CHAPTER 3

SUCCESS FACTORS OF NEW PRODUCT INTRODUCTION PROCESS

The days of 100% margins and premiums for faster delivery are gone. In today's economy, price points and time to market determine a product's success.

Fast time to market means that a company can move fast and efficiently from an idea to its realization. This means that the problem solving cycles have to be executed quickly, but still generate a high quality output at low cost.

The whole new product introduction project can in itself be seen as one big integrated problem solving cycle, consisting of smaller problem solving cycles at different levels. There are at least four ways companies can manage problem solving cycles to shorten overall lead times: by performing a cycle faster, by overlapping the cycles, by reducing the total number of problem solving cycles, and by identifying and solving problems early, i.e. shifting the problem solving to earlier phases.

As problem solving tasks in new product introduction tend to be highly interdependent, the output from one problem solving cycle is usually the input for another, or they even mutually depend on each others outcomes. If problem definitions, goals, and feasibility of solutions are uncertain, this affects many other problem solving cycles at different levels. Important aspects cannot be frozen, some problem-solving cycles cannot start, and already solved problems can be redefined and solutions rendered obsolete.

To speeding up the problem solving cycles, new product introduction time can also be shortened. If new product introduction speed is an issue it is important that they should be dealt with fast and efficiently at the early phases.

According to the Global Study on Product Development conducted by Kenneth, Kenneth identified four capabilities that are needed or desirable for good performance in the early phases which will result in a faster and smoother project implementation phase.

The four capabilities are Knowledge Integration, Problem Solving and Uncertainty Reduction, Continuous Concurrency, and Simplicity.

1. **Knowledge Integration**
   A company's ability to integrate and embed in external knowledge, internal knowledge, and past knowledge.

   - External knowledge such as knowledge about customers and markets, new technologies, and supplier capabilities;
   - Internal knowledge such as the company's available technology and internal capabilities in R&D and production;
   - Past knowledge such as knowledge about old mistakes and good solutions from previous projects.

2. **Problem Solving and Uncertainty Reduction**
   A company's ability to identify and solve problems early and the ability to avoid and reduce uncertainty already in the early phases.

3. **Continuous Concurrency**
   A company's ability to overlap tasks in the early phases and keep relevant people and functions continuously involved from the early to the late phases; thereby reducing the target setting lead-time, assuring that targets are shared, accurate and feasible, and enable continuous learning throughout the project. Supports early knowledge integration and uncertainty reduction.

4. **Simplicity**
   A company's ability to reduce complexity in products, processes, systems, documentation, and organization, and by this reducing the overall development task and making the individual tasks simpler, thus enabling the other capabilities.

   The principle is to reduce the total number of tasks in the development project, and make each task easier to accomplish. The more complex a product, a process, a document is, the more times and resources have to be spent dealing with it.

3.1 Knowledge Integration

Product development is information/knowledge intensive work (Clark and Fujimoto, 1991). Developing highly successful new products is possible through the integration of the abilities of both upstream (e.g., design engineers) and downstream knowledge workers (e.g., manufacturing engineers). Firm's superior product development capabilities are derived from their ability to create, distribute and utilize knowledge throughout the product processes. While there is a substantial body of literature on work integration in product development, much less attention has been focused on knowledge integration (knowledge sharing).

This study focuses on knowledge sharing in new product development. This integration in product development takes increasingly complex forms to capture the synergy of intra-company and inter-company integration and relationships, such as team integration (i.e., forming a team with members from all the appropriate functions), intra-process integration (i.e., managing the entire development project from its concept formulation through market introduction), resource integration (i.e., giving the team the authority and resources to carry out the project), and chain integration (i.e., involvement of customers and the supply chain for product development) (Lambert and Cooper, 2000).

Empirical studies of product development have supported the importance of organizational integration for competitive advantage by correlating integrating practices and superior performance (Ettlie and Reza, 1992; Ettlie, 1995, Moffat, 1998). Such integration efforts have brought noticeable improvements to companies and resulted in good marketplace performances. Cross-functional coordination has improved, but at the expense of depth of knowledge within functions (Sobek, Liker and Ward, 1998). It is not clear how knowledge integration can actually enhance performance outcomes in the new product development.

Hoopes and Postrel (1999) propose that this correlation results from integration leading to patterns of shared knowledge among firm members, with the shared knowledge constituting a resource underlying product development efforts of a scientific software company. They aim primarily at measuring the importance of the relationship between shared knowledge and performance and focus on project failures and a lack of shared knowledge. Their study confirms that shared knowledge is an important resource underlying product development capabilities.

They define the 'glitches' as a costly error resulting from knowledge not being shared, and measure the influence of glitches on firm performance. They also identify a set of 'syndromes' that can lead to glitches, and measure the relative importance of these syndromes. The glitch concept may offer a general tool for practical measurement of the marginal benefits of shared knowledge.

In view of these prior research works, this paper explores the content of knowledge integration and possible causes of the integration-performance correlation in product development. Our study identifies three types of knowledge sharing: (1) shared knowledge of customers; (2) shared knowledge of internal capabilities; (3) shared knowledge of supplier's capabilities. This research model is based on the pioneering works of Khurana and Rosenthal (1997, 1998), Kim (1993), Paashuis (1998), and Hoopes and Postrel (1999) in regard to the importance of shared learning and knowledge. Empirical studies by Madhavan and Grover (1998), Li and Calanton (1998), and Zander and Kogut (1995) have helped to identify and measure underlying variables of shared knowledge.

Shared knowledge is one of the unique, valuable and critical resources that is central to having a competitive advantage (Nonaka and Takeuchi, 1994, 1995; Prahalad and Hamel, 1990). Firms increasingly rely on building and creating a shared knowledge base as an important resource capability (Nonaka, 1994). On a project level, teams share knowledge of individuals in order to solve problems and find innovative solutions (Davenport, Jarvenpaa and Beers, 1996; Drucker, 1991; Kogut and Zander; 1992). Shared knowledge is viewed as an understanding and appreciation among different functions and effective shared knowledge is regarded as a synergy between team members (Bostrom, 1989; Hoopes and Postrel, 1999).

