LCD Module)	Module 2 (Top cab. Module)	Module 3 (Bottom Cab.)	Module 4 (Battery)	Module 5 (Docking)
Rubber Pad Mount Brackets PVC Icon Heat seal Paper 1 Heat seal Paper 2 Touch Panel LCD	1. Top Cab. 2. Cover 3. Hinge 4. Left-track 5. Right-track 6. Pen End Shaft 7. Pen-Top 8. Pen-Mid 9. REC Button 10. Silicon Key Pad (Handle)	1. Rubber foot 2. ABS cover Pin-up 3. ABS cover Pin-lower 4. Silicon key pad (Rubber-cap) 5. Infrared emitter & receiver 6. Key Power 7. Key Pen 8. Pen holder 9. Tray 10. Bottom Cab.	Battery Door Battery Lock Alkaline Battery/Li-ion Battery Batt. Contacts +ve Batt. Contacts –ve Batt. Contacts +/-ve	1. Combined Docking 2. Single Docking 3. Cascade Docking

Customers' preferences and the technical aspects associated with the preferred design features are basic inputs to this layer. Module Part is basically a database for storing the information of the existing parts grouped in appropriate modules according to certain criteria. Information stored in these MC classes is: cost, history of developing a module, the production time and quality, etc., and will be very useful for the selection of suitable modules later on for configuring the product as shown in Figure 7.6.

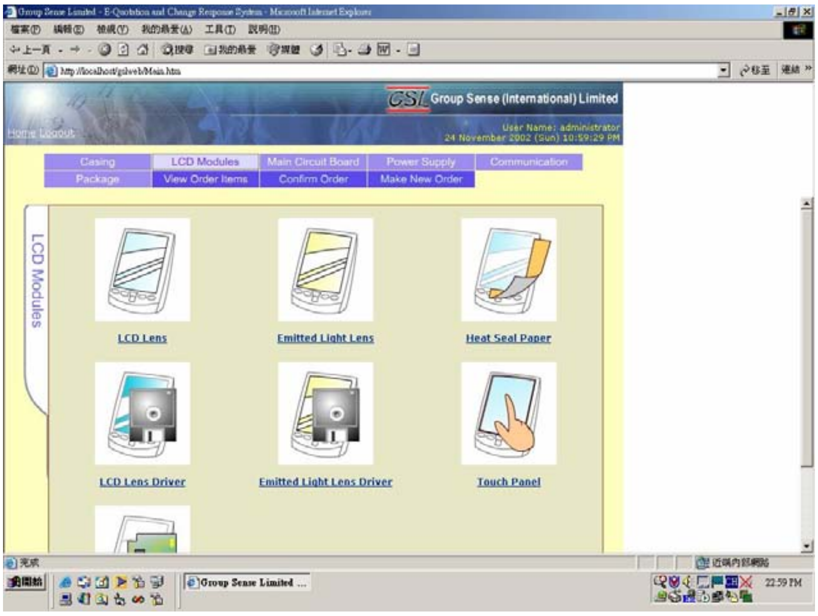

Figure 7.5 Prototype of the Modulation

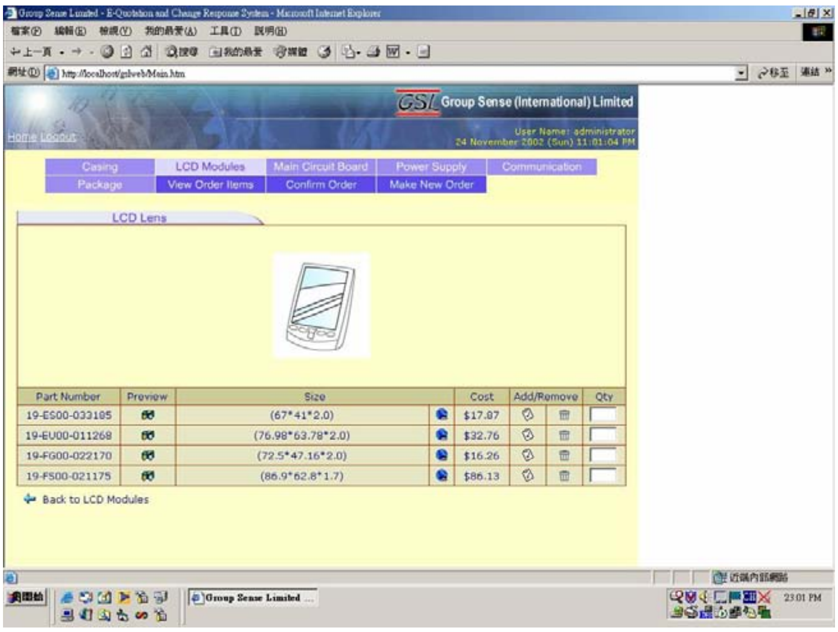

Figure 7.6 Information Stored in Module List

The output of the MC cycle goes to draft product design, which includes the modules for the new product. The Module Part serves a number of functions in the MC cycle. This includes a database, for storing the description of parts, which is used for mapping. Besides this, it stores the relationship between parts. This means the information about which parts or modules can be combined to form a product. Draft Product Design works out the modules using existing parts that can fulfill the specifications based on customers' preference.

7.2.5.3 Building of Process on Demand Module

After the initial concept has completed in the PSE module, a preliminary product design is formed to help create the component modules and their relevant classes in the Process on Demand module. This module contains all the details and reveals every facet of information needed to support the other two modules. After the parts have been chosen, the next step is to work out the appropriate process for making the parts in terms of cost and time duration. The ABC is then used to identify the product development activities and to calculate the cost of these activities. The detailed process break down is shown in Figure 7.7. After new product specification is documented, the project flow and task time will then be defined as shown in Figure 7.8.

Since costs from several activities or activity centres are allocated to each cost object, the total costs of the cost objects will then become the total product cost. Accuracy of product cost depends upon accuracy of the breakdown of activities cost. Also, by summarizing the activities of staff, the manager can then have solid data on which to base the allocation of resources. An example of activity list of one of the staff and a weekly staff report are shown in Figure 7.9 and Figure 7.10 respectively.

