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Effects of work integration and knowledge integration in integrated product development

By

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An abstract of

Effects of work integration and knowledge integration in integrated product development

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The purpose of this study is to examine the effects of work integration and knowledge integration in new product development. The first objective of this study is to develop a theoretical framework of work integration and knowledge integration in an integrated product development environment. The second is to test the relationships among the drivers of concurrent engineering, among the drivers of shared knowledge, the relationship of all these constructs with product development performance outcomes, and to test the interaction between work integration and knowledge integration variables on the sound theory and standardized measures developed in the research. Finally, the last objective of this dissertation is to advance the theory of work integration and knowledge integration in product development.

To develop a survey instrument, an extensive literature review was performed along with extensive in depth interviews with practitioners and academicians to gain brevity as well as to establish face and content validity. A total of ten hypotheses were established to test relationships among work integration and knowledge integration variables in product development performance. A pilot study was later conducted to achieve reliability, purification, and convergent validity. Finally a large scale survey was then conducted from the Society of Automotive Engineers (SAE). Using mail and web responses, a total of 171 usable responses were received. The large scale study was evaluated through structural equation modeling methodology using AMOS.

Results indicate that both work integration and knowledge integration are important aspects of product development performance. However of these two forms of integration the latter, knowledge integration seems to be the major driver of development success. Two bridges were found linking these aspects of work and knowledge integration. The first was the use of a heavyweight manager which was a significant driver of the level of team vision for the project. Additionally a second bridge was the level of concurrent engineering which was a significant positive drive of the level of shared knowledge for the project. Following these results, future recommendations and discussions were raised for future research.

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Chapter One

Introduction

1.1 Importance of product development

Product development has evolved as the major focus of emphasis for companies today. In industries such as automobiles, biotechnology, consumer and industrial electronics, computer software, and pharmaceuticals, companies often depend on products introduced within the last five years for more than fifty percent of their annual sales (Shilling and Hill, 1998). Firms that get to market faster and more efficiently with products that are well matched to the needs and expectations of target customers create significant competitive leverage (Thieme, Song, and Shin, 2003; McDonough, 2000; Brown and Eisenhardt, 1995; Wheelwright and Clark, 1992). Failure to respond to competitive new product introductions with appropriate speed can result in a permanent loss of market share and dissipated profits. Despite the emphasis in both research and practice, the success rate for new product development remains relatively stagnant at 59 percent. (Thieme, Song, and Shin, 2003; Griffin, 1997).

The long term success of companies has shifted from one time order winners of economies of scale (1960s & 1970s), to practicing total quality management (1980s), to lean manufacturing and just in time techniques (1990s), to effective product development. According to Wheelwright and Clark (2000), the long term competitiveness of any manufacturing company depends ultimately on the success of its product development capabilities. Quality and price are no longer a unique source of competitive advantage in many markets (Wills and Jurkus, 2001). For example, in automotive plants today, production runs are short, as the number of styles and features produced have greatly increased. Changes in markets and technologies for automobile and textile firms have accentuated the importance of speed and variety in product development. A study by Vickery (1995), found that the most consistent predictor of business performance was new product introduction, followed closely by the product development cycle time. Honda introduced or replaced 113 models in an 18 month period in the early 1980s (Stalk, 1988) to improve market performance. Motorola first developed a cellular phone fifty percent smaller than competitive Japanese products and was able to sell that product for twice the price (Dean and Evans, 1994). New product development's objective and desired outcome is to commercialize a successful and profitable product in a timely fashion. (Griffin and Hauser, 1996; Thieme, Song, and Shin, 2003). New product development holds hope for improving market position and financial performance, creating new industry standards and new niche markets, and even renewing the organization.