Technologically more advanced products take longer to develop than less advanced products. When shortening product development cycle time, the challenge is not to cut corners, but to carry out the development task faster without sacrificing quality or eliminating steps (Gupta and Wilemon, 1990; Karlsson and Ahlstrom, 1999). According to Ward, et al. (1995) and Sobek, et al.(1999), in the case of Toyota's product development system, Toyota considers a broader range of possible design options and delays key decisions longer than many other automotive companies, yet has what may be the fastest and most efficient vehicle development cycle in the industry Toyota maps the design and establishes feasibility before commitment. In brief, Toyota teams generate a great deal of shared knowledge in considering a broader range of possible designs and manufacturing options.

Figure 3-1 shows the causal relationships of how shared knowledge (of customers, of internal capabilities and of suppliers) affect product development design processes and as a consequence impact product development performances. All the items of each construct are aggregated to test the nature of relationships.

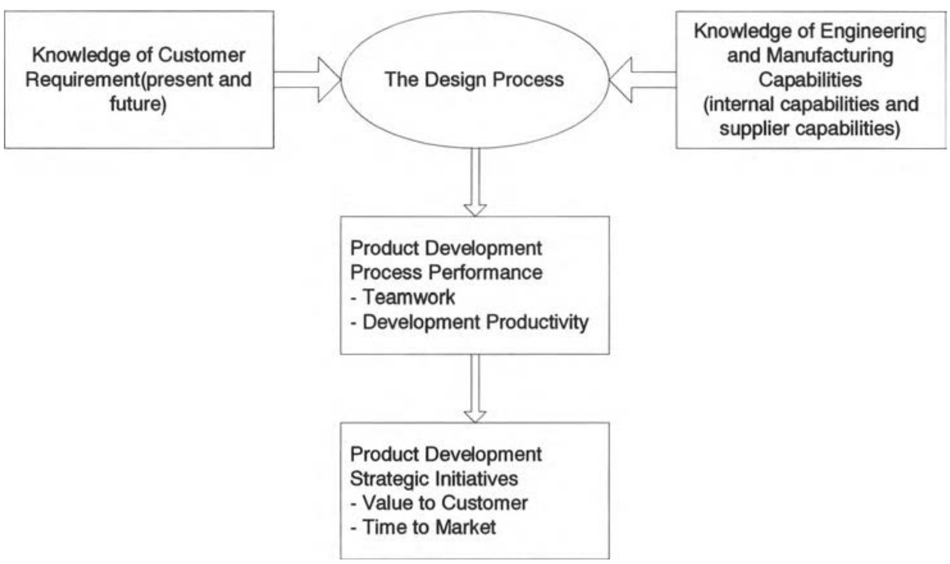

Figure 3.1: Matching customer requirements with engineering and manufacturing capabilities

3.1.1. Knowledge Sharing

Over the years, many firms have streamlined workflow and tried to improve the processes of product development. Such integration efforts have brought noticeable improvements to companies and resulted in good marketplace performance. Cross-functional coordination has improved at the expense of depth of knowledge within functions (Sobek, Liker and Ward, 1998). Developing team-learning capabilities can provide the overall depth of knowledge required for sustainable innovation.

According to Kim (1993) team learning process goes through Kofman's OADI cycle (observe, assess, design and implement). In his model, conceptual (i.e., assess and design) and operational (i.e., implement and observe) learning is distinguished. On a team level, the conceptual aspect of learning is knowledge integration (knowledge sharing) and the operational aspect of learning is work integration (i.e., operational optimization of cross-functional workflow for enhancement of multiple product development outcomes). Work integration is the natural first step towards integrated product development. However, since product development is knowledge intensive work, integration must go beyond work integration and naturally knowledge integration (i.e., knowledge sharing) needs to be equally emphasized.

Knowledge sharing attracts much attention in recent years. There is no doubt that knowledge sharing plays an important role for sustainable advantages. Firms increasingly rely on building and creating a shared knowledge of individuals in order to solve problems and find innovative solutions (Davenport, Jarvenpaa and Beers, 1996; Drucker, 1991; Kogut and Zander; 1992). Dyer and Nobeoka (2000) explored the 'black box' of knowledge sharing within Toyota's network and demonstrate that "Toyota's ability to effectively create and management network-level knowledge sharing processes at least partially explains the relative productivity advantages enjoyed by Toyota and its suppliers." Nonaka and Takeuchi (1995) explored the importance of shared knowledge for the success of a firm's product development efforts. In that sense, shared knowledge is central to enhancing a firm's competitive advantage.

However, studies of shared knowledge are limited in a particular industry: information systems (Nelson and Cooprider, 1996), and the software industry (Li and Calanton, 1998; Hoopes and Postrel, 1999). At present, little is known about the impact of shared knowledge in IPD for manufacturing firms. Also, little is known about whether, or under what conditions, a particular aspect of shared knowledge enhances a firm's product development outcomes.

1. Shared knowledge of customer

Shared knowledge of customer refers to the extent of a shared understanding of current customers' needs and future value to customer creation opportunities among product development members (Narver and Slater, 1990; Griffin and Hauser, 1991; Calantone, et al., 1995; Calantone, et al., 1996). The extent of shared knowledge is an indication of a continuous intellectual work toward creating high customer values across the functions of an organization. It is regarded as an essential aspect of product development (Deshpande, et al., 1993). Those who have a high level of contact with customers (e.g., a marketing manager or a chief engineer) may have high degrees of understanding the changing needs of customers (Slater and Narver, 1994), the value to customer attributes (Slater and Narver, 1995) and levels of customer satisfaction with the products (Gatignon and Robertson, 1991; Day, 1993; Gale, 1994).

2. Shared Knowledge of Suppliers

Shared knowledge of suppliers refers to the extent of the shared understanding (i.e., know-why) of suppliers' design, process, and manufacturing capabilities among product development team members (Maas, 1988; Hahn, et al., 1990; Slade, 1993). Since suppliers are actively involved in key processes of IPD, the knowledge of suppliers' capabilities is critical for timely and cost-effective decision making in IPD (Evans and Lindsay, 1993). Shared knowledge of suppliers allows product development members to improve their product processes (e.g., communication and collaboration among design and manufacturing engineers) and enhance customer values (e.g., fairly assessing costs of raw materials of the product supplied by the suppliers) because a substantial portion or part of their final product depends on suppliers' work.