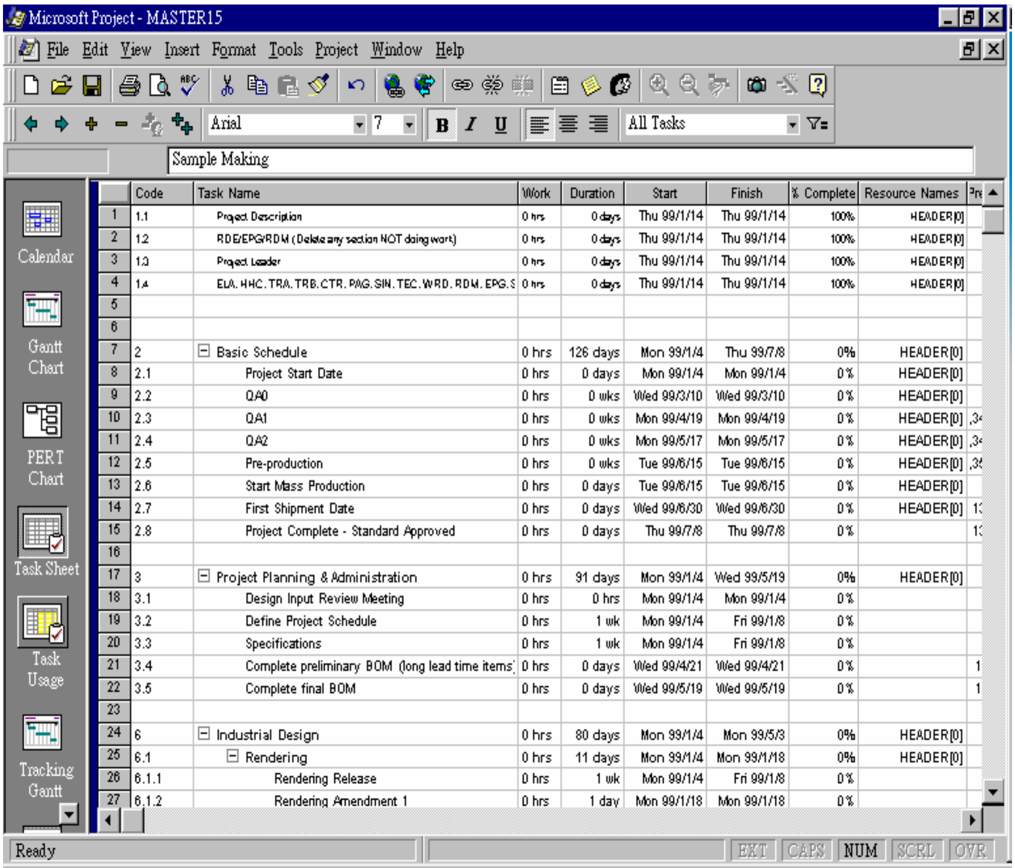

Figure 7.7 Detailed Process Break Down

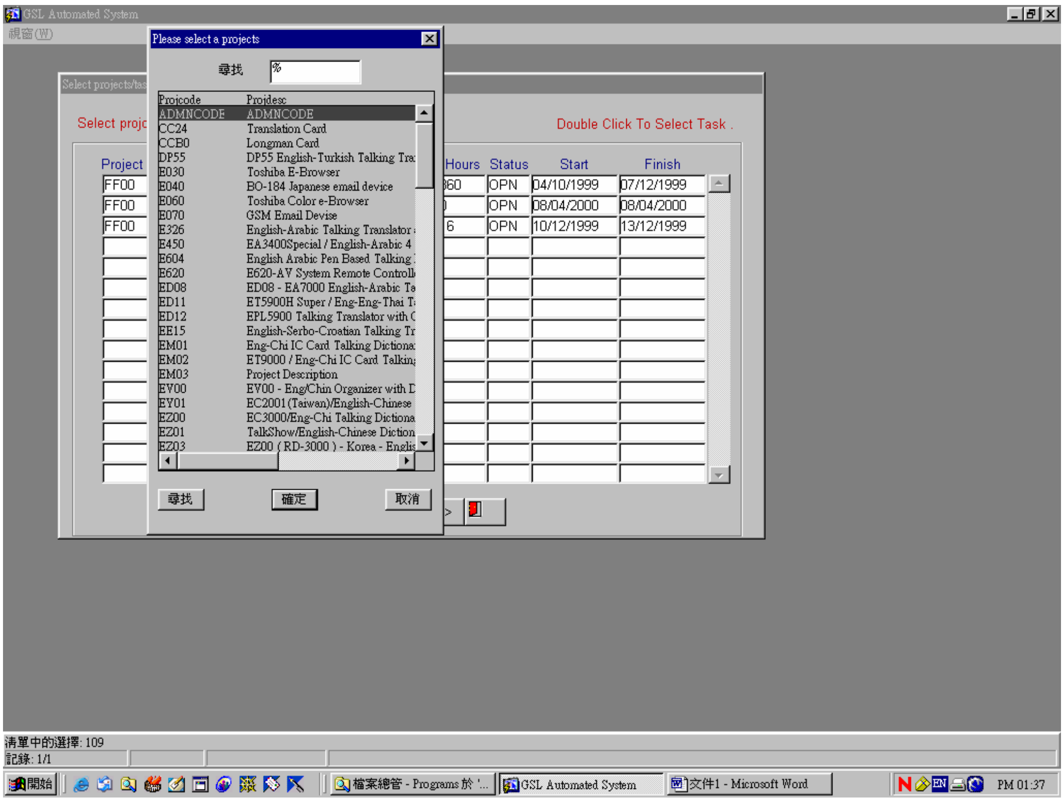

Figure 7.8 Define Project Flow and Task Time

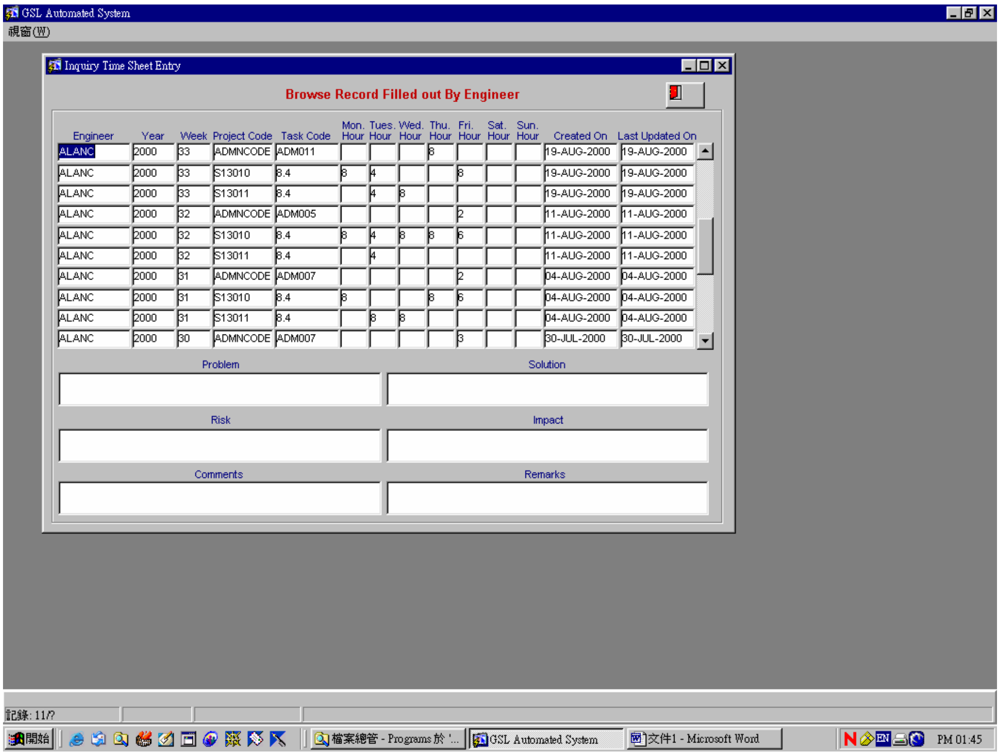

Figure 7.9 Activity list of a member of staff

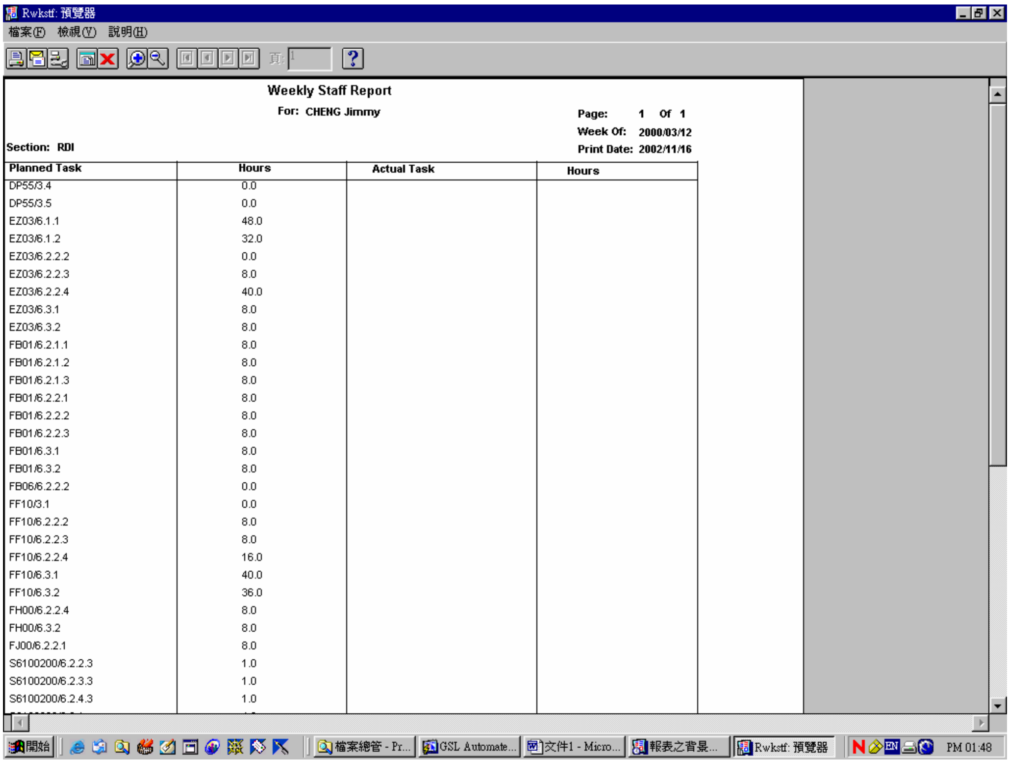

Figure 7.10 Weekly Staff Report

It is not the intention of this chapter to fully illustrate how the ABC works in the POD module as this was clearly shown in Chapter 5. In this case study, only the analysis of the *Top Cabinet* module using the ABC analysis is described. The making of this part involves a number of activities including ID drawing, preliminary drawing, detailed drawing, selecting material, mould drawing, developing a mould for a test shot, test mould sampling, modifying a mould and remoulding. The mould drawing activity is selected to illustrate the analysis. Table 7.2 shows the analysis of the mould drawing activity to determine the best option among those alternatives available.

Table 7.2 Analysis of Mould Drawing Activity

	Mould Drawing			
	Subcontract Outside		Made In-house	
	Vendor 1	Vendor 2	China	Hong Kong
Activity factor	4	1	2	2
Part reliability	3	1	3	3
Relative rate	12	1	6	6
Overall importance	0.48	0.04	0.24	0.24
Assigned resource	$5000/day	$6000/day	$3500/day	$6000/day
Resource rate	0.244	0.293	0.171	0.293
Duration (days)	6	8	10	7
Estimated cost	30000	48000	35000	42000
Relative weight	**1.967**	0.137	1.404	0.819

Activity factor – Degree of importance for each activity to the whole project (1-5, least important-most important)

Part reliability – The reliability level required in order to accomplish the activity

Relative rate – Activity factor X Part reliability

Overall importance – For Vendor 1 is 12/(12+1+6+6)

Resource rate – For Vendor 1 is 5000/(5000+6000+3500+6000)

Relative weight - For Vendor 1 is 0.48/0.244

The concept of ABC can be used to suggest the most cost-effective activities for producing the part. In this example, Vendor 1 scores the highest point (1.967) and is therefore suggested for this activity, with the duration of 6 days and an estimated cost of $30000.

7.2.6 System Integration of the Three Modules

7.2.6.1 Managing Change in the Product Development Stage

In a dynamic business environment, the requirements of stakeholders are ever-changing. We should note that "change" is a complex subject because it requires the efforts of several departments for just a minor change. Also, changes in the product development process will possibly lead to project delay. In our case, any alternation in the product features of PDA product may have unexpected effects on the products and on customers as well. To deal with the increasing amount of change required, the Change and Response Feedback Loop of CARDS is designed. This can accommodate any change. If this loop is not in place any new project has to start again from scratch and be re-done from the very beginning. If each project is a new project, this will result in a large amount of redundant work and a waste of resources.

We can take designing a PDA as an example. Owing to the fact that the targeted customers have changed, the initial definition of the PDA, with digital camera, may need to be modified. This will mean that the Bill of Material (BOM) needs to be redefined. With the loop in place the Project leader just needs to go through the product specification module again to check what needs to be changed and to determine the next step. During the process, the QFD cycle needs to be run through again. Project leaders can classify the level of changes and loop to the corresponding module in order to re-design or modify the product. They do not need to re-start the product development from the very beginning of the TT module. In our case study, engineers are required to re-run only the PSE module in order to modify the product design. Thus the PDA provides the basic functions of personal data management at an affordable price; it is of good quality, and it also meets the expectations of customers.

After having formed the HOQ matrix, information regarding the customer's feedback and product characteristics is collected and organised prior to being reviewed by relevant staff. In order to meet the expected budget of customers, some features of the PDA are deliberately deleted. The Cost per PDA unit will be lowered because fewer features are required. For example, we can delete extra features or functions like the digital camera, games and the medical dictionary in the PDA. The simplified features save the work of software engineers and reduces the cost of raw materials by about HK$40; manpower cost for the development of such extra functions is also saved. As a result, customers can have a cheaper PDA. The reduced cost gives customers a better idea of the relationship between embedded features and product cost. With this quotation system of CARDS, customers can evaluate the products by themselves and buy their preferred PDAs at their target price. In this way, the final product can better fit the expectation of customers. Before making any decision on such a change, project leaders can follow the "use case" modelling to find out all relevant information about the impact of change on cost from various departments. Customers and top management can then have more solid information before they have to make up their minds. Without the "use case" model, the project flow is unclear and the whole process control heavily depends on the project manager's personal experience. The quality of the project is then very difficult to control and the resignation of any key member may cause serious project impact or delay.

7.2.6.2 Project Review

In product development, past experience and precedent cases are numerous, many of which are so valuable that they can or should be reused or shared. The project review and learning meeting is therefore proposed to improve the product development cycle by utilizing this experience, empowering engineers when solving problems and making decisions, and also stimulating people to think up new ideas for new products. All knowledge gained during product development in the sharing and learning meeting will be stored in a knowledge database. The knowledge needed to design a PCB is a case in point. To design a PCB, the designer should have the knowledge of how to layout a PCB to reduce EMI and how to layout a component pattern to improve the yield of the manufacturing process. This piece of work experience and knowledge will be written down as a design guideline after the sharing session. When created, the knowledge database will contain different kinds of standard component patterns which can be reused for other projects. The experience of staff thus helps improve the conventional development process. In this meeting, experience can also be shared among project teams, thereby cultivating a learning culture.

7.2.7 System Validation

The system for carrying out each project is based on a standard workflow, which is applied to all kinds of projects. If the process is repeated again and again, it might result in wastage of manpower and resources. Since the product features, customers' needs and technical requirements are diverse in different projects, a business process model applicable to one specific project may not be suitable for another. So, the project workflow should be customized for an individual project and a specific customer. Customization of this workflow can be achieved by the employment of object-oriented technology, QFD, modularization and ABC. This was demonstrated in the above case.

There are six major deliverables:

(i) The TT Module

During the product definition stage of the production of PDAs, the processes, including project scheduling (i.e. the proposed completion date of the project and the launch date of PDAs) and team formation (i.e. the parties involved and their roles and relationships), and the products, including product specification preparation (i.e. product features) and technology application (i.e. technical requirements), are broken down into objects. Under such “objectized” schema, each object can be easily and clearly defined. When any of the objects is found to be the same as or similar to that of a previous project, GSL (the “company”) can then simply modify or reuse the existing objects without the need to repeat the whole process from scratch again. Therefore, the company can create a self-responsive team enriched with knowledge and expertise in handling change.

(ii) Deliverable of the PSE Module

Knowing the customers’ preference is also important in the process of product definition. In this case, QFD is used to quantify the voice of customers. In a common and open platform, the project team liaises with the customers and listens to their feedback. Ideas and information are exchanged between them. With a better understanding of the specifications of customers, the company can produce products that meet customers' expectations.