1.2 Importance of integration in product development

Many of the world's successful companies create product concepts that have high value to customers and move these concepts from R & D to design, from engineering to production and into the marketplace with speed and efficiency (Clark and Fujimoto, 1991; Brown and Eisenhart, 1995; Hong, 2000, Lee et al 2000). During the course of the last decade, many US companies were not successful in the market because they were highly bureaucratic with functional structures that inhibited the flow of information (Liker, 1996). These companies lacked integration, a key attribute in product development. Markets were characterized by a rapid introduction of products into the market with short product life cycles. Companies that were not integrated in development could not compete and respond to rapidly changing conditions. These companies experienced a decline in market share and poor performance in the marketplace. To compete, firms had to adjust to a changing environment and adapt an organizational design that was efficient in acquiring and processing additional information but also one that was capable of processing rich information. Such an organizational design as an integrated problem solving approach includes an early involvement of constituents who belong to a cross functional team. This type of cross functional team works on different phases of product development concurrently. (Wheelwright and Clark, 1992).

This research in chapter two will be supported by integration literature in product development, in both the front end and also in downstream activities. For this study *integrated product development* (IPD) is defined as a managerial approach for improving new product development performance, which occurs in part through the overlap (partially or complete) and the interaction (exchange of information) of certain activities in the new product development process. (Gerwin and Baerrowman, 2002).

Through early involvement, time and communication are linked both upstream and downstream in the product development chain. Benefits are derived from fewer mismatches between product characteristics and existing process capabilities. These mismatches are often caused by the designer's misperceptions of factory capabilities (Langowtiz, 1988). For example, manufacturing may also suggest ways to design the product for ease of manufacturing by designing the product with fewer parts, to be assembled or tested more easily, or accommodated to automated equipment.

Table 1.1 Definitions in IPD

Terms	Definition
Integrated Product Development (IPD)	a managerial approach for improving new product development performance, which occurs in part through the overlap (partially or complete) and the interaction (exchange of information) of certain activities in the new product development process.
Work Integration	operational optimization of cross-functional workflows for enhancement of multiple product development outcomes
Knowledge Integration	the extent of shared understanding of cross-functional team members through strategic focus and disciplined problem solving to enhance multiple performance outcomes in product development
Heavyweight Manager	the extent of use of a senior manager that has substantial power and influence to reassign people and reallocate resources to direct the project team
Supplier Involvement	the extent to which suppliers are actively involved in the new product development process
Customer Involvement	the extent to which customers are actively involved in the new product development process
Concurrent engineering	the early involvement of a cross functional team to simultaneously plan product, process, and manufacturing activities
Team Vision	the extent of a shared understanding of the project mission, strategic fit and the project target for product development
Mutual Trust	mutual expectation among product development team members that everyone will work together in good faith
Mutual Influence	symmetrical power relationships among members of the product development team
Shared Knowledge	shared understanding of customers, suppliers, internal capabilities, and process in cross-functional product development team
IPD Outcomes	performance measurements of IPD in terms of process outcomes and product outcomes

1.3 The contribution of the integration of work and knowledge

New product development (NPD) is a process by which an organization transforms data on market opportunities and technical possibilities into information assets for commercial production (Clark and Fujimoto, 1991). This transformation necessitates integration throughout the product development process. In spite of all the integration literature in product development, there has been little work in the area of integration between work integration and knowledge integration. However, this does not underscore the importance of integration in product development. In the literature, both themes are held to be critical for market success in product development. This integration has been noted by Hong 2000, "Product development is knowledge intensive work". Product development involves integrated product development team members solving complex problems. Individuals working in the context of a business process are essentially engaged in problem-solving activities as they attempt to make sense of some phenomena (Gray and Chan, 2000).

Information is crucial to efficient product development (Eppinger, 2001), as organizations have viewed integrated teams to help seek and capture knowledge in the NPD process. Integrative practices help product development team members acquire this crucial environmental information, exchange views, interpret the task environment, resolve cross-functional conflicts, and reach a mutual understanding of the development task. These cross functional teams provide an avenue for constituents to express concerns, a mechanism for capturing learning, and an opportunity to reduce equivocality (Koufteros, 2002). Sheremata 2000, proposes that successful development requires structures and processes that generate and collect new ideas, knowledge, and information and then integrate this intellectual material into collective action. The challenge is to develop team learning capabilities to provide the overall depth of knowledge required for sustainable innovation (Hong, 2000).