3. Shared Knowledge of Internal Capabilities

Knowledge of internal capability refers to as the extent of a shared understanding (i.e., know-why) of the firm's internal design, process and manufacturing capabilities among product development members (Clark and Wheelwright, 1993; Garvin, 1993; Adler, et al., 1996). Knowledge of internal capabilities resides usually among design and manufacturing team members. The key is how many different functional specialists (e.g., product design engineers, marketing managers) are aware of the strengths and weaknesses of various aspects of design capabilities, manufacturing processes, facilities and other manufacturing capabilities. Standard work processes (e.g., standard forms and procedures that are simple, devised by the people who use them, and updated as needed) are an important element of process technologies (Sobek et al., 1998).

3.1.2 Learning

Learning practices within product development are subjects of growing interest to academics and practitioners alike. These issues are directly relevant to the thesis as they are closely linked with successfule new product development. This section looks in more detail at what the literature has to say on these themes in the context of the NPD process.

The role of learning within the NPD process is recognised in some of the more recent literature. The ideal product development process becomes in effect of learning process, with the learning occurring among everyone involved in the process, including stakeholders.

In the early 1980s, a study in Japan revealed the important role of learning within NPD in certain firms there, which went beyond learning from failure to influence many aspects of the development process such as human resource practices (Imai, Nonaka et al., 1985; Takeuchi and Nonaka, 1986). In these companies learning, which takes place across multiple levels (individual, group, company) and across multiple functions, "plays a key role in enabling companies to achieve speed and flexibility within the new product development process" (Imai, Nonaka et al., 1985, p.354). The researchers advocated the use of a company-wide programme to foster learning at the corporate level, citing the example of Fuji-Xerox which had "used the total quality control (TQC) movement as a basis for changing the corporate mentality", enabling it to develop a more creative and speedy NPD process (Takeuchi and Nonaka, 1986).

The role of learning within NPD was subsequently taken up by US academics, in particular in the context of developing organisational capabilities. In contrasting the traditional, tactical approach to NPD with an emerging, strategic model, Adler (1989) describe how the latter views development projects not just as opportunities to apply past learning but also to generate new learning. In this context, each new development project should include as a key objective development of new technical know-how and new organisational capabilities. Firms adopting this more strategic perspective should therefore make the fostering, encouragement and support of learning a top management priority.

Wheelwright and Clark (1992, p.284) stress the importance of learning to the process of building development capability, claiming that *"The ability to sustain significant improvements in development over long periods of time rests on the capability to learn from experience."* They warn that organisational learning from development projects does not happen automatically and suggest a more structured approach to capturing learning about the NPD process. Post project learning is seen in terms of closing the continuous improvement loop, making sure that the lessons that can be learnt from each project are identified, shared, and applied throughout the organization. This emphasis on going beyond reviewing what happened and extracting lessons to actually apply the lessons learnt. An in-depth study of 20 development projects which had been carried out from the mid 1970s to 1992 led researchers to conclude that "the key to becoming and remaining a leader is not just getting it right one time but developing a system for applying what was learned in one project to subsequent projects" (Bowen, Clark et al., 1994a).

Other recent work has looked more closely at the type of learning that takes place within NPD. A distinction may be made between single-loop, or adaptive, learning which refers to action taken to correct a situation without changing existing policies or objectives; and double-loop learning which involves challenging underlying organisation policies and objectives (Argyris, 1977). McKee (1992) relates these concepts to the type of innovation companies are engaged in. He argues that firms involved with incremental innovation need single-loop learning skills, while firms doing discontinuous innovation must have double-loop as well as single-loop learning skills. However, companies who engage in both types of innovation routinely must also be able to generalise learning from particular projects to the next innovation, a process McKee terms 'meta-learning'. Meta-learning involves institutionalising the ability to learn. It is focused on "the organisation's generalised ability to improve its performance at a class of tasks (e.g. to learn to innovate)" and involves management seeking "to learn to improve the effectiveness of future innovation projects based on experience with previous product innovations, both successful and unsuccessful." In short, meta-learning is about using learning to improve the NPD process.

Bartezzaghi et. al (1997) elaborate on the concept of meta-learning in their examination of inter-project learning in NPD. Inter-project learning involves abstracting knowledge from each project and generalising it so that it can be used on subsequent innovations. Project after project a firm progressively refines its stock of abstract and general knowledge, giving rise to a set of meta-models which the company uses as a basis for building the models used by future projects. Like the models used by specific projects, meta-models may relate to the context in which the product will be developed or sold, the product, or the project. The authors claim that inter-project learning can enhance performance in the long term and should be an additional objective within a single NPD project.

3.1.3 Effective communication and information evaluation

The importance of good communication and co-ordination for successful NPD is a recurrent theme in the literature (Lawrence and Lorsch, 1967; Barclay, 1992a; Hart, 1995). The current emphasis on parallel processing means that effective information flow between those involved is essential for the smooth working of the 'best practice' NPD process models.

For Clark and Fujimoto (1989) the main reason why US companies apply the concept of overlapping development stages less effectively than Japanese firms rests with differences in their approaches to information processing. They claim that a typical US company following the overlapping approach engages in 'batch information processing' at the end of the upstream stage. This means that those involved with downstream activities have had to start work without any early information about the upstream output. The common approach in Japanese companies, however, is for a continuous stream of data on upstream events to be released downstream, and vice versa. Such 'intensive information processing' avoids any confusion or surprises when the project moves downstream.

Wheelwright and Clark (1992) have defined four modes of interaction between upstream and downstream groups. In Mode 1, 'serial/batch', communication is "sparse, infrequent, one-way, and late; the information is serial and lengthy". In this mode downstream activity does not start until after the batch communication has been made. Mode 2, 'early shot in the dark', and Mode 3, 'early involvement' are the same as Clark and Fujimoto's 'batch information processing' and 'intensive information processing'. In

Mode 4, called 'integrated problem solving', the intensive two-way communication starts much earlier, before any downstream activities are underway.

There is more to the effective use of information in NPD than communication between participants in the process. Information needs to be acted upon. Research has found a very strong relationship between market information processing (that is, the getting, sharing and usage of market information) and new product success (Ottum and Moore, 1997). Although all three activities are necessary, information usage is the one most strongly linked to success. Data has to be evaluated in order for good decisions to be made, for example, whether or not to move on to the next stage, or whether to abandon a project.