(iii) Deliverable of the POD Module

Traditionally, the quotation for any new product is made with reference to the cost of an old and similar product. This quotation is not accurate enough as it excludes the cost of new developments of a new design. Besides, the cost is shared by all the parties involved in the project. In other words, each party has to bear the same cost, regardless of its degree of participation and involvement in the project. By applying the POD module, the innovative products, PDAs, can be produced in a more cost effective way.

(iv) Effective response to change in GSL

By applying object-oriented technology and polymorphism, a single stimulus can provoke different responses. Whenever the customers ask for any changes, such a system will let the project team know what (e.g. cost and time) will be affected and how they will be affected. For example, if customer wants to change the LCD to the larger size. By searching the database, the GSL marketing team can provide a solution to Sharp in a very short period of time, and that is an increase of $14.89 for the BOM cost. Please refer to figure 7.6, the different types of LCD lens can be found in the LCD module listed with cost, size, photo and part number. All the information is very important in new product formation, which saves time on searching for relevant information, encourages the use of common parts and increases the accuracy on cost estimation. Furthermore, the system provides the project team with an alternative and transparent approach so that it can always compromise with the customers when they ask for changes. For example, customers may need to wait for longer time if they want more features. Because of CARDS, the communication between the project team and the customers will be greatly enhanced. From our pilot test, the company can reduce the development time from 12 months to 9 months. Despite that the 6 months target is missed, CARDS is still proven to be of value in shortening the product development time.

(v) Results Measurement of CARD System

From Table 7.3, we can see that CARDS has improved the product development process with shorter time needed to respond to changes, shorter product development time and lesser project delay. The effects of CARDS are not clearly seen in the first project because it takes time for the company to incorporate the three modules and the staff need some time to adapt to the new workflow of CARDS. However, in the second project when CARDS is applied, product development time has been successfully shortened. It is expected that the time required to develop a new product in the third project would be further cut down and that project delay may be avoided. A company can launch a product earlier so that the new product can have amble time in winning the market, and product may be launched in a timely manner so as to catch the peak selling season. In this way, new products can have a better competitive edge when developed using CARDS. CARDS can improve the agility of a company and details are shown in Table 7.4.

Table 7.3 Quantitative Analysis of CARDS

Project Number	Project A (CARDS was not applied)	Project B (1st Project applied CARDS)	Project C (2nd project applied CARDS)
Time to respond to changes	1-4 weeks	1-2 weeks	Within 1 week
Product development time	12 months	12 months	10 months
Project Delay	4 months	3 months	1 month

(vi) Improvement in Agility

Table 7.4 Improvement in Agility after the Implementation of CARDS

Level of Agility	Before CARDS	After CARDS
Feature	By customer request	A module library built with 6 classes and 200 modules parts in the Repository of Product Family
Process	With 10 main processes	Broken into 1300 sub-process (in the Process Database) to reduce interdependency
Organization	By functional project team	A dynamic and reconnectable workforce supported by an O-O based humanware library
External Collaboration	With a few partners	An outsourcing library built with more than 20 partners

7.3 Case Two – E-Talent

7.3.1 Company Background

E-Talent Company is a Hong Kong based company, which provides value-added architecture of comprehensive, integrated software solutions, services and support designed to improve manufacturing and e-Business processes. Packaged IT systems, for instance, sometimes lack the special functionality that organizations need. E-Talent can customize solutions and backfill gaps to provide the best possible functionality for the company's operations. It can modify legacy systems to meet current needs such as integrating stand-alone applications, customizing reports in line with new reporting requirements. E-Talent provides complete software development lifecycle services, as well as care for systems after implementation. Its services encompass web page design, software design and development quality assurance, documentation and support. In this test, the web page development team is employed, which is facing keen competition due to a huge amount of similar services provided in the market. Managing the optimum time and cost is the basic winning criteria for survival.

7.3.2 Goals and Expected Deliverables of E-Talent

In this case study, the model was applied in E-talent limited company, a software house. The nature of the products provided by this company is totally different from the one of the previous case. They are intangible products, and so it is difficult to control and monitor the development process, time management and even the outcome quality. Time as a competitive weapon has been hailed as the 'next strategic frontier' for companies operating in a global market (Musselwhite, 1990, Stonich, 1990). The term (time) refers to the "totality of time required to perform all activities on a critical path that commences with the identification of a market need and terminates with the delivery of a matching product to the customer". The company considers the expected deliverables to be:

(i) Faster response time to customer request

(ii) Faster delivery of customized products that attracts more customers and encourages brand loyalty (provided quality of the product is good). This results in an increase of market share.

(iii) Better control of process and schedule.

The model was employed in this company which expected to improve its agility in product development by removing the black box operation and improving the transparency.

7.3.3 Formation of CARDS Team in E-Talent

Major problems related to Web page design lie in the huge volume of design variations of components that have to be maintained and accessed. Associated with these variations are the profusion of formats, duplication of work, poor quality control and difficulty in standardising the development process. To overcome these problems one needs the formulation and application of standards. The major problems existing in software development houses are:

(i) Imprecise development time causing serious profit loss

The profit margin of web page development is low due to acute competition in the market. Serious software development delay has been found, which can be up to 4 or 5 times of the original time estimated. However, previous practice by software firms leads to great profit loss. The database from which project managers draw in order to estimate the length of time it would take to complete the project is extremely limited. There is little reference material for a manager to draw upon other than his or her own experience. Consequently, unless a manager is to plan a project he or she has already completed before, the chance of arriving at a reasonably accurate time line is low.

(ii) Low utilization rate of historical knowledge

Every designer or engineer designs a web page from the very beginning. Some of the new parts they design might have already existed or be similar to another one. In such a case, the effort is duplicated.

(iii) Misalignment of customer's need

Misalignment of customer's need with the engineer's interpretation, due to the lack of a physical prototype

(iv) Impacts of specification changes on the schedule

Upper management and the user community have trouble appreciating the impacts of specification changes on the schedule.

Owing to the profit margin in software industry being low, cost control becomes an essential consideration for the company. The team is formed to solve the above problems.

7.3.4 Evaluation of the Existing Product Development Operation

The business clients of E-talent Company require a unique web-based design within a short development time, at a low cost. The traditional method of building a new Web page starts with the idea generation stage. This stage is time-consuming and it is difficult to keep up with the sometimes incessant customer’s changes during the development process. The detailed breakdown of the process is shown in Figure 7.11. As might be expected, the estimation of development cost and time is very imprecise in the current practice due to it being time-consuming to find out all the similar Web pages for reference. It is doubtful whether the product cost calculated using such indicators or experiences is a reliable one.

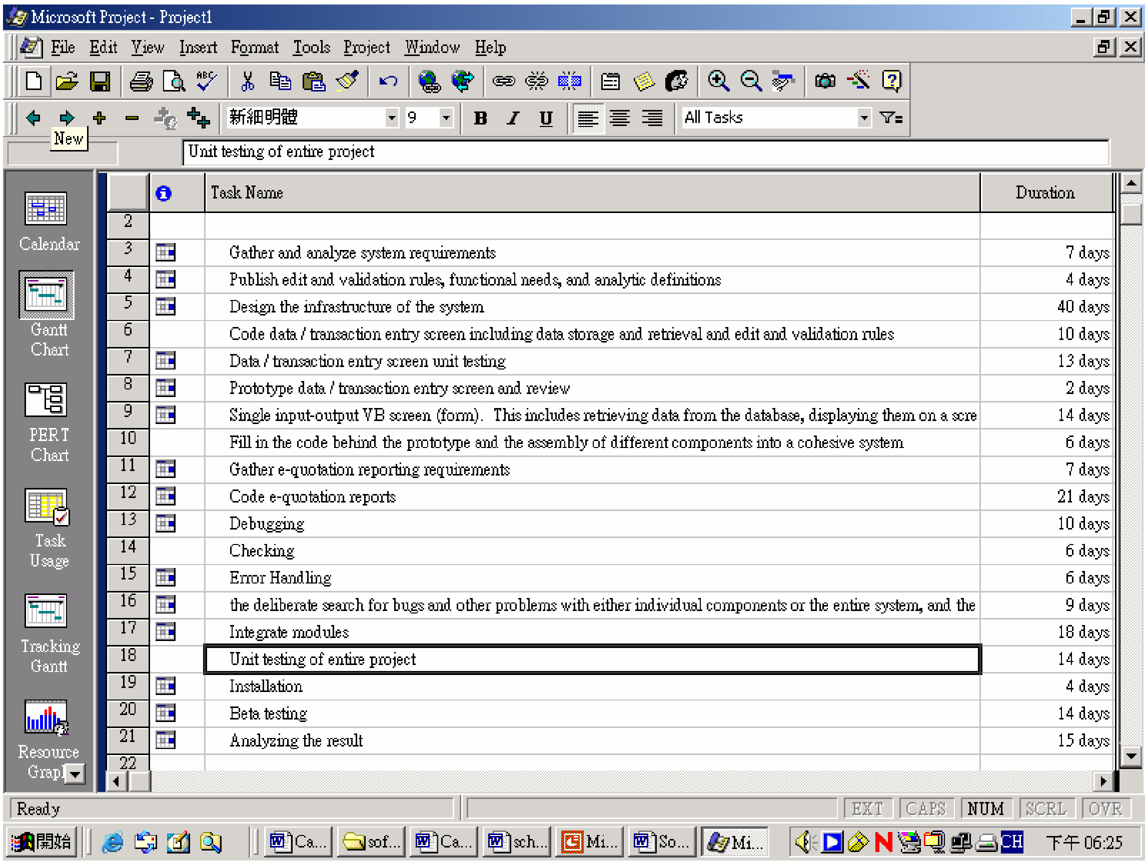

Figure 7.11 Example of a Software Development Schedule

7.3.5 Key Modules - Formulation Stage

7.3.5.1 Building of the Team Transformation Module

The team transformation module is initiated upon request from customers. After the customer’s request is accepted, everyone in the company knows well about his/her own role and can give a quick response to the market. The first step is to formulate the project team by applying the object technology concept. There are a lot of building blocks available, namely, the re-configurable object repository, an application prototype and a data updating mechanism, which were built when GSL Co. Ltd implemented this system. They can be reused in E-talent Co. Ltd. Each of these building blocks is considered an object unit that interacts with each other through an inherent information exchange mechanism among the objects. Therefore, the first step is to modify these building blocks to formulate the project team for web page development.

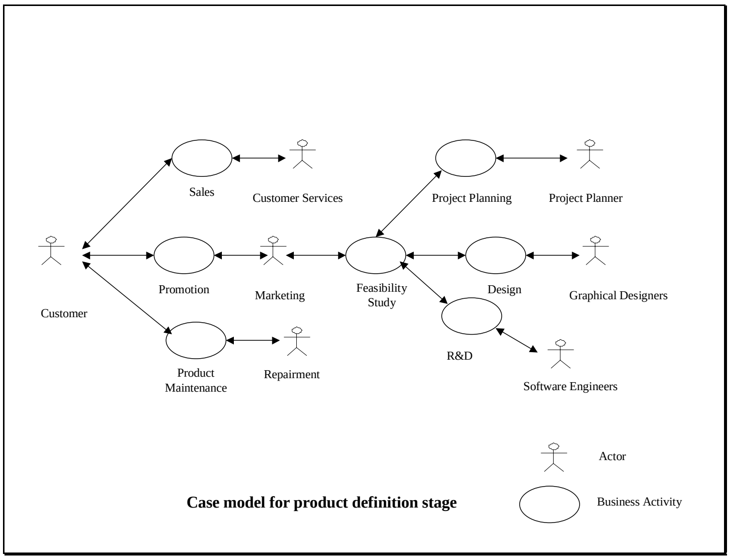

Figure 7.12 Case Model for Product Definition Stage

Figure 7.12 shows the typical workflow of the product definition stage in E-Talent Ltd. The data updating mechanism updates the repository, based on the output of the application prototype. External to the project team is the customer requirement input which feeds information into the system through the House of Quality, the second step of the schema. Typical information to be entered into the system includes product specification, time constraints, cost constraints, other situational constraints, etc. Prior to the commencement of any development project, a project schedule must be made up.