1.4 Objectives

The dissertation aim is to contribute to the understanding of integration in the product development literature between work integration and knowledge integration by identifying relevant constructs and measures. As such, the study has several objectives.

The first objective of this study is the development of a theoretical framework of work integration and knowledge integration in IPD environment. An understanding of these relationships may provide an important missing link in IPD research. The theoretical framework of IPD is generally based on fundamental concepts such as total quality management, multi-functional teams, computer-aided tools, process simplification, data standards, enterprise integration, and reengineering (Hunt, 1993). The theoretical domain of IPD has been determined by its objectives: time reduction (Paterson, 1993; Gupta and Wilemon, 1990; Blackburn, 1991), cost reduction (Hartley, 1990; Carter and Baker, 1992; Handfield, 1994), quality enhancement (Zairi, 1994), effective design of product and process (Rosenthal, 1992), and manufacturability (Ha and Porteus, 1995; Swink, 1999). Given the large body of relevant theoretical and a few empirical studies concerning the constituent concepts of the interaction of work integration and knowledge integration, and product development performance, the research involves a substantial theoretical exploration stage combined with an investigation of product development teams in practice.

The second objective of this study is to test the relationships among the drivers of concurrent engineering (among the variable of heavyweight manager, supplier involvement, and customer involvement), and drivers of shared knowledge (i.e., among the variables of team vision, mutual trust, and mutual influence). Additionally interrelationships between work integration and knowledge integration variables will be tested along with the relationship on product development performance outcomes. These tests will be performed by utilizing sound theory and standardized measures developed in this research. However, since some of these variables are being studied for the first time in the context of IPD, the research would take an exploratory mode rather than a confirmatory approach. Alternative models could be generated to test for alternative relationships among these proposed constructs.

The third objective of this dissertation is to advance the theory of work integration and knowledge integration and to provide insights to practioners in the IPD field. Research in IPD requires a good understanding of the subject matter based on sound theories, research methodologies, and valid and reliable empirical findings. As of now, this study is one of a few in the integration of work and knowledge in IPD of manufacturing industries. Many studies in this area have been conceptual and case studies. Based on the empirical results of this study, future direction of research will focus on methodological, structural and practical dimensions of IPD research. Additionally, the research may provide valuable insights to practioners in the IPD field. More specifically, it may shed better light on how to enhance IPD performances through work and knowledge integration.

Chapter 2

Integration Literature in Product Development

2.1 Introduction

In product development literature, integration has been a heavily researched area (Wheelwright and Clark, 1992; Clark and Fujimoto, 1991; Brown and Eisenhart, 1995; Hong, 2000; Koufterous, 1995). Authors have documented the importance of integration of the fuzzy front end (upstream and downstream activities) (Rosenthal, 1997; Khurana and Rosenthal, 1998; Clark, 1995; Cooper, 1994; Rosenthal, 1992; Smith, 1991)., product and process engineering (Ettlie and Reza 1992; Ettlie 1995;, Stroll, 1986; Sobeck, 1998) , and integration between functions (McDonough, 2000; Brown and Eisenhardt,1995; Swink, 1998; Souder, 1987; Souder, 1988; Dougherty, 1990) . While in the organizational learning literature, integration has also been emphasized between conceptual learning and operational learning (Kim, 1993). However, integration between work integration and knowledge integration presents a gap in the current product development literature. Currently, there have been no empirical studies and little conceptual work of this critical linkage in product development. Below is a review of relevant integration literature and its contribution to product development. Additionally, table 2.1 provides a summary of the integration literature and how each literature stream adds supports to the proposed model in chapter three.