3.2 Problem Solving and Uncertainty Reduction

3.2.1 'Lean' product development

The 'lean' concept was originally useed to describe manufacturing and engineering practices in the Japanese automobile industry which led to much higher levels of productivity and flexibility. Continuous process improvement is one of the principles underpinning the lean prescription. In the context of product development, 'lean' refers to a number of interrelated techniques taken together: supplier involvement from the beginning of the project; cross-functional teams; concurrent engineering; integration (as opposed to coordination) of various functional aspects of each project; use of a heavyweight team structure; and strategic management of each development project by means of visions and objectives rather than detailed specifications (Karlsson and Ahlstrom, 1996).

However, lean product development has not been without problems. Honda and other Japanese companies used the shortened development cycles it brought to follow a strategy of rapid model replacement and frequent model-line expansion. These were high cost strategies. The problems caused by too much product variety, environmental concerns and recycling costs caused the companies to rethink (Cusumano, 1994). These companies subsequently decided to produce fewer model replacements and variations, and to increase the sharing of parts across projects and the amount of parts and materials recycling. To force more commonalty across products project managers were made less 'heavyweight' by limiting their authority.

3.2.2 Process improvement

Adler et al. (1989), describing a firm's ability to organise new product and process development projects as a 'key capability', exhort senior managers to "ensure that the whole organization knows the importance of continual improvement in the management of the development process". Some firms appear to have recognised this to a certain extent. For example, the Gate Procedure introduced by Northern Telecom in 1985 was not intended to be rigid, but was modified and improved by each division in light of experience (Wood and Coughlan, 1990). Barclay (1992b) recommends that an NPD process should be designed to "allow continuous changes to be made, to react incrementally in line with changing environmental needs". However, his review of research into NPD found that

> "little has been reported on practical evaluation and improvement methodologies. Most of the methodologies that have been suggested are specific and not comprehensive... ....They are, in effect, 'one off solutions that are not continuous, not taking into account future changes affecting the NPDP."

His own study of 149 UK firms found little evidence of continuous improvement of NPD methodologies. Other research in the UK discovered that "a majority of companies did not have appropriate resources and mechanisms in place to identify and implement opportunities for process improvement" (Maffin et al., 1997). Although Barclay (1992b) identified a move towards adopting certain practices associated with good practice NPD, such as teamwork, CI was not built in to the NPD process. He found that responsibility for ideas and process changes rested with new product staff in 24% of firms, with a review system or committee in 26% of cases, and with a specified individual in 7% of companies; in just over twc thirds of the firms senior management were responsible (in some companies there were dual responsibilities).

Wheelwright and Clark (1992, p.53) also refer specifically to the continuous improvement of the NPD process, claiming that

> "the most successful organizations at learning and improving are those that follow a path of continuous improvement in the fundamental capabilities that drive development performance. Each project results in an incremental, but cumulatively significant, improvement in the capabilities of the organization."

Sustained learning is the goal of those companies trying to build development capability and inevitably that requires a systematic, managed process of improvement. It simply does not happen by chance or good fortune. Those firms that do achieve systematic improvement in development seem to do so on a continuous, incremental basis.

Continuous improvement has also been discussed in the context of mass customisation. Some researchers argue that companies aspiring to mass customisation first need to go through CI, in order to obtain the high levels of quality and skills, and low costs, required by mass customisation. They claim that although the two approaches require very different organisational structures, values, management roles and systems, learning methods and ways of relating to customers, CI can be a subset of mass customisation (there can be CI within autonomous operating units) though not vice versa.

Krehbiel (1993) states management must support the NPD team by providing resources that are necessary to continuously improve the process. However, it is not clear if he sees responsibility for generating ideas for improvement lying with managers or team members. Moreover, the examples he gives of ways in which the process can be improved appear somewhat costly and technology inspired (e.g. application of tools like CAD and CAE systems, 3D modelling and analysis software, electronic data interchange capabilities) rather than incremental, creative solutions.

The Japanese product development strategy which Funk (1993) refers to as 'learning' is all about NPD staff improving the development process. He points out that the decentralised approach to improving the NPD process followed by Mitsubishi's Semiconductor Equipment Department (i.e. via incremental improvements using small, decentralised working groups) sounds "very similar to the methods of improvement used by Japanese factories". Adler et al. (1996) also highlight the transferability to NPD of process improvement techniques that have produced results in production settings. They argue that process management, which has revolutionised manufacturing, can be used to streamline the product development process. Companies adopting this approach have cut development times by 30% to 50%.

CI developed in some manufacturing organisations alongside the implementation of lean production. Similarly, Karlsson and Ahlstrom (1996) believe that a move toward lean product development should be seen as

> "an initiation of a journey on the road of continuous improvement. The implication of this is that lean should not be seen as a state, but as a direction. There is always room for improvement, and the aim is to continue to improve organizational practices in the direction indicated by lean product development."

3.2.3 Quality management practices

Much has been written about Total Quality Management (TQM) during the last decade, most of it in the context of either manufacturing or in general terms relating to an organisation as a whole. More recently, however, some researchers have focused on the applicability of TQM and quality methods to NPD. There are very close links between continuous improvement and TQM, with CI commonly held to be one of the key principles underlying TQM. It is therefore appropriate to look briefly at literature spanning TQM and NPD.

May and Pearson (1993) conclude from a review of the literature that "TQM is relevant to R&D and produces results, particularly in reducing product development time". This is confirmed by their own research carried out in 1990 into the applicability of TQM to the R&D function. Of thel 4 R&D departments studied in the UK and Canada, 11 had initiated TQM. The authors found that "despite being in the early stages, these initiatives are regarded as being successful, and TQM is accepted as being highly applicable to the R&D function". Miller (1995) drew a similar conclusion after examining quality approaches to R&D in 45 multi-national firms in North America, Europe and Japan. Another study, this time in New Zealand, was carried out to investigate the findings of May et al. Using data derived from responses of 89 Chief Executive Officers to questions relating to the incorporation of TQM in R&D the researchers concluded that "TQM principles could play an important role in R&D activities" in these firms (Fisher, Kirk et al., 1995).