7.3.5.2 Building of the Product Specification Enhancement Module

By using QFD, customer's requirements are always taken into account in a product design project. MC and ABC are the second and the third steps in proposing a design process plan with time schedule and estimated cost. Ideally, Product Specification Enhancement module should also propose an optimum human resources allocation. The class of Customer's Requirements and that of Design Requirements are used for mapping the Customer's need with the corresponding parts of the Web pages.

For example, R&D Department receives a request from the Marketing Department to design and develop a web page for a local trading company. And it is allowed six months to complete the project, the target cost of the product being $X. Before any design work begins, the project leader responsible must first develop a project plan that includes a design process plan and the corresponding resources allocation. He/She should collect all the information that is available including product specification, time, cost and other constraints. Such information is stored in a document template and then used in the House of Quality as shown in Figure 7.13. At the same time, the engineer with the information tries to match the appropriate modular process plan with the corresponding manpower requirements.

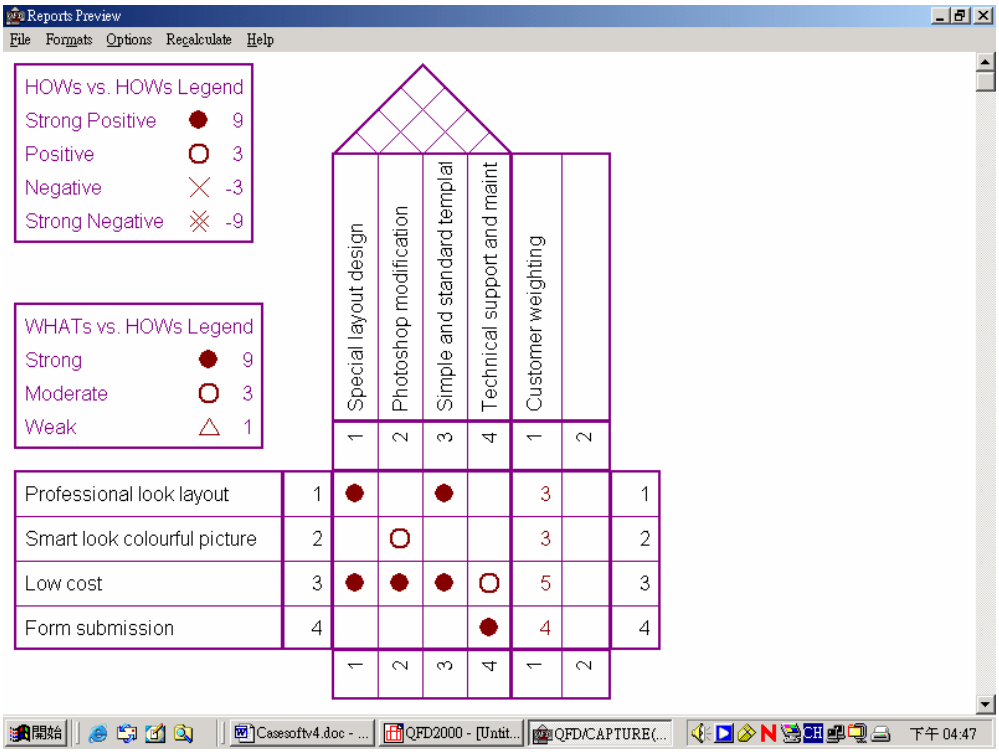

Figure 7.13 Result of QFD for a Kindergarten Customer

E-talent Ltd. starts mass customisation without new green-field operations (which consists of a lot of current existing web pages). It therefore uses the MC principles when developing its existing products. What is important, however, is to standardize the current existing web pages before implementing MC. There are two main steps to be done before MC, namely, modulation and standardization. Emphasis is put on the elimination of proliferation of parts and on modularisation of design in order to achieve commonality in design.

After in depth analysis, out of the 35-layout designs, 15 types are seen as being the most popular. The results of the modulation are listed in the following Table 7.5.

Table 7.5 Results of the Modulation

Banner	Main Content	Photo	Background Music
(i) Background (ii) Title (iii) Picture	(i) Background (ii) Sub-title (iii) Table (iv) Counter (v) Form	(i) Animation (ii) Hyperlink	(i) Pure music (ii) Pop music (iii) Cartoon music

It is recommended that E-talent Ltd. uses the part commonality approach rather than the part type reduction approach. If it does this, the different sizes of banner and photo, word length and types of background music will be standardized. Up to this moment (February 2005), 30 sets of Web pages have been developed in the company. The standardization was concerned with the following parameters:

(i) Width and height of banner
(ii) Number of words in main content
(iii) Size of photo
(iv) Types of background music

MC comprises a number of classes which are primarily the classified component modules containing various parts and components belonging to the same group. By grouping similar components into component families as shown in Figure 7.14, it is possible to narrow the spectrum of Web page designs so as to reduce design variations and optimise reusability. This reduces not only production cost but also the labour cost as fewer parts are involved. Information stored in these MC classes includes cost, history of developing a module (elements of web pages like buttons, graphics, banners etc.), the production time, quality, etc., and will be very useful when selecting suitable modules or elements later on when configuring the product.

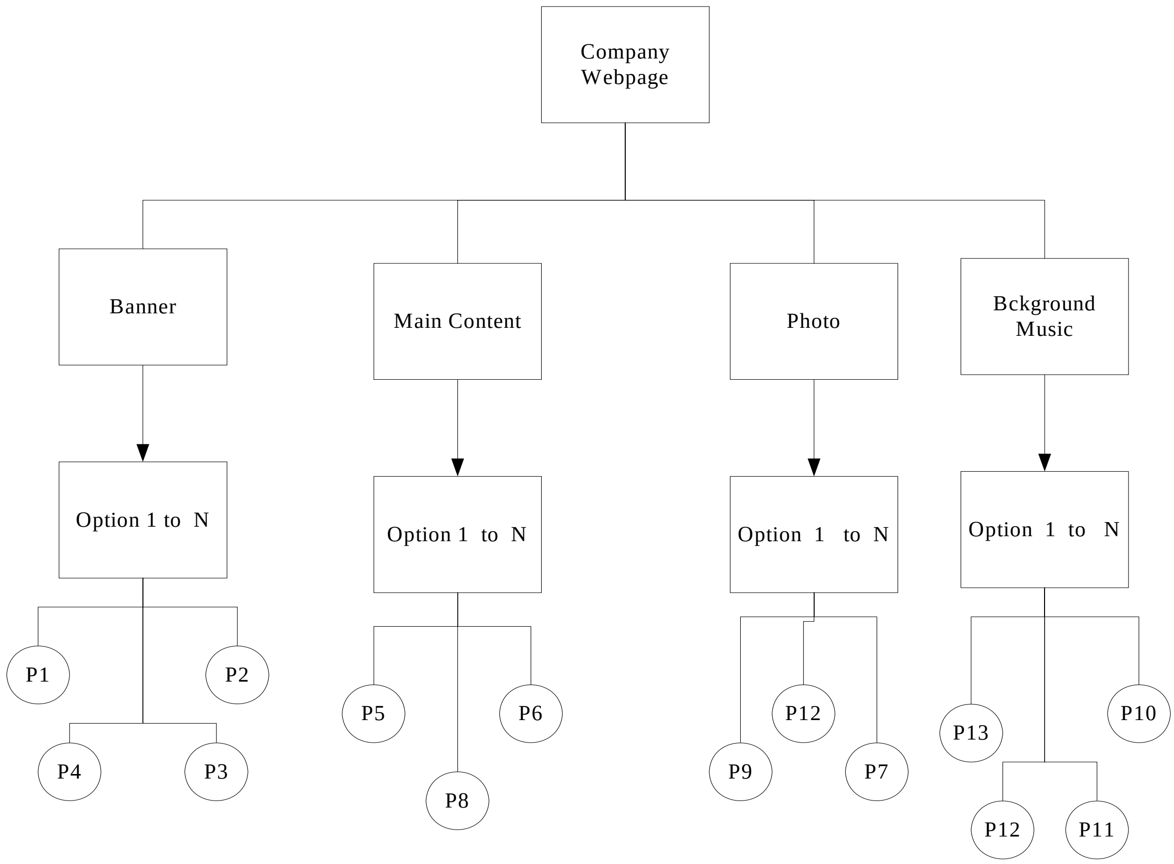

Figure 7.14 The Component Family of Different Modules

7.3.5.3 Building the Process on Demand Module

The Process on Demand module starts with the customer placing an order. The user will input details of what the customer needs. In a new product design, customers are interested mainly in two values, i.e. time to market and the cost involved for the development. The product specification will therefore be transferred to this module and to the relevant sections of the company through its reporting system. A Draft_Webpage Design is the output of the PSE module. The class of Draft Product Design is made up of the modules with existing parts that can fulfil the customer's requirements. It will be in the form of part numbers and photos. The photos help the engineer and the customers to make a quick decision. The part numbers (like 1520, 1530, 1540 as shown in the figure) can provide a link to most of the information, which is needed for Web page development such as development time, cost, etc. There is an example selection of different sized photos in Figure 7.15. This output will be used to provide information to support ABC in terms of the identification of relevant activities for developing the new Web pages and for estimating the development time, and cost of the Web pages. It will be analysed for identifying the underlying activities and the corresponding costs. As a result, the product cost will be passed back to the MC system and then feedback is provided to the customers. Meanwhile, the quotation will also be reported to the parties involved. Then the software in the system will check whether this customer's requirements exists the total cost or not. If it does not exist, a meeting would be held to determine what should be the output to cheer the customer up. If the customer's requirement does exist, it will be mapped with the corresponding design parameter.

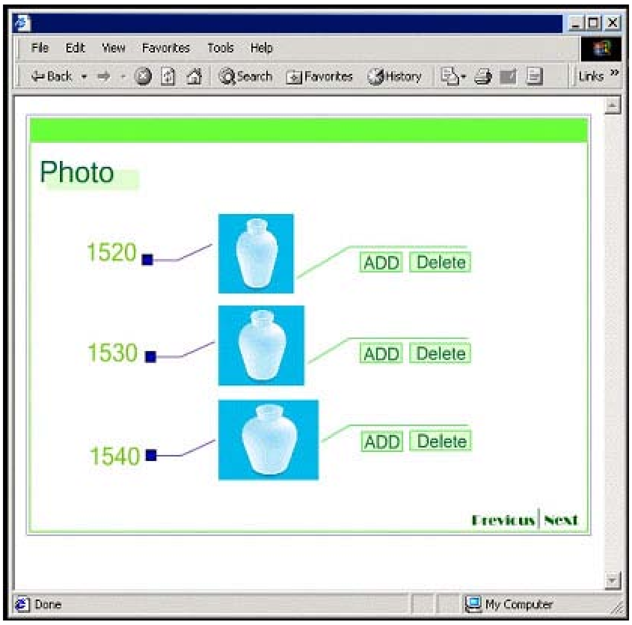

Figure 7.15 An Example of Selection of Photos in Different Sizes

7.3.6 Managing Change in the Product Development Stage

For various reasons, it is not uncommon to see frequent ad hoc changes in design and delivery requirements in each of the software development checkpoints. These frequent changes call for frequent re-scheduling and re-planning which are time-consuming and make the cost and time unpredictable. After each change the data updating mechanism updates the status of the human resources pool and also registers the new plan based on the new constraints, in the repository. This is shown in Figure 7.16. The new plan will be available for re-use in the future, when similar constraints arise. The plan will then be fed to a project management system that is responsible for project monitoring.