Table 2.1 Integration Literature support to research model

Integration Literature	Support to Model Items	Authors
Fuzzy Front End (FFE)	Supports the need for a heavyweight manager to drive a common team vision (Strategic fit, mission, and clarity of project targets) and to drive the IPD team to seek integrated answers to problems in the PD effort. Additionally, the FFE literature supports work integration variables of heavyweight, supplier involvement, and customer involvement, which need to be present to reduce uncertainty.	Rosenthal, 1984; Clark and Fujimoto, 1991; Crawford, 1991; Lengnick-Hall, 1996; Cooper, 1999; Rigby, 1996; and Takeishi, 2001
Product and Process engineering Integration	Supports the involvement of suppliers, customers, and internal functions which are necessary to smooth upstream and downstream activities. Integration leads to shared knowledge to ensure optimal trade off decisions are made throughout the NPD process.	Sakakibara and Westney, 1991;Kodama, 1992; Ettlie, 1995; Bergen and McLaughlin, 1992
Cross Functional Integration	Through cross functional integration, communication barriers (physical, organizational, and cultural divisions) are removed which prevent personnel from effectively addressing dependencies in new product development. Cross functional integration leads to shared deep rooted functional knowledge which leads to better tradeoff decisions in the NPD process.	Olson et al, 2001, Van Hippel, 1994; Rosenthal, 1998; Swink, 1999; Clark and Fujimoto, 1991; Cooper, 1998
Conceptual and Operational Learning Integration	Supports the proposition that both work integration and knowledge integration need to be present in order for a NPD project to be successful. If teams experience work integration without any or low levels of shared knowledge, proper trade off decisions cannot be made and glitches will occur throughout the process. In this situation, cross functional members are busy at their tasks, but they are not productive, no knowledge is being shared. Likewise, if shared knowledge is occurring without interaction across functions, the team will not be able to bring an integrated solution to typical NPD problems. Knowledge is sticky, meaning team members must share their deep rooted functional knowledge with each other to be successful in NPD.	Kim, 1993; Lewin, 1984; Kofman, 1992; Argyris and Schon, 1978

2.2 Fuzzy Front End Integration:

Management attention has begun to shift to the cross-functional front-end strategic, conceptual, and planning activities that typically precede the detailed design and development stages of a new product. (Rosenthal, 1997). The real causes of failures in most product development are not in its backend but are found in front end activities. Front-end activities include concept development and prior to system design. Typically, stages like pre-phase zero (idea generation), phase zero (assessment of market, technology, and competition) and phase one (product definition, project justification, and action plan) are regarded as front end activities (Khurana and Rosenthal, 1998). In new product development literature, this integration is commonly referred to as the fuzzy front end.

The fuzzy front end literature supports the proposed model in a number of ways. First is from the leadership aspect in IPD. "The required process orientation often requires deliberate organizational intervention because it naturally cuts across boundaries of responsibility and expertise." (Rosenthal, 1998 p.66). The front end requires extensive information gathering and analysis to facilitate the development, testing, and refinements of the product concept, but this information is not available in one place, role, or function. A leader is needed in this process not only to drive a common team vision (strategic fit, mission, and clarity of project targets) of the process, but also to drive the IPD team to seek integrated answers to problems in the NPD effort. Secondly, the fuzzy front end literature supports work integration variables by listing key examples of front end planning processes such as: the heavyweight manager (Clark and Fujimoto, 1991), early involvement of customers (Crawford ,1991; Lengnick-Hall, 1996; Cooper, 1999), and early involvement of suppliers (Rigby, 1996; Takeishi, 2001). These entities need to be present in order to reduce uncertainty in the fuzzy front end. Finally, this literature links improvements in the performance and integration of front end activities to some of the most significant benefits in the IPD effort (Clark, 1995; Cooper, 1994; Rosenthal, 1992; Smith, 1991). A review of the relevant literature in the fuzzy front end can be viewed in table 2.2.