Miller found that the penetration of quality practices was uneven in the firms he studied. A hierarchical cluster analysis revealed four clusters, each of which emphasised different types of practices for managing R&D. The clusters are: managing R&D at the science frontier; managing R&D in revenue-dependency contexts (where internal clients buy research services from the R&D division); managing R&D for TQM integration; and managing R&D in the strategic arena (i.e. using R&D as a major tool for the strategic development of the firm). In the cluster geared to TQM integration the emphasis is on cross-functional integration and reducing cost and lead time, while the most commonly used quality management practices are technology assessment, competitive analysis, new product development systems, strategic audits, and international quality certification (Miller, 1995).

A case study of the implementation of TQM in a large complex laboratory concluded that implementing TQM in R&D is more likely to be successful if, rather than taking existing TQM systems from manufacturing and marketing and modifying them for R&D, organisational analysis is used as a basis to design a bespoke system (Taylor and Pearson, 1994). Having studied a company in which quality principles were introduced to R&D via the application of Quality Function Deployment, Debackere et al. (1997) concluded that "the uncertain and ambiguous nature of R&D activities requires that TQM be implemented in a systemic manner rather than a mechanical program.

3.3 Continuous Concurrent

3.3.1 Integration

The current prevailing view is that the development process should be designed to enable the inputs of separate functions to be integrated effectively. Lawrence and Lorsch (1967) highlighted the links between cross-functional integration and performance, and since then much has been written about the need for better cross-functional coordination and the use of multi-discipline development teams. Concurrent Engineering is an important approach for achieving integration encompassing a range of mechanisms and is discussed below under 'parallel approach'.

Functional coordination has been identified in the literature as crucial to the success of NPD (Hart, 1995). Integration, including joint decision making among all functional units and divisions involved in a project, is a key element in optimising development (Bowen, Clark et al., 1994a). Kahn (1996) defines integration as comprising both interaction (i.e. meetings, documented information flows) and collaboration (i.e. various departments working collectively toward common goals). He found that although a certain level of interaction between departments is necessary throughout the NPD process, it is collaboration that differentiates between success and failure. Survey data indicate direct links between collaboration and performance, and between collaboration and employee satisfaction (Kahn and McDonough, 1997). Another study found that the strongest drivers of cross-functional co-operation and NPD performance were perceived to be internal facilitators such as evaluation criteria, reward structures and management expectations (Song et al., 1997).

Much attention has been given to the need to improve the R&D/marketing interface and to build marketing activities into the development process from the outset (Johne and Snelson, 1988b; Cooper, 1988; Pearson and Ball, 1993; Hart, 1995; Griffin and Hauser, 1996). Souder et al. (1998) found that although R&D/Marketing integration and direct R&D/customer integration both have a positive impact on NPD effectiveness they affect it in different ways. Others emphasise the need for early manufacturing involvement and for integrated product and manufacturing strategies such as design for manufacturability (DFM) (Rothwell, 1992; Wheelwright and Clark, 1992).

Wood and Coughlan (1990) argue that in addition to DFM techniques and cross-functional teams, integration of design, manufacturing and marketing requires a disciplined management approach, such as that provided by a stage-gate procedure. Quality Function Deployment (QFD) is put forward as one mechanism for dealing with issues at the interface between engineering, manufacturing and marketing, though it is best suited to projects concerned with incremental product innovation rather than radical change (Davenport, 1993). Firms leading the field in terms of commercialisation of technology have gone beyond QFD and DFM in their quest to develop cross-functional skills, for example by building extensive networks connecting R&D, manufacturing, sales, distribution and service (Nevens, Summe et al., 1990; Harryson, 1997).

The cross-functional, multi-discipline team is seen as an important mechanism for achieving integration (Cooper and Kleinschmidt, 1993; Swink et al., 1996). A team approach can help to overcome the differences and resistance to change among people from different parts of the organisation who should be working together (Thomas, 1993). Japanese companies have a number of practices to promote multi-functional problem solving. These include, for example, getting engineers involved in a wider range of tasks (e.g. purchasing, marketing, sales, manufacturing cost analysis) and evaluating subunits and employees against a broader set of performance measures than in US firms (Funk, 1993).

Use of multi-disciplinary teams is an aspect of 'good practice' NPD which many companies have adopted. The PDMA's 1995 survey found that multi-disciplinary teams were used for 64% of all projects (Griffin, 1997). Although in general they were much more common for more innovative projects, the best performing firms used multi-functional teams in the majority of their NPD projects regardless of the level of innovativeness. An earlier study of product development practices in UK firms revealed "an increased emphasis on teamwork and teamwork training" (Barclay, 1992b).

However, not all writers favor total integration. Several suggest that a some differentiation should be preserved to allow high quality inputs derived from specialised expertise. Hart (1995) takes a contingency view, proposing that managers select the most appropriate approach, on a continuum from 'boundary spanning' to 'boundary eliminating', depending on the particular project in question and the organisational context. Similarly, although Wheelwright and Clark (1992) stress the importance of integration across the functions and propose a framework for cross-functional integration with integrated milestones, they also point out that not all development projects need deep, cross-functional integration. Adler (1992), too, advocates a contingency approach to the use of co-ordination mechanisms within product and process design. The amount and kind of integration needed depends on the specific circumstances such as the phase of the project and the inherent project complexity (Griffin and Hauser, 1996; Song et al., 1998).

3.3.2 Interfirm integration

Interfirm integration is becoming increasingly relevant for NPD. Rothwell's (1992) predictions for NPD in the 1990s include more collaboration during product development, a large increase in collaboration in pre-competitive research, and a growing number of strategic technology-based alliances. R&D partnerships and technology-sourcing alliances offer powerful learning opportunities and lead to tangible performance improvements, but need to be properly managed (Ingham and Mothe, 1998; Inkpen, 1998; Lambe and Spekman, 1997).

Close relationships with customers and suppliers are a feature of product development in Japan (Funk, 1993). There interorganisational networks of suppliers have helped to speed up product development and increase flexibility (Imai, Nonaka et al., 1985). Several studies have found that integrating key suppliers early on in the product development process can bring significant performance improvements including, for example, innovations in the system architecture, improvements in product design, and moe consideration given to design for manufacturability (Bozdogan et al., 1998; Ragatz et al., 1997; Wasti and Liker, 1997). It is important, though, that customers give their suppliers an appropriate level of responsibility, to avoid wasting their own resources (e.g. by involving suppliers too early in concept sessions) and those of their supplier (e.g. by requiring suppliers to develop capabilities which will not be fully utilised) (Kamath and Liker, 1994). As noted earlier, strong upstream supplier linkages are characteristic of the fourth generation 'integrated' innovation model, and strategic integration with primary suppliers, including codevelopment of new products and linked CAD systems, is a feature of the fifth generation model (see Section 3.6 below) (Rothwell, 1992).