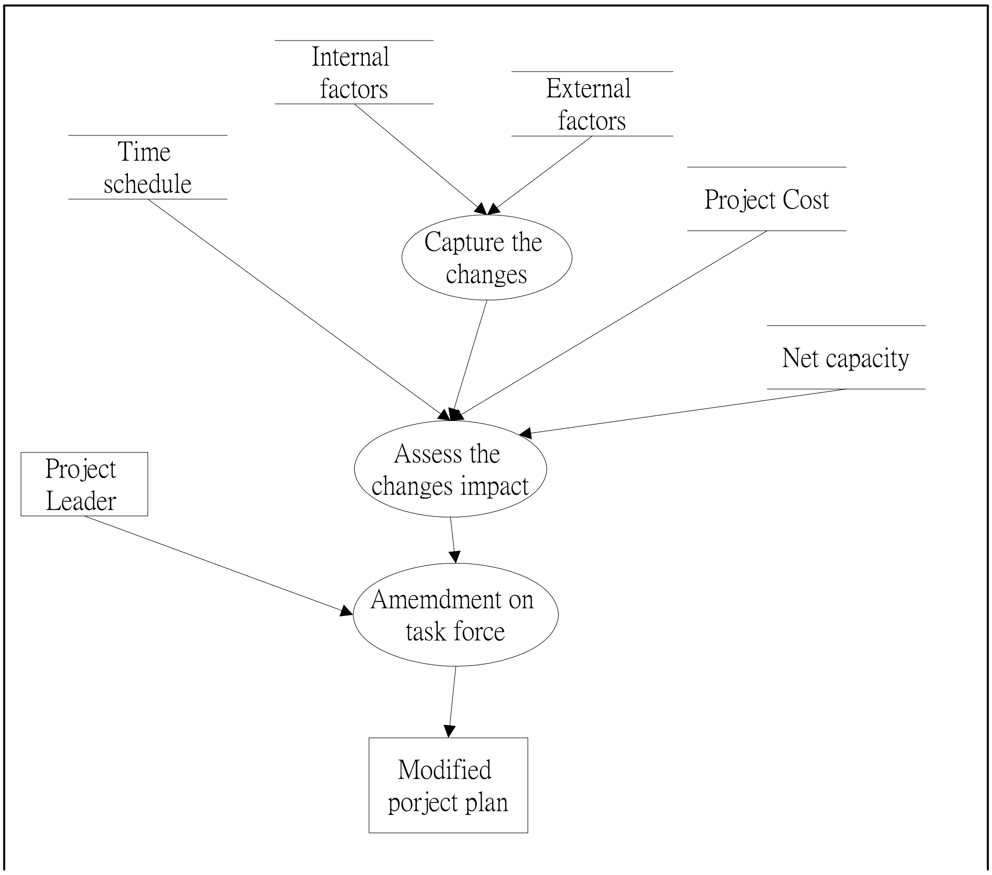

Figure7.16 The Process of “Change” Handling

For example, objects involved in a product development environment will respond to a message indicating that development lead time has been reduced by 2 weeks. Then, the R&D manager object, after going through the Process on Demand module once again, might respond by increasing the number of project team members, while the project manager object might adjust the project duration. This ability of different kinds of objects to respond differently to the same message is called polymorphism (Goldberg & Rubin, 1995). Any change caused in the product development period will stimulate re-looping of the particular layer once again. Response to these changes therefore becomes systematic and automatic.

7.3.7 System Validation

Table 7.6 Comparison before and after CARDS

	Before CARDS	After CARDS
Feature Agility	By customer request	A module library built with 4 classes and 100 modules parts in the Repository of Product Family
Process	With 10 main processes	Broke into 100 sub-process (in the Process Database) to reduce interdependency
Change Request Time	1 week	Within 3 Days

With the implementation of CARDS, the design and development tasks are broken down into modules. When any task is found to be similar to or even the same as that of the previous project, the project team can merely reuse or redesign some existing modules or elements in the repositories. There is no need for the team to go through the whole process again. This in turn saves much cost for the labour intensive development of the web design and reduces time to market of new products. Therefore, the delivery time for new products is also shortened.

Since there is a great variety of design components and a profusion of formats, the project team and the customers may find it difficult to make a decision on which components and formats should be used. By standardizing the design components and the formats, the design variations can be minimized while at the same time the uniqueness of the final products, i.e. the web pages, can be maintained. In addition, the design and development process is mass standardized to reduce duplication and optimize reusability. A module library with 4 classes and 100 modules is built that standardized modules was stored in the repository of product family and features agility was achieved. Therefore, CARDS enables E-talent to meet the expectations of their customers at a lower cost.

As each customisation of the design components, including time and/or cost components, would result in a different process and/or web page configuration, a simulation system has been developed and is linked to the Product Specification Enhancement module to produce a simulation of the web pages based on the configuration chosen by the customers. If the customers find the simulation is not perfect enough, they can give the project team feedback immediately and ask for changes. This not only facilitates the decision-making process of the customers but also eliminates misunderstanding between the customers' expectation and the project team's interpretation. From the conversion of a conceptual idea to a physical prototype, there is no more black box operation and the communication barriers between two parties disappear. As a result, the customers can get what they want at the start. Then in the Process on Demand Module, main processes in web design were broken into 100 sub-processes that accelerated the whole design process with improved process agility. With the application of CARDS, the change request response time has been shortened from one week to within 3 days.

In both case studies, we found that CARDS works as intended. It reduced the product development time and improved the agility of the company in the product development process.

7.4 Chapter Summary

In this chapter, two pilot tests on CARDS, which were carried out, in an electronic company and a software company respectively, have been described. After the pilot tests, we interviewed staff of both companies so as to get their feedback on the system and to find out areas for further improvement. From their comments, it is clear that CARDS can be implemented successfully in the two tested companies for new product development. Further discussion of the results of pilot tests will take place in the next chapter.

CHAPTER 8 DISCUSSION

8.1 Introduction

The challenges arising from globalization raise the need for cooperation and interaction between processes executed in different organisations. A sense of being in a networked enterprise, and a mindset that supports cooperation between organisations should be cultivated. Such synergy not only shortens the response time of a manufacturing enterprise towards change, but also improves organisational competitiveness in the global battlefield.

The objective of this research is to develop a new Customizable Agile Reconfigurable Design System which can adapt to frequent customer changes, lower the cost of bills and produce fewer cases of project delay. Applying object technology, concurrent engineering and good practices like QFD, MC and ABC, CARDS handles both product and technology changes and maximizes the product competitiveness. As seen from the two case studies in the previous chapter, it is proved that the adoption of CARDS in product development helps the companies to cope with the ever-changing situation; and the effect is positive. In addition, the comments from the international conference indicate that CARDS is a feasible and systematic system for product development.

8.2 Discussion of the Key Characteristics of CARDS

Employing object technology and modeling, the automated sign-off and notification of CARDS enhance the transparency of work procedures by means of its three modules – Team Transformation, Product Specification Enhancement and Process on

Demand. Inheritance, encapsulation and polymorphism are characteristics peculiar to object technology. Process, people and products are converted into simple self-contained objects which can be manoeuvered and organised.

With CARDS, product development time is reduced because both knowledge and information is systematically captured and converted into useful data which is stored in its libraries. Upon starting a new project, the system first calls the library for available references or seeks for external alternatives whenever necessary. The system is, thus, agile enough to cope with changes. The libraries in each module create a customisable and reconfigurable infrastructure for CARDS. From our case studies in Chapter 7, we can see that CARDS is workable for both tangible products like the electronic dictionary and the Personal Digital Assistant, and for intangible products like web site design.

8.2.1 Customisability

From the case studies, it is found that the proposed system could customize project teams who have the right talents so they can work on different product designs. Firms can pick the best talents with the most appropriate skill set to suit project requirements. For example, in designing a new V88 product by GSL, object-based "**use case**" modelling is successfully adopted to analyse the business process. Management can search its internal humanware object library for the best team alternatives for such a business process. Then, they are able to find expertise with the relevant skill set, experience and talent to form a new project team promptly. At the same time, if any skill is not currently available in the company, management can include vendors or recruit new staff to fill the gap. Hence, the organisation can have a team with a combination of the most appropriate team members. According to the feedback from E-Talent such a customisability feature of CARDS gives many benefits to management.

8.2.2 Reconfigurability

The humanware object library in the TT module, the repository of product families in the PSE module and the process database in the POD module collect important data on human knowledge, product features and manufacturing processes which are assimilated into the product design schema. Such data can be recalled, manipulated and adjusted throughout the whole product design process so as to fulfill complicated project requirements. In POD, the sequence of processes and sub-processes needs not be one after the other. The sequence can be rearranged according to the actual specifications. The feedback from E-Talent reconfirmed that resources could be easily allocated and planned in a distributed manner using the data repositories. One respondent said “The reconfiguration of processes and information smoothen the design workflow”.

8.2.3 Agility

Agility refers to quickness of response to change, uncertainty and unpredictability. To put it concretely, CARDS achieves agility with continuous improvement of workflow, and results in four areas of agility – features, process, organisation and external collaboration.

(i) Features -- In CARDS, product features are enriched and modified in the Product Specification Enhancement module. After evaluating customer needs, internal and external resources as well as development budget and schedule, cost-effective products with powerful features can be developed. In the case study, E-Talent was able set up a set of product specifications for customers to choose from so that the customer can pick those features which match their needs and their budget.

(ii) Process -- Process agility refers to processes conducive to rapid development and timely response to customers and the market. In GSL, processes in product development are objectized into various sub-processes. The company is, therefore, able to manufacture new products or enhance the functions of existing products with less development time. The company found that its manufacturing process became less rigid through adopting CARDS.

(iii) Organisation -- CARDS provides organisational flexibility by breaking down the hierarchical structure of an organisation. Team formation should never be limited by departmental barriers. Instead, it should be formed according to personal skill sets and profiles. As in the case of GSL, an inter-departmental team is formed for each project. People can apply their expertise to the project so that the team would have broadened knowledge and could inspect problems from multiple perspectives. The chemical reaction among team members with their multi-faceted personalities improves the elasticity of the team and the organisation captures external resources like customers, vendors, technology and competitors, so it provides better decision support for the system. The collaboration of external parties will also strengthen the competitiveness of the mother enterprise. This is attributed to the fact that an organisation can monitor the market situation and changes in co-operation with its partners. On the other hand, if there is any deficiency in the internal resources, the mechanism of CARDS allows importation of extra resources from outside the organisation. Organisations do not need to be self-contained. They should try to maximize their usage of external resources and convert the resources to internal resources, skills and knowledge. The pilot study in GSL showed that component suppliers, vendors and customers could have a better understanding of market intelligence with this form of synergetic relationship.