The fuzzy front end of product development focuses on integration of project-specific and foundational elements. Project specific activities concentrate on the individual project and include project concept statement and evaluation, product definition, and project planning. The project concept is an understanding of customer needs, market segments, competitive situations, business prospects and alignment with existing businesses and technology plans. Product definition incorporates judgments about the target market, competitive offerings, and the time and resources for bringing the new product to market. The definition includes identification of customer and user needs, technologies, and regulatory requirements. These lead to the choice of product features and functions, target market segments, and design priorities which have been shown to be important success factors in product development. (Eisenhart and Tabrizi, 1995).

Table 2.2 Literature Review of Fuzzy Front End

Fuzzy Front End Literature	
Contribution	Literature
Importance of interrelated activities in the fuzzy front end	Bacon, 1994; Dougherty and Heller, 1994; Rosenthal, 1992
Developed case studies of Japan and US, discussed importance of process integration, and holistic front end	Rosenthal, 1997; Rosenthal, 1998
Integration of fuzzy front end leads to better new product manufacturing from better communications between product designers and downstream users of product designs and design support personnel	Fleischer and Liker, 1992
With access to top management and sufficient authority in the project team heavyweight managers help the team to rationally plan and align project targets with the firm's strategic objectives	Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Koufteros et al, 2002
Early customer involvement enables the team to reduce uncertainty in relation to identifying customer requirements and changing expectations	Crawford, 1991; Crawford, 1992; Lengnick-Hall, 1996; Cooper, 1999
Early supplier involvement enables the team to reduce uncertainty on what suppliers can do and cannot do in relation to overall project goals	Rigby, 1996; Liker et al, 1998; Takeishi, 2001
Knowing internal design and manufacturing capabilities allows the team to reduce uncertainty in regard to cost, time, and quality targets	Langowitz, 1988; Susman 1992; Rosenthal and Tatikonda, 1992; Clark and Wheelwright 1993
Understanding the competitors' responses and threats in advance allows the team to better decide the product development options	Bowman and Gatignon, 1995; Tersine and Hummingbird, 1995; Waarts and Wierenga, 2000

However, focusing on project specific activities alone will not ensure success for the project. In the product development process, foundational elements must also be integrated throughout the fuzzy front end. Foundational elements cut across projects and form the basis for project-specific activities. Without an organizational structure that promotes product development through ongoing communications and cross-functional sharing of responsibilities, a clear product strategy, and a well-planned portfolio of new products, front-end decisions become ineffective (Rosenthal, 1997).

An organizational structure is essential for product development. Rosenthal (1997), has recommended using a matrix or project form, organizing new product development around core business / product teams rather than traditional functions, using design and communication tools including information systems, and establishing controls and incentives for rewards. Product strategy includes the formation and communication of a strategic vision, a product-platform strategy, and a product-line strategy to support the go/no-go decisions on new product development timing. Additionally, strategy includes target markets and an assessment of the fit between the product and the core competence of the business unit. Looking into the business's portfolio, planning should map all new product initiatives across the business to balance risk and potential return, time horizons, and maturing or emerging markets. At the same time, the portfolio plan should ensure consistency with the product and business strategy. This successfully facilitates the allocation of scarce resources to the developing projects. These require enterprise-wide support, senior management participation, and cross-functional participation (Rosenthal, 1998).

Rosenthal has argued along with previous empirical evidence (Bacon, 1994; Cooper and Kleinschmidt, 1995) to simultaneously consider / integrate overall product strategy (foundation elements) with project-relevant input such as product ideas, market analysis, and technology options. Designing products in the front end phase with downstream implications considered can reduce delays, costs, and product-strategy mismatches. Success depends on how companies integrate dimensions and elements of product development. To become less fuzzy in front end activities, there must be a balance between strategic and operational activities, typically crossing cross-functional boundaries. Thus Rosenthal (1998) concluded, understanding the interrelationships between the activities is as important as the activities themselves.