Customer focus is a basic principle that applies to all effective development processes (Wheelwright and Clark, 1992). We have already seen that a well-designed stage-gate process is market oriented (Cooper and Kleinschmidt, 1993) and that close coupling with leading edge customers is a feature of the fourth generation innovation model (Rothwell, 1992). The more successful innovators actively involve customers in the development process (Rothwell, 1992). Customer needs change so it is important for a company to maintain interactive communication with major stakeholders throughout the development process (Thomas, 1993).

3.3.3 Top management

There is agreement in the literature that the behaviour of top management is a crucial factor in NPD (Hart, 1995). Top management commitment and visible support is essential for successful NPD (Johne and Snelson, 1988b; Rothwell, 1992). Writers give many prescriptions for how senior managers should behave to support NPD. For example, senior managers must accept risk and know how to learn from failures (Rothwell, 1992). As a company moves towards a strategic (as opposed to tactical) approach to NPD top management should become more deeply involved in NPD and pay particular attention to managing the interfaces between key functional areas (Adler, Riggs et al., 1989). Firms which are good at NPD make commercialisation capability a top management priority and get managers directly involved in the commercialisation process, to speed up actions and decisions and to demonstrate to the rest of the organisation that it should be taken seriously (Nevens, Summe et al., 1990). Another important role of senior executives in product development is to develop effective leaders by expecting leadership, supporting leaders and rewarding leaders (Bowen, Clark et al., 1994b).

Imai et al. (1985) show how in Japanese companies following a holistic, overlapping approach, top management act as a catalyst by setting goals which are vague but have very challenging parameters, thus creating a tension which, if managed properly, "helps to cultivate a 'must-do' attitude and a sense of cohesion" among the project team members. To support the iterative and dynamic process characteristic of this holistic approach management must adopt a highly adaptive style (Takeuchi and Nonaka, 1986). Examples of actions senior managers can take to support heavyweight development teams include drawing up the project charter, which includes a mission and broad performance objectives, and acting as an executive sponsor (Wheelwright and Clark, 1992). The latter role involves coaching and mentoring the team and its leader, and serving as a liaison channel between the team and other executive staff.

3.3.4 Shared values within an innovative culture

A feature of best practice NPD is a shared belief in the value of change. Acceptance of the need for change is a prerequisite for successful NPD (Johne and Snelson, 1988b). Sustained corporate innovation requires an organisational culture that is "innovation-accepting and entrepreneurship-accommodating", and is best achieved "when 'championing change' becomes an integral part of the firm's culture" (Rothwell, 1992).

Openness and interchange between different functions and units at all levels of the organisation can help to foster such an innovating culture (Johne and Snelson, 1988b). Highly innovative companies in the US, Japan and Europe share a set of characteristics, qualities and behaviours and recognise the importance of strong alignment between organisational and personal purpose (Zien and Buckler, 1997).

3.3.5 Parallel approach

Parallel processing within a development project, with activities taking place concurrently rather than in series, is a feature of all the current 'good practice' models reviewed earlier: the holistic, overlapping ('rugby') approach; a modern stage-gate process; the 4th generation 'integrated' innovation model; and the convergent process model (Imai, Nonaka et al., 1985; Cooper and Kleinschmidt, 1993; Rothwell, 1992; Hart, 1995). Parallel processing provides the means to have a complete development process while reducing time-to-market and, because of the simultaneous involvement of different functions, avoiding ineffective hand-offs between departments (Cooper, 1988).

Overlapping the stages of the NPD process inevitably leads to at least some parallel activity, during the overlap. As noted above in the review of the Japanese holistic approach, the degree of overlapping observed there varied between companies with some having overlap only at the border of adjacent phases, and others ensuring that overlapping extended over several phases. US companies have adopted the practice of overlapping phases and incorporated it into their stage-gate processes. However, they manage overlapping differently to the Japanese: the latter start die design and cutting earlier but still have lower costs for re-engineering charges (Clark and Fujimoto, 1989). The explanation given for this is that many US companies have failed to introduce the intensive information processing necessary to make the most of overlapping. Research in Europe found that overlapping was successful in those cases where it was an explicit approach and the flexibility it needs was properly planned and activated (Verganti, 1997).

Some commentators seem to use the phrases 'parallel development' and 'concurrent engineering' (CE) interchangeably (e.g. Davenport, 1993). This thesis takes the view that parallel development is a wider concept, applying to all activities e.g. business analysis, market investigation and supplier involvement, not just to engineering and design tasks. Hart's (1995) convergent processmodel is a good example of this interpretation. CE "consists of the paralleling of the design and manufacturing activities of a product" (Pawar and Riedel, 1993) and is considered a good practice feature of engineering and design processes (Davenport, 1993). The phrase CE encompasses a range of integration mechanisms and companies use different combinations of them depending on their particular situation and needs (Swink et al., 1996). Pawar and Riedel (1993) have reviewed a number of studies from which they identify the following generic elements amongst the integration mechanisms:

- cross-functional teams;
- computer integrated design and manufacturing methods such as CAD, CAM, and CAE;
- analytical methods to optimise a product's design and its manufacturing and support
- processes, including Design of Experiments, Taguchi Methods, Design for Manufacturability and Assembly, and Quality Function Deployment.

Techniques for achieving the integration necessary for effective CE include TQM, co-location of design and manufacturing engineers, up-fronting, design modification control, integrative prototyping, and production modification control (Pawar and Riedel, 1993). Ward et al. (1995) have described a variation on CE which they call 'set-based concurrent engineering'. Under this system engineers and managers delay making decisions and give suppliers partial information, while exploring numerous prototypes. The researchers found this method to be prevalent at Toyota and believe it is the reason for that company's speed and efficiency in product development.