8.2.4 Deployment Features of CARDS

CARDS adopts a holistic system approach that handles features, process, organisation and external collaboration agility effectively. It has taken into consideration the organisation, external stakeholders and people issues, from the formulation to the implementation stage. The feedback from the two cases confirmed that synergistic and collaborative results could be achieved. The respondents said that with the human expertise, product families and process repositories in the system, CARDS was more powerful than the system previously used by their companies.

8.3 Discussion of Team Transformation Module

The key characteristic of this module is to transform team and team members through empowerment so as to enhance the project development team's responsiveness and flexibility. By breaking down barriers in the organisation, individuals and their skill-sets will be broken down into small objects and put into the resource pool using object technology. Then each object is transformed according to its behaviour and class. Then, project leaders will select team members from the resource pool to form a project team. If a particular kind of skill set is missing from the pool, project leader can invite customers and external members like vendors or consultants to join the team as well. In this way, a flexible and agile team is formed. Also, team members are empowered with the decision-making authority to enable them to make changes and call for external resources. As discussed in Chapters 6 and 7, a team transformation loop allows for a flexible combination of human resources as the project leader can pull in external resources or release resources based on the requirements of the latest situation.

8.3.1 Feasibility of the TT Module

Teams were transformed according to "**use case**" requirements, the involvement of customers, and according to the definition of the project leader in the tested companies. In other words, the project team and operation data were first objectized. For instance, "**use case**" diagrams were constructed for the GSL owned products and OEM products of GSL. At the same time, team members were divided into various classes according to their skill sets and knowledge in the Team Transformation module. The encapsulation of the behaviour of each class improves its predictability and reduces the occurrence of dead-end loops. Thus, each loop can encompass the appropriate task in the system. With the standardization of objectized skills and processes, the company has found it easier to search for alternatives in the resource pool.

8.3.2 Benefits of TT Module

(i) Reduction of project queueing time -- In the past, projects in the two tested companies were queued according to department and operational functions.

That means people could only start their assigned task after the completion of the previous task in the workflow sequence. Such a rigid functional division of labour prolonged aggregate project time. If any communication problem arose, the back and forth processes between departments would truncate the whole progress of the project. In the past it was not possible for several processes to work concurrently.

With the application of concurrent engineering in CARDS, the enterprise can rearrange all its available resources according on its priority; and the project leader can assign projects to team members in order of priority. Project members should work on the more important and critical tasks first.

Since human resources are not limited by the departmental schedule, the company can outsource the project to external vendors if necessary. The feedback from the case studies was that the queueing time of the projects in their companies was reduced after their pilot test of CARDS, and they could start a project within a shorter period of time.

(ii) Flexible team formation -- Team mapping transforms a normal team into a flexible and multi-functional unit. An organisation can train and recruit multi-tasking talents for agile project development regardless of departmental and hierarchical boundaries. Team members are multi-facetted receptors who can keep themselves constantly updated. Teaming is not only limited to internal organisation, external organisations are also allowed in the CARDS. This makes the team more sensitive to its surroundings. Team members are required to pass on latest information to other team-mates in due course if they come across any new and useful information. E-talent has involved the participation of customers in some of its projects and they found that it is of paramount importance and extremely effective to have customers' input in the project team because of the smoothened project workflow. The Project Manager of E-Talent further commented that "with the involvement of customers and vendors, the company is more capable of gaining talents with a wider range of skill sets which enhances the sensitivity of team members towards market situations; and the teams are more versatile and experienced to handle changes and problems." The benefit of CARDS to the company is thus recognized.

8.3.3 Limitations and Considerations of TT Module

(i) Problems in performance measurement and in the incentive system – The team transformation which breaks down departmental barriers, makes the rewarding of well- performing staff problematic. The respondents commented that defining criteria for good performance in the new system was a vexed issue for their senior management. Because the performance measurement was not clearly defined, the project leader found it hard to pick team members who had performed well and promote them to higher positions. They also found it hard to give remuneration for good work. As job satisfaction comes from position in a hierarchical structure as well as from reward and compensation, the lack of a clear promotional path may discourage good workers. It would be ideal if we could devise a system which can reward according to the quantity and quality of response to change.

In the long run such incentives would also encourage project members to make changes. Having a good performance measurement and incentive system will motivate staff to perform at their best.

(ii) Problems in team knowledge sharing – Because of the lack of a hierarchy and a dedicated department head as the mentor for staff in TTM, the respondents expressed concern about knowledge transfer within their enterprises. It seems that in CARDS, since knowledge is kept in the mind of each individual instead of its department, it may not be so easy to recall past knowledge. Therefore, a centralized knowledge database is suggested in order to retain the collective knowledge of an enterprise and serve the purpose of knowledge sharing.

(iii) Transparency of the system -- An enterprise needs special arrangements to increase the transparency of the company so that external parties can be involved in the product design process more easily. On the other hand, respondents found it difficult to grant customers, vendors and suppliers access to confidential corporate information. The company may lose their product proprietership if they disclose too much information to external parties. So it is very hard to define how much and how extensively information is to be shared.

8.4 Discussion of Product Specification Enhancement Module

The PSE module enables team members to react to changes in an open platform such that each action can enhance the competitiveness of the final products. Product information and market intelligence, such as customer voices, is captured. The results are then quantified and translated for further processing so that the result of each change request is made known to team individuals. The data are dispatched to team members so that they can make decisions and deliver the change request according to the input and output of the module. The evaluation criteria are translated into a customer satisfaction index which includes benefits of products to customers, prices of products, time to market, product features and so on. In the past, individuals found it hard to make decisions on the change request because they did not have such authority and they did not know how to implement change due to a poor understanding of the needs of customers and the opinions of management. With the participation of customers in the module, team members are empowered make changes while referring to the customer satisfaction index. It is a self-responding mechanism and does not require intervention from top management. As team members are not required to wait for the decision from above before making changes, the open platform of PSE enables an organisation to develop products with enhanced features or specifications which matches well with customer needs.

8.4.1 Feasibility of PSE Module

(i) Simulation Process -- The simulation process in PSE enables customers to see prototypes of products before production. Hence, changes in customer requirements, even last-minute changes, can be accommodated. According to the project leader in E-Talent, product prototype allows customers to make all the changes they want and so they will feel more satisfied with their products.

(ii) QFD -- From the case studies, it was found that the company could transform customer voices into clear product specifications using QFD. This good practice improves the understanding of department staff of product features so that they can work more efficiently. The respondents found that they were able to design more "feature-rich" products that improved customer satisfaction and product competitiveness.

8.4.2 Benefits of PSE Module

(i) Voice of customers captured -- The module contains good practices for the companies to collect customer voices systematically, and manipulate custom-made features. Due to the participation of customers in the module, feedback from customers can be easily and promptly received. Companies in the case studies are benefited from the enhanced product designs after adopting the module.

(ii) Repository of the Product Family -- In the PSE module market intelligence and corporate strategies are analysed before the looping of QFD and MC cycles. The analysed data will be cross-checked with those product specifications or features in the repository of the product family. Thus, developers need not waste time to re-deploy a product from scratch and they can use past knowledge to build new features. Compared to the past, a wider range of new features can be developed in the same project period.

8.5 Discussion of Process on Demand Module

The objective of the POD module is to minimize project delay even after changes have been accommodated. By splitting product development workflow into processes and sub-processes, organisation can be more adaptive to changes. Traditionally, team members need to work according to the workflow sequence. A new task will be started upon completion of a former task. This lengthens the total development time. However, in CARDS, with the application of concurrent engineering, team members can work on different processes and sub-processes in parallel. Project workflow can be greatly shortened, and the product can be delivered to market in a timely manner. We have to note that cost will be incurred in internal overheads and external manpower when development time is shortened. In order to have a better estimate of the total production cost by including these additional costs, activity-based costing is incorporated in the POD module. Here, a new quotation system is built so management can assess and justify spending time and money on development.

8.5.1 Feasibility of POD Module

(i) Quotation System -- The quotation system provides clearer information to customers and producers so that they have a better understanding of the trade-off between time, features and cost. Customers can pay more to get more powerful features and a shorter time to market span. Or else, they can opt for cheaper alternatives with fewer functions and an acceptable delay in time to market. The quotation system is very useful for customers and producers as it helps them to make their own decisions. The project leader of GSL claimed that the quotation system provided a good guideline for their customers, helping them to evaluate the trade-off between time, cost and features, and thus was useful in the product development process.

(ii) ABC -- It has been shown that it is feasible to implement ABC in the product development process. In fact, ABC has been found to be a reliable method which enables project leaders and accounting professionals to calculate the cost for each activity. ABC makes it easier for project members to control the cost in the development process. For example, GSL might outsource some development processes to its Mainland China operation so as to lower the cost.

(iii) MC and HOQ -- In the POD module, MC and HOQ provide various products that match quality standards, for customers to choose from. For instance, E-Talent pre-defined templates for its customers so they can choose from the past successful cases through MC and HOQ. Customers can then either choose one from the selection offered or modify the template to suit their own preferences.

8.5.2 Benefits of the POD Module

(i) Quick Handling of changes -- Using object technology, data of complicated processes are abstracted. The breakdown of process into various sub-processes reduces their dependency and interdependency. This enables certain sub-processes to operate concurrently resulting in quicker implementation of changes. One of the team members pointed out that different team members could work on their tasks at the same time and were not necessarily in sequence. Project schedule was, therefore, much shortened.

(ii) Establishment of Process Database -- A process library enables quicker response to change requests. Team members can search for the most appropriate processes in the database and if such process can be found in the process database they do not need to duplicate their efforts by reproducing the process. Indeed, the library captures a number of tedious processes which are continuously updated. Respondents commented that the process database was very useful and reduced their workload in product development. Also, past experience minimized the possibility of future human errors.

8.5.3 Limitations and Considerations of POD Module

(i) Innovation -- Because of clear specifications by customers and other external parties, the main responsibility of engineers is to act as good receptors to external stimuli. They should concentrate their effort on receiving information and making quick responses. In this sense, engineers are not required to be creative. In fact, the tight project schedule does not give much room for creativity. And the engineers cannot afford much time to create novelty and make innovation.

(ii) ABC is too detailed and tedious for engineers -- Though ABC is a good scientific approach, it is very tedious and demanding if one is to adopt it. According to the engineers in the case studies, ABC was too detailed to them and they disliked such practice. They found that the requirement of ABC consumed much of their working time. They preferred to spend their time on product development rather than calculating the activity cost. Also, the companies' management in the case studies considered that the overhead cost and workload in enforcing ABC in their companies were too large. It seems that in reality it was not always efficient to implement ABC.

8.6 Discussion – Integration of Product Definition Schema

The integration of the three modules eases the passage of information between modules. When using object technology and standardization, the complexity of information is reduced and all information can be defined to common operations in a super-class. Therefore, information can be collected, translated and dispatched between modules easily. When using CARDS every team member is working at the same language like UML in our case, so it is not surprising that, according to the respondents, communication and information transfer is easier than before.

The installed change response loop, inter-connecting the three modules, classifies responses to changes into different levels. For example, if engineering problems of the internal system arise, modifications should be made in the POD module. On the other hand, problems in product features should be solved by starting from the PSE module. We should note that if serious problems are found in the system, modifications from the very beginning, at the team transformation module, are necessary. According to the project leaders in the two companies tested, the feedback loop provides an efficient and effective way to respond to change because the system can automatically signify a problem and then deal with it according to its seriousness and its nature.