2.3 Product and Process Engineering Integration:

Another form of integration in product development literature is between product and process engineering. Ettlie and Reza 1992, defined integration as that set of focused, disciplined, rigorous practices designed to concentrate efforts on evolving concepts to market introduction. Successful product development involves integration of product design and manufacturing process design (Ettlie and Reza, 1992; Ettlie, 1995; Hong, 2000). Managing this product-process connection is one of the top challenges of the era. Defects and product failures reduce initial customer satisfaction, which can damage future sales. Authors have suggested that poor integration between product and process design can have serious long term effects as up to 80% of the production decisions and resulting production costs are determined by product design decisions (e.g. Stroll, 1986). Ettlie and Reza 1992, have found that design-manufacturing functional integration was significantly correlated with new flexible manufacturing system utilization which is an antecedent to new program success.

The product and process engineering integration literature emphasizes the complexities of product development. Many Japanese companies in the NPD process have integrated suppliers, customers, and internal functions to smooth upstream and downstream activities (Sakakibara and Westney, 1991; Kodama, 1992; Ettlie, 1995; Bergen and McLaughlin, 1992). Integration leads to shared information in the product and process engineering effort to ensure optimal trade off decisions are made throughout this critical product development phase.

Table 2.3 Literature review of product and process integration

Product and Process Engineering Literature	
Product performance (time to market, cost reduction, commercial product success) is significantly enhanced if production is involved in product design	Bergen and McLaughlin, 1992; Rubenstein and Ginn, 1985; Ettlie and Reifeis, 1987; Youssef, 1995, Ettlie, 1995
Techniques for design for manufacture (DFM) for improving design-manufacturing integration and coordination	Atkinson, 1985; Hales, 1986; Stoll, 1988
New computer systems and software for assisting product-process innovation launch	Zeidner and Hazony, 1992
Integration between product planning and process design decisions enhance product development	Kim, Ritzman, Benton, and Snyder, 1992; Susman and Dean, 1992
Corporate strategy focus on integrated strategies for product and process	Prahalad and Hammel, 1990
Japanese invest more resources in process innovation and link applied R&D with applications	Hull and Azumi, 1989; Reitsperger and Daniel, 1990
Japanese are more integrated in their approaches to product-process development, resulting in better exploitation of technologies and faster to market with new products	Sakakibara and Westney, 1991; Kodama, 1992
Incorporating incremental technology, which is typical of a Japanese firm, is a significant factor in speed to market with new products	Schoonhoven et al, 1990
Empirical study of 43 firms, discussed relationship between product-process integration and the technical resource capability of firms and their ultimate performance	Ettlie, 1995

Effects of successful integration between product and process can be seen at Toyota. Chief Engineers at Toyota integrate the work of functions by planning how all parts will work together as a cohesive whole, soliciting input from various engineering, manufacturing, and marketing functions. Sobeck et al, 1998 concludes, “the key to Japanese success and the US industry weakness is integration, - both between product design and manufacturing process, and with marketing, purchasing, finance, and other business functions. Sobeck's (1998) article studying Toyota's vehicle-development process found that Japanese companies were outperforming US companies on nearly every measure: speed to market, design quality, product design manufacturability, cost, and productivity.

Toyota also integrates two main managerial practices of social processes (mutual adjustment, close supervision, and integrative leadership from project leaders) and standardization (standard skills, work processes, and design standards) to combine a highly formalized system with twists to ensure that each project is flexible and builds upon shared knowledge in the organization. An example of this captured knowledge in the product development process is engineering checklists. Engineering checklists facilitate organizational learning across generations of vehicles. Toyota trains its engineers not only to record product histories but also to abstract from these experiences in order to update existing capabilities. When new knowledge is obtained, the knowledge can be incorporated into the checklist and then applied across the company to every subsequent vehicle. Thus, if an engineer leaves, the knowledge is embedded in the checklist and remains in the company. As a result, standardization and knowledge establish a close link at Toyota. Together, these mechanisms give Toyota a tightly linked productive development system that achieves cross-functional coordination while still building functional expertise (shared knowledge). It is this combination of work integration and knowledge integration that this research attempts to explore. In the following sections, integration literature adds support to the integration of work and knowledge through the literature streams of cross functional integration and organizational learning theory.