Some firms using CE have documented savings in overall product development costs of approximately 20%, and reductions in engineering design changes of 45-50% (Swink et al., 1996). However, despite the benefits to be gained from parallel processing, a comparison of the time companies spent on each development activity with the reported time to develop a new product suggested, that in the early 1990s, US firms were not engaging in much concurrent working (Page, 1993).

3.4 Simplicity

3.4.1 Flexibility

Flexibility is a feature of good practice NPD. Corporate flexibility and responsiveness to change is a strategic factor involved in sustained corporate innovation, and flexibility - of the organisation, the product, and manufacturing - is increasingly important (Rothwell, 1992). The NPD process should be flexible enough to cope with different types of new product (e.g. breakthrough, incremental) and to allow continuous changes to be made in response to changes in the environment and customer needs (Cooper, 1994; Thomas, 1993; Barclay, 1992b). Flexible or 'agile' design allows firms to quickly develop a broad portfolio of niche market products, build products to order, mass customise individual products at mass production speed and efficiency, and introduce a steady stream of 'new' (variant) products (Anderson, 1997).

3.4.2 Organisational style and control

There is agreement among a number of writers that an organic organisation is conducive to innovation while a mechanistic one stifles innovatory activity (Baker, Brown et al., 1983; Rothwell, 1992; Johne and Snelson, 1988b). Rothwell (1992) has extracted from the literature the characteristics of organic and mechanistic organisations. The former is participative and informal, non-hierarchical, outward looking, flexible, lacks rigid rules; in this type of firm many views are aired and considered, departmental barriers are broken down, information flows downward as well as up, and communication is face-to-face. The mechanistic organisation, on the other hand, is hierarchical and bureaucratic; there are rigid demarcations between departments, many rules, formal reporting and long decision chains; individuals have little freedom of action and while information flows upwards, directives flow downwards.

However, the degree of innovation required at different stages of the NPD process varies and the management style needs to reflect this. The organic style is best suited to the early, more creative part of the innovation process. As the project moves through prototype production to manufacturing and out into the market, the innovation becomes better defined and the activities required are more routine, making the use of more formal controls appropriate (Baker, Brown et al., 1983; Rothwell, 1992; Johne and Snelson, 1988b). In other words, the recommended approach is for firms to shift between 'loose' and 'tight' forms of co-ordination and control during the NPD process.

3.4.3 Supportive management style

A review of a number of research studies, carried out from the 1950s to the late 1980s, which had looked at the factors influencing NPD success found that many of these factors were associated with "open-minded, supportive and professional management" (Barclay, 1992a). In fact, this attribute accounted for 30 of the 140 factors identified in total and had been identified in over three quarters of the studies. Other research has led to the conclusion that an organic management style is better than a mechanistic approach in helping to develop a culture appropriate to innovation, while a more horizontal management style with increased decision-making authority at lower levels influences speed to market (Rothwell, 1992). Recent work in the UK suggests that practice may be moving in the same direction as theory with an increasing number of companies adopting "a more democratic, professional and supportive management approach" (Barclay, 1992b).

3.4.4 Roles

There is some discussion in the literature of specific roles associated with successful NPD. For example, Roberts and Fursfield identified the following work roles as being critical to innovation: idea generating; entrepreneuring and championing; project leading; gate keeping; sponsoring and coaching (Hart, 1995). The gate keeping role may be fulfilled by a 'technological gatekeeper' while a 'product champion' embodies the entrepreneuring and championing role. A technological gatekeeper brings into the firm relevant technical information gathered from seminars, conferences, a network of external contacts and literature, and disseminates this information internally to others within R&D (Rothwell, 1992). A product champion enthusiastically supports an innovation and is personally committed to it, helping the project to maintain momentum when it runs into difficulties.

Despite the importance given to this role in the literature, a 1990 US survey found that only 43.4% of companies encouraged product champions; another 31.7% acknowledged the existence of product champions, 18% were indifferent and 6.9% had none or discouraged them (Page, 1993). In a similar survey carried out five years later 15.4% of responding firms made no use of champions, while 77% used champions to lead and/or support the more innovative projects (Markham and Griffin, 1998). A recent study of eight discontinuous product development projects found that champions were a driving force in all but one of the projects (Veryzer, 1998).

The data from the PDMA's 1995 survey led Markham and Griffin (1998) to conclude that although champions seem to have an indirect impact on firm-level performance by improving program performance and operating in concert with processes and strategies, using champions does not lead to generally more successful NPD. They also suggest that, as more firms adopt NPD processes, the role of champions may be changing from leading projects to supporting the processes in which projects are embedded.

3.4.5 Structures

Organisational structure is another of the themes identified in the literature as crucial to the success of NPD (Hart, 1995). A variety of structures, leadership styles and ways of organising NPD have been described, including the merits of matrix structures, organic structures and free standing business units (Johne and Snelson, 1988b).

However, there is growing recognition that different types of structure are appropriate to different types of product development project (Johne and Snelson, 1988b; Bowen, Clark et al., 1994b; Wheelwright and Clark, 1992; Hart, 1995). Current 'best practice' in this respect can therefore perhaps be described as having the understanding and ability to apply the most appropriate form of organisational structure on a project by project basis.

Wheelwright and Clark (1992) review the strengths and weaknesses of each of the four basic categories of development team structure: functional, lightweight, heavyweight, and autonomous. The key distinction between these structures is the extent to which responsibility and authority rest with functional managers or with the leaders of development projects. While the authors stress that different types of team structure are appropriate for different types of project they warn that organisations tend to have a 'dominant orientation' which determines the range of approaches the firm can hope to apply successfully. The functional and the heavyweight models represent dominant orientations.

A firm with a functional orientation will be able to also run lightweight teams but it is unlikely to succeed with heavyweight teams. However, a company with the heavyweight team as the dominant orientation should be able to adjust the standard approach to accommodate all four types of team. The recommendation is, therefore, that if a firm wants to have the capability to run heavyweight teams it must create the heavyweight team as its dominant orientation.

The popularity of heavyweight teams has increased, no doubt influenced by the practice of successful Japanese companies. For example, self-organising teams which are completely autonomous, devise their own very challenging goals, and enable cross-fertilisation of thought processes and behaviour patterns between members from different disciplines, have been identified as contributing to speedy and flexible product development in certain Japanese firms (Imai, Nonaka et al., 1985).