In CARDS, we have three repositories: on humanware objects, product families, and processes, in each module . Integration of the three modules provides a good platform for team members to retrieve and update data that is in the repositories easily. The data in each of the repositories can interact with each other resulting in more seamless and effective exchange. The repositories refine their data into useful information and knowledge and this further benefits the product development process. This is confirmed by the respondents of the companies that were tested, who concluded that the repositories helped them reduce uncertainty on information and improve their understanding of the whole development process.

8.6.1 Benefits of the Integration

Understanding the viewpoints of customers -- Because customers are involved in the three modules, the company need to evaluate the merits, features and limitations of its products or services from the perspectives of their customers. In PSE, the value of products is assessed by the buyer instead of by the manufacturers. Thus, serious errors made by wrong judgments of project team members can be minimized.

Furthermore, the respond and feedback loops in CARDS enable customers to change their mind and modify the product design accordingly. In this way, a company can focus on the products' benefits to the customers. This is further shown in the case studies as the company representatives expressed the opinion that their products became more popular in the market because of implementing CARDS in the pilot test.

8.6.2 Limitations and Considerations of the Integration

(i) IT System Integration -- For the successful implementation of CARDS, the availability of a computer system software that supports object technology is essential. As the simulation in our case studies only dealt with parts of the system automation while the others were solved by manual methods, it seems that it would take longer to put the whole system fully in place. Senior management would have to consider whether their companies have the IT capacity to install CARDS.

(ii) Integration with external parties -- Definitely, external stakeholders can achieve agility; and the company can gain knowledge from external stakeholders by integrating with them. A company can share the knowledge library with its partners. It should be noted however that there is no sharing without disclosure. Thus, integration with external parties also implies the possibility of losing trade secrets and proprietorship on technology. People may hide something in order to protect themselves and to prevent their counterparts from becoming their “copy cats”.

In a bid to create better integration between modules and to realize the effectiveness of networked enterprises, better intellectual property right protection in laws and codes of ethics is essential. People need to learn how to respect the intellectual property of their counterparts and must not infringe the copyright of others.

Furthermore, a mechanism which improves mutual trust between organisations will surely help the integration between two parties so that they feel psychological comfort in the cooperation. So, we need a networked enterprises culture to support the mindset of "integrating with external parties". But, it seems that such culture has not been cultivated yet and people still have reservations about collaboration. Nonetheless, CARDS provides a good direction for us to go in the future.

(iii) Property capturing -- In CARDS, the properties of each element are captured through object technology. Here, we need an effective and efficient methodology to capture properties of elements such as the skill of team members and their knowledge so as to ensure the smooth operation of the three modules in the system. Properties of each element should be broken into small units which should be small enough so that each property can be recorded and flexibly recalled when necessary. This concern of effectively capturing of object property was also raised by the participants during our conference presentation. We need to note that there is room in this regard for further improvement of CARDS.

(iv) Standard Language for communication – How are we to establish effective communications between departments and organisations? To be agile, information should be effectively passed, otherwise, the enterprise will have a slow response to market stimuli. A standard language provides the common ground for such communication.

The respondents found that they might not use the same computer system as its partners. Just like ERP systems, we have brand names like SAP, PeopleSoft, SSA, Oracle and so forth. Data transfer between computer systems must be solved before smooth integration can be achieved. In addition, a common system language also affects the establishment of the knowledge library. We need a common language for inter-system communications. Some researches found that XML could be one of the solutions.

In our case study it is suggested that UML be used for inter-departmental communications. **Use case** diagrams are formulated in order to analyse product information and processes. Though a newer version of UML 2.0 has been developed, it seems that it is not very popular in the market at present. Not many companies have adopted UML in their business process. The applicability of UML in intra- and inter-organisational communications still needs further exploration.

Will UML or XML be the standard for future communication? Or will more powerful and advanced language be invented in the near future? There is much room for further work to explore these possibilities.

8.7 Chapter Summary

Product design is always regarded as a demanding, difficult and risky issue and prompt reaction to market changes is needed. It is because life cycles of products nowadays have become shorter; any delay will imply loss of market share and loss of profit. That is the reason why we need a new system which minimizes possible wrong prediction of the customer needs, environmental uncertainty and project delay. In our case studies, the companies we tested concluded that CARDS did improve and shorten their product design cycle, and allowed for external stakeholder involvement. Adopting the TT, PSE and POD modules, features, process, organisational and external collaboration agility have been achieved. Though some modifications and refinements are needed, it seems that CARDS is a generic system that is applicable to different industries for new product development.

CHAPTER 9 CONCLUSION AND FURTHER DEVELOPMENT

9.1 Introduction

The aim of this dissertation is to present the features of **CARDS**, a business process model for agile product development that meets the needs of businesses to respond rapidly and efficiently to the constantly changing market environment. As global competition is intensifying and the torrent of information is beginning to flow faster, companies are pressured to develop and launch products of wide diversity more rapidly than ever before. Concurrently, development efforts are becoming increasingly complex. It is necessary to align cross-functional teams, cross-enterprise partners, suppliers, and customers. Consideration has to be given to resource constraints, complex market needs, and shorter market windows. Global competition allows customers to expect and demand “the best”. Customers expect to get the best product at the best price with immediate availability, with the best service. For many producers, the era has passed when competition focused primarily on quality, price, or reliability. The competitive challenge for manufacturers in thiscentury will be flexibility, speed, and responsiveness to the customer’s needs. In product development, something is always changing -- perhaps a design requirement, an unanticipated simulation or test result, the availability of a component, or an improvement to the manufacturing process. Reacting quickly to such changes and getting the information to the right place is an essential prerequisite for success. Designers need to assess the impact of their decisions on other people, and notify the affected parties in an appropriate way.

9.2 Summary of the Research Work

The Customizable Agile Reconfigurable Design System (CARDS) is a novel unified system comprising three modules, namely the Team Transformation Module, the Process on Demand Module, and the Product Specification Module. The CARDS works through these three distinct modules. Each module is designed to deal with different facets of the product development cycle, and to address different specific needs and purposes. The ultimate goal of each module is to achieve the required agility in a certain area. There are in total four areas of agility being targeted. The Team Transformation Module aims at delivering organizational agility, the Product on Demand Module is for achieving process agility, whereas the Product Specifications Enhancing Module targets at optimizing the feature agility of products. The three modules are closely and dynamically integrated, interconnected, and interrelated. With them together, overall agility may be achieved. One distinguished feature of CARDS is its ability to include extensive involvement of outside parties in the product development. Outside parties like customers, vendors, or outside resources are allowed to play a role in the product development or even in high level decision making. This form of external collaboration provides the form of agility that makes this system unique and particularly effective in meeting market needs.

In implementing and operating the three modules, several supporting technologies or good practices are adopted. These supporting technologies are carefully chosen in relating to the actual business practice. Through deploying object technology, CARDS is able to magnify the benefits of the selected best practices namely: QFD, MC and ABC.

In particular, with the inherent benefits of object technology such as inheritance, polymorphism and encapsulation, the progressive inclusion of knowledge in the entire value chain of activities can be realised. The three objectized schemas of the practices have been successfully integrated to form a unified system which is able to cope with the ever-changing demands of customers, thereby contributing to the research domain related to the enhancement of agility, customisability and reconfigurability in various aspects of product development. The test of this approach with the support of a system prototype proves that the proposed system is a feasible solution in an actual design environment.

(i) The object technology approach is viable for the achievement of agility, reconfigurability and customisability

The generic nature of the proposed system allows the user to customize it to suit the unique business nature of individual companies without the need to modify or replace existing hardware and software. Apart from customisability, agility and reconfigurability are also introduced in the system through the incorporation of object technology. Object technology also enables the implementation of the three modules, which then achieve various levels of agility including feature, process, organization and external collaboration.

(ii) Objectization of good practices or supporting technologies makes for company growth

Most of the emerging practices such as MC, QFD and ABC can be objectized to transform themselves into modular-based practices so that they are more flexible during the actual operation of the three modules. They do this by virtue of the inherited features of OT including polymorphism, encapsulation and inheritance.

(iii) The cross-discipline infrastructure is essential in order to achieve organizational learning

Companies embark on continuous improvement as they face increasing demands from customers. The TT module, which allows the company to form a new team for each new project, drives each team member to deliver value-added products for the customers. The formation of a project team across various disciplines is important as this approach not only eliminates the disadvantages of hierarchy, but also allows team members to share their knowledge of areas in which they have relevant expertise. The participation of customers in the Product Specification Enhancement (PSE) module creates a list of product features for the company and its stakeholders to share. Each party can learn more about the product and enhance its features and functions. When it comes to the development stage, the Process On Demand (POD) Module enables not just a flexible and reconfigurable development process, but also allows the participation of external parties. Processes which are more economical or better in quality may be sourced from outsiders in order to form the kind of development process which is more efficient and effective. And through external involvement, companies could learn from the others' production methods or technological know-how. All in all, CARDS provides a distinct character of being able to extend the operation platform to involve outside parties and an opportunity for inter-organizational learning.

In short, the significance of CARDS lies in that it provides a holistic and systematic system to address the problems of handling changes during the product development stage. Also, the system brings into play a whole new paradigm shift in organizational thinking. It breaks down the departmental and organizational barriers within an enterprise and brings in a system which enables the staff to make changes. In this way, CARDS may support continuous improvement to the products under development, and this is the key to success for most manufacturing companies.

9.3 Contributions to the Discipline

A successful product development process has long been one of the key factors for enhancing the competitive advantage of firms, and helps differentiate a company from its competitors. Using development models that are more agile has become a popular way to produce quality products in a timely way. However, the efficiency of these agile methods and the way to enhance these processes have not been studied sufficiently (Please refer to the literature review for details). This study attempts to study these processes and proposes a model to manage them effectively.

The major contribution of this research is to assist the product development process to adapt to continuous change. In other words, it makes the development process agile enough to cater for continuous changes. The product development process is a collaborative process involving the flow of lots of information and many development steps and processes .The complexity of products is increasing so it is necessary for a modern networked enterprise to have a structure which includes professionals from different disciplines or departments of an enterprise, or even personnel located in different parts of the world. For example, mechanical engineers from Hong Kong, software engineers from mainland China, wireless professionals from Singapore need to work together. As the actual team members and product development processes differ with different products, how to ensure tight and dynamic collaboration of these development teams and a good flow of information between them has created enormous management problems.

From the results presented, through the three modules of CARDS, the firms' operating efficiency in product development can be enhanced, and that different team members can work together in a tightly coordinated manner. Our approach is, in essence, a way to manage workflow and information flow. We have also dealt with organizational workflow modelling and its enactment. Decision making and team members' behaviour will become more and more important as the applications become more complex. The CARDS develops the kind of culture and provides conceptualisations that are agreed upon by people engaging in collaborative actions. The shared nature of these conceptualisations allows people to communicate effectively and gives to the development process the ability to adapt to changes. This is because the decision-making framework can be built on the availability of clearly and consistently defined information. This requires new thinking about tradeoffs between development cost, product cost, feature sets, performance, and product strategy. It also requires members to broaden their roles within the team.

After implementing CARDS, every agile team member can fully understand the firm's perspectives and the users' requirements. With these in mind, and together with the product definition scheme, team members may work together and make decisions. Each member will also know about his/her role in the product development process, as well as the effects of his/her decisions on other members in the same team or in other teams. Once a member of an agile team takes over the task undertaken originally by another member, they can understand the ideas of that member, the finished part of the task, the remaining part to be completed, and the requirements of the task. They can do this in the earliest possible time frame. To enable them to do this it is necessary to standardize the firm's requirements, the users' requirements, the decision-making methods and the documentation. For example, in order to standardize users' requirements, the QFD (quality function deployment) method is adopted as QFD enables them to identify and manage all these requirements. The CARDS therefore renders the decision making process more predictable and controllable.