However, some companies have found that a combination of large engineering organisations and heavyweight project managers can result in too much product variety (Cusumano, 1994). These firms are now placing limits on the budgets and discretion of heavyweight project managers in an attempt to reduce the number of unique parts and product variety.

3.4.6 Tools and methods

There are a number of tools and methodologies associated with current "good practice" NPD include:

- Quality Function Deployment;
- Design for Manufacturability;
- Design of Experiments;
- Computer-based tools;
- Prototypes;
- Target cost management.

3.4.6.1 Quality Function Deployment (QFD)

QFD is a methodology which uses a series of matrices to translate customer requirements into design parameters (Wheelwright and Clark, 1992). It requires multi-functional involvement thus helping to overcome problems caused by departmentalism (Eureka, 1988). Although QFD increases the time spent upfront defining the product, overall development time is reduced as a result of focusing priorities and better documentation and communication (King, 1989). Benefits claimed from the application of QFD include: better understanding of customer needs; comparison and analysis of competitors' products are facilitated; shorter product development cycles; fewer design changes; fewer manufacturing start-up problems; improved quality and reliability; cost savings through product and process design optimisation (Eureka, 1988; King, 1989). Pilot applications of QFD within a European multi-national company had a positive impact on the fuzzy front end of the innovation process, bringing clarity and consistency to problem-framing and definition (Debackere et al., 1997).

However, it has been pointed out that a lot of development activity takes place between the matrices (e.g. testing a concept would come between the first and second matrices) and so is not included as part of the formal QFD method (Ettlie, 1992). Although in western firms QFD is most commonly used as a technique for translating the requirements of one functional group into the supporting requirements of a downstream functional group (e.g. from marketing to product engineering to manufacturing), it can also be used as a comprehensive organisational mechanism for planning and control of NPD (Rosenthal and Tatikonda, 1992).

3.4.6.2 Design for Manufacturability (DFM)

DFM is about bringing issues of manufacturability into the design process earlier. It encompasses a wide variety of methods including: design rules, which state the boundaries within which the manufacturing process is capable of meeting design requirements; and design for producibility, which is concerned with the interaction between specific parts and products and the manufacturing system (Adler, 1992; Wheelwright and Clark, 1992). Analysis of over 60 applications of one particular design for assembly/manufacturing analysis (DFA/MA) methodology found an average part count reduction of 46% and average assembly cost savings of 47% (Miles and Swift, 1998).

3.4.6.3 Design of Experiments

Design of Experiments involves taking a disciplined, systematic approach to planning experiments rather than responding to problems in a haphazard manner. Statistical methods are used to determine the optimum settings for one or more product or process parameters (Rommel, Bruck et al., 1996).

A number of techniques have been developed to overcome difficulties in analysing experiments that occur when the repeatability of measurements is low and the effects of a factor depend on the settings of the others. These include Taguchi methods (used mainly in design and problem prevention), Shainin methods (used mainly for problem solving in processes), and Evolutionary Optimisation (used for the gradual improvement of current processes) (Bandurek, 1992).

Although usually associated with design and engineering, Design of Experiments can be useful for other functions within the innovation process and it has many applications in sales and marketing (Starkey et al., 1997).

3.4.6.4 Computer-based tools

Technology has helped to cut development time. For example, in the mid 1980s Canon's semi-conductor equipment division used CAD tools to eliminate some phases of project management and overlapped others. The results were impressive: development costs were cut by 30% and time-to-market by 50%, and the division launched two generations of equipment in the time it took competitors to introduce one (Nevens, Summe et al., 1990).

Several writers (e.g. Davenport, 1993; Rothwell, 1992) suggest other ways in which technology can influence speed to market, including:

- groupware technology such as Lotus Notes, which supports horizontal communication and allows all team members to work on the most up-to-date version of the design, thus helping to reduce the number of change notes - but implementing groupware is not always straightforward (Ciborra and Patriotta, 1998);

- computer-based laboratory modelling and analysis - used by 54% of respondents in a survey of UK manufacturing companies (Maffin et al., 1997);

- computer-based field trials and communication of results;

- fully developed internal databases including integrated design databases, standard component databases, and component performance history databases;

- efficient upstream data linkages and inter-company liaison;

- conferencing systems;

- using expert systems as a design aid;

- and replacing physical prototyping by simulation models based on research data.

3.4.6.5 Prototypes

Prototypes have been found to optimise development, foster learning and initiate change throughout an organisation (Bowen, Clark et al., 1994a). The focus on prototyping in the research stage at Canon and Sony encourages researchers to exchange knowledge with manufacturing up-front, and makes R&D application-driven (Harryson, 1997). Prototypes are a powerful tool for outbound communication and to elicit information, and rapid prototyping cycles enable development teams to learn quickly (Leonard-Barton, 1995).

Since the process of stereolithography in was invented in 1984 a number of other techniques for rapid prototyping have been developed (Costanzo, 1993). Wheelwright and Clark (1992) put forward four best practices' derived from industry experience which any company can use to improve its prototyping process. These include making better use of low-cost prototypes (e.g. simple industrial design models and simulation models), and avoiding overlapping prototyping cycles. They also advocate the use of 'periodic prototyping'. This is achieved by restructuring the sequence, number and duration of prototyping cycles into a periodic pattern of prototyping which the authors claim is particularly beneficial for platform or next generation projects carried out by a cross-functional team.

3.4.6.6 Target cost management (TCM)

A very high proportion - up to 80 or 90% - of the life cycle cost of a new product is built in during the design and development phase; target cost management (TCM) is a technique applied to keep the cost within specified limits (Tanaka, 1996). Before the design work starts, the cost target for the new product is established taking into account all the activities of the product's life cycle (including, for example, sales, usage, and disposal costs).

> The designs for the product are accepted at the concept, basic design and detailed design stages only when they meet the cost target assigned. If the target is not met the designers will have to alter the designs, perhaps by using value engineering techniques.

Use of these tools and techniques can result in significant gains. For example, Polaroid achieved a 50% reduction in development time through a combination of CE, CAD and rapid prototyping (Baxter, 1995). Rosenthal and Tatikonda (1992) argue that design tools and practices such as those described above promote two strategic capabilities, cross-functional integration and an efficient and effective NPD process, which can then become a source of competitive advantage.