The contribution of this dissertation is the proposal of development and testing of a model that integrates four areas of agility – the product features agility, the process agility, the organizational agility and the extended collaboration agility. This is made possible by three modules which ensure timely dissemination of information, accurate coordination of decisions and efficient management of actions among people and systems. This is what ultimately determines the efficiency of enterprises and their viability in the world market. The product features agility refers to the ability of firms to produce products with the kind of specifications or features which cater well for customers' needs or match competitors' products. The process agility refers to the capability of realigning or reconfiguring the development process with ease when changes in the product designs or features are deemed necessary, Also, external parties may be made use of, for example outsourcing part of the development processes to capture others' economic or technological advantages. The organizational agility refers to the ability to break down the various functional parties in different disciplines of an enterprise into many standardized objects so that they may be reconfigured and fit into a development team which is agile enough to cater for changes in requirement. Also, by organizing the product development process as a network of cooperating professionals, each performing one or more functions, and each coordinating their actions with those of other members of the network, overall organizational agility may be achieved. Modular and reconfigurable processes together with a suitable mechanism for decision-making are crucial to agile product development and provide means to produce a variety of products that satisfy various customer requirements. The object-based approach offers the benefits of speeding up the formation of the business process while at the same time provides the ability to produce a wide variety of products that are customized for individual customers by mass customization, with predictable cost calculated using an activity-based costing method.

Pham, Dimov and Tsanev (2001) agree that the proposed system balances the dilemma between highly customized products and services and reduction in lead-time of products through the application of object technology. They share the view that new management techniques are necessary for enterprises to cope with frequent changes in customer requirements with the minimization of possible lead-time.

The CARDS brings into play a whole new paradigm in organizational thinking. Most importantly, it brings in a change in corporate culture which encourages the staff to take risks, and that the whole organization and its staff will be converted to “change” and become “customer needs” oriented.

One distinguished feature of the CARDS is its ability to have extended involvement of outside parties in the product development process i.e. extended collaboration agility. All too frequently manufacturing firms work by resorting to their internal staff for the making of decisions and for developing their products. It is an important feature of the CARDS that outside parties like customers, vendors, or outside resources are allowed to play a role in the product development and even decision making regarding product development . This form of external collaboration provides the form of agility that makes this system unique and particularly effective in meeting market needs.

9.4 The problems of implementing CARDS

There are a number of problems which may hinder the introduction and successful implementation of CARDS in a company.

(i) Top management skepticism

In order to introduce CARDS into a company, the first and foremost step would be to secure the trust and approval of the top management in implementing this novel system in the company. As usual, any new working process or protocol incurs certain risks and uncertainties to the top management, and therefore, most management will feel hesitated or uncomfortable in trying new things. How to win their hearts and faith in adopting a new working system is thus of paramount importance in introducing CARDS to a completely new environment setting. And it is also difficult to convert the benefits of CARDS into financial figures though it is crucial.

(ii) Managing change in the working team

Organizations almost always encounter resistance when they change the way they do business. People resist change for many reasons. Internal power struggles, confusion and competition between subunits are some of the transition chaos issues that can arise by not having, and communicating a clear strategy and managing the transition state. Without a clear strategy, subunits may vie for power, even to the extent of competing for the same customers. Therefore, good communication and better plans are needed when introducing CARDS to a new company. Moreover, a good incentive system must be in place so as to motivate the staff to take up a new working system and face up to new challenges and uncertainties.

(iii) Adequate information infrastructure support

In order to facilitate the working process of CARDS, and to achieve the highest degree of agility, information sharing and information transfer has to be smooth and continuous. Seamless information flow is the prerequisite in CARDS implementation and indeed is the key to successful achievement of various agilities. Therefore, in assessing whether a company is a suitable candidate for implementing CARDS, we need to look at its information infrastructure, and see if the infrastructure is good enough to support the smooth operation of CARDS. Without a good information flow, CARDS will not function as it should have been and the outcomes of implementing CARDS will be much undermined.

9.5 Suggested Further Work

Concerning the further development of CARDS, instead of using a case-based approach to outline the product specification, estimate the project schedule and design the development process, product definition and development by artificial intelligence (AI) technology, which is a promising approach, can be used. With the application of AI, project planning can be carried out based on similarity rather than merely on past experience. By analyzing the data, an accurate project plan can be formulated in a short time.

In order to promote the use of AI, a portal for the system should be developed and provided for users in various types of business so that they are able to use it online. Also, a customized template should be built to facilitate its use.

Another topic worthy of further research is knowledge management. Knowledge management refers to a process of identifying and extracting the intellectual assets of a company. Based on such intellectual assets, new knowledge with competitive advantage can be generated. When all the valuable data and information are easily accessible, best practices and high-end technology can be shared among all the staff. By doing this, project planning can be done in a more cost-effective way, and will yield greater return.

Although knowledge management is the hottest subject in today’s business world, it is not widely practised in the business community. Knowledge management in a firm ranges from accessing and controlling to delivering the company’s business intelligence to all staff members. Furthermore, it is regarded as an extension of concepts like “encouraging innovation”, “risk management”, and “performance measurement”. However, all such features are absent in current practice. As can be seen, many important features related to CARDS have not been adequately explored, so further research in these areas is highly recommended.

Survey objective

Hong Kong Polytechnic University and Group Sense Limited is now conducting a survey about product design and development management system survey. Please fill up the following questions. Thanks for your cooperation.

1. Which department are involved in product design and development?
   (Can select more than one opinion)

   - ☐ Top management
   - ☐ R & D
   - ☐ Marketing
   - ☐ Production
   - ☐ Purchasing
   - ☐ Accounting
   - ☐ Other ________________________________

2. Based on your experience, what is/are the major problem(s) of product design and development? (Can select more than one opinion)

   - ☐ Frequent customer requirement change
   - ☐ Product specification is mismatch with customer need
   - ☐ High bill of material cost
   - ☐ High turnover rate of R & D staffs
   - ☐ Project delay
   - ☐ Workflow management is too human dependent
   - ☐ Other ________________________________

3. There are a lot of different management systems, which have been used in organizations. For example, MRP for managing material schedule, ERP for managing enterprise resource. One of example for managing product design and development is Computer Supported Collaborative Work System (CSCWS), do you company use this system also?

   ☐ Yes ☐ No

4. There are a lot of concepts and tools, which have been applied in product design and development. Do you know them or apply them？

a. Concurrent Engineering (CE)

☐ Do not Know ☐ Know

➔ Does it help on product design and development？
☐ Yes ☐ No

➔ Does the company apply it？
☐ Yes ☐ No

If not，Why does not apply？
☐ No easy to handle
☐ Too complex
☐ No necessary
☐ Other ______________________

b. Design For Manufacturing (DFM)

☐ Do not Know ☐ Know

➔ Does it help on product design and development？
☐ Yes ☐ No

➔ Does the company apply it?
☐ Yes ☐ No

If not，Why does not apply？
☐ No easy to handle

- ☐ Too complex
- ☐ No necessary
- ☐ Other ______________________

c. Mass Customization (MC)

☐ Do not Know ☐ Know

➔ Does it help on product design and development？

☐ Yes ☐ No

➔ Does the company apply it？

☐ Yes ☐ No

If not，Why does not apply？

- ☐ No easy to handle
- ☐ Too complex
- ☐ No necessary
- ☐ Other ______________________

d. Quality Function Deployment (QFD)

☐ Do not Know ☐ Know

➔ Does it help on product design and development？

☐ Yes ☐ No

➔ Does the company apply it？

☐ Yes ☐ No

If not，Why does not apply？

- ☐ No easy to handle
- ☐ Expensive
- ☐ No necessary

- ☐ Too complex
- ☐ Other ______________________

e. Activity Based Costing (ABC)

☐ Do not Know ☐ Know

➔ Does it help on product design and development？

☐ Yes ☐ No

➔ Does the company apply it？

☐ Yes ☐ No

If not，Why does not apply？

- ☐ No easy to handle
- ☐ Expensive
- ☐ No necessary
- ☐ Too complex
- ☐ Other ______________________

5. Other suggestion or comment

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____

____

- End and thank you -

香港理工大學工業及系統工程學系與權智(國際)有限公司現正進行一項產品研發管理系統之研究，希望收集業界的意見，盼閣下能用一些時間，完成以下問卷，謝謝！

1. 請問貴公司哪個部門有份參與產品研發的呢？(可選擇多項)

☐ 管理層
☐ 科研部
☐ 市場部
☐ 生產部
☐ 採購部
☐ 會計部
☐ 其他 ______________________________

2. 從你過往的經驗，在產品研發上曾遇到最大的困難是什麼？(可選擇多項)

☐ 客人經常改變主意
☐ 產品規格未能符合客人需求
☐ 成本價格太高
☐ 科研人員流失量高
☐ 產品研發期延遲
☐ 流程管理過於人爲化
☐ 其他 ______________________________

3. 現時有不同的管理系統，如處理物料的有「物料需求計劃」(MRP)，企業方面的有「企業資源規劃」(ERP)，至於在產品研發管理方面，有「電腦協同工作系統」Computer Supported Collaborative Work System (CSCWS)，**請問貴公司有否採用 CSCWS 呢？**

☐ 有　　☐ 沒有

4. 爲改善產品研發的管理，現有不少的概念和工具，你認識它們嗎？

a. 「並行工程」Concurrent Engineering (CE)

☐ 不認識 ☐ 認識

➔ 你認爲這對產品研發有沒有幫助？

☐ 有 ☐ 沒有

➔ 你有否採用過？

☐ 有 ☐ 沒有

如沒有，爲什麼不採用？

☐ 不容易掌握

☐ 很複雜

☐ 不需要

☐ 其他 ____________________

b. 「可製造性設計」Design For Manufacturing (DFM)

☐ 不認識 ☐ 認識

➔ 你認爲這對產品研發有沒有幫助？

☐ 有 ☐ 沒有

➔ 你有否採用過？

☐ 有 ☐ 沒有

如沒有，爲什麼不採用？

☐ 不容易掌握

☐ 很複雜

☐ 不需要

☐ 其他 ____________________

c. 「大量客製化」Mass Customization (MC)

☐ 不認識 ☐ 認識

➔ 你認爲這對產品研發有沒有幫助？

☐ 有 ☐ 沒有

➔ 你有否採用過？

☐ 有 ☐ 沒有

如沒有，爲什麼不採用？

☐ 不容易掌握

☐ 很複雜

☐ 不需要

☐ 其他 ____________________

d. 「品質功能部署」Quality Function Deployment (QFD)

☐ 不認識 ☐ 認識

➔ 你認爲這對產品研發有沒有幫助？

☐ 有 ☐ 沒有

➔ 你有否採用過？

☐ 有 ☐ 沒有

如沒有，爲什麼不採用？

☐ 不容易掌握

☐ 價錢貴

☐ 很複雜

☐ 不需要

☐ 其他 ____________________

e. 「基於活動的成本分析」Activity Based Costing (ABC)

☐ 不認識 ☐ 認識

➔ 你認爲這對產品研發有沒有幫助？

☐ 有 ☐ 沒有

➔ 你有否採用過？

☐ 有 ☐ 沒有

如沒有，爲什麼不採用？

☐ 不容易掌握

☐ 價錢貴

☐ 很複雜

☐ 不需要

☐ 其他 ____________________

5. 你有沒有其他意見？

____

____

____

____

- 完 -

多謝你的意見

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