2.4 Cross-Functional Integration:

Cross functional teams have recently been called the "heart of product development". (Brown and Eisenhardt, 1995 p369). Cross-function integration of personnel in product development has reportedly produced great positive effects on new product development in many firms (Olson, 2001; McDonough, 2000; Swink, 1998 Griffin, 1997; Cooper and Kleinschmidt, 1994). The prevalent explanation is that collaborative, concurrent design processing promotes greater integration of various functional concerns. Through cross functional integration, communication barriers (physical, organizational, and cultural divisions) are removed which prevent personnel from effectively addressing dependencies in new product development. (Olson et al, 2001;Souder, 1987; Souder, 1998; Hauptman and Hirji, 1996).

The cross functional integration literature highlights the importance of the integration between work integration and knowledge integration. First, an integrated team is needed to make key decisions on technology, cost, schedule, risk, demand, organizational resource, etc. A holistic process is needed because knowledge for making these decisions is dispersed throughout the organization (Rosenthal, 1998). However knowledge is sticky (Von Hippel, 1994), just because the necessary functions are represented on the team, it does not necessarily mean the project will be successful. Meetings could be taking place that achieve no purpose, no shared information. For the NPD effort to be successful, the right product development team members must be on the team, sharing the appropriate knowledge and expertise with their team members. Thus, the model described in chapter three, highlights this relationship between concurrent engineering and shared knowledge and also links important drivers of this construct.

Studies of product development projects have found team effectiveness related to the frequency and content of external communication (Ancona and Caldwell, 1992; Katz and Tushman, 1979; Allen 1971; Allen, 1977), internal cohesiveness and communication (Dougherty, 1990; Dougherty, 1992), team tenure (Katz, 1982), powerful project leaders (Clark and Fujimoto, 1991; Katz and Allen, 1985), and top management political and resource support (Cooper and Kleinschmidt, 1987; Katz and Allen, 1985). When product development personnel are accessible and team-oriented, they are presumably more proficient at intense information processing and making the organization more responsive to the interplay of design decisions affecting various product and process functions (Swink, 1999; Cooper 1988). As a result, capabilities and requirements are better understood and problems are solved earlier. Through cross functional integration, design characteristics such as manufacturability, complexity, and design for quality can be improved, leading to shorter manufacturing lead times later in the product life cycle, premium pricing, and better quality. (Putman 1985; Whitney 1988; Raturi et al, 1990; Fleischer and Liker 1992; Ulrich et al, 1993).

2.5 Organizational Learning Theory

All organizations learn whether they are conscious of it or not. (Kim 1993). Some organizations develop extensive plans to enhance organizational learning while others make no focused effort and therefore acquire habits that are counterproductive.

2.5.1 Conceptual and Operational Learning Integration:

Learning in a new product development team involves the transformation of knowledge or skill. Thus, learning encompasses two meanings: the acquisition of know-how, which implies the physical ability to produce some action and the acquisition of know-why, which implies the ability to articulate a conceptual understanding of an experience. This interaction of work integration (concurrent engineering) and knowledge integration (shared knowledge) is critical in a new product development team. A team must not only understand how to develop and integrate tasks among functions but also possess the necessary knowledge involved with this particular task.

This interaction of both work integration and knowledge integration must be present in order for a NPD project to be successful. If teams experience work integration without any or low levels of knowledge integration, proper trade off decisions cannot be made and glitches will occur throughout the process. In this situation, cross functional members are busy at their tasks, but they are not productive. No knowledge is being shared. Likewise, if shared knowledge is occurring without interaction across functions, the team will not be able to bring an integrated solution to typical NPD problems. Von Hippel (1994), argues knowledge is sticky, meaning team members must share their deep rooted functional knowledge with each other to be successful in NPD.

Various authors in the literature have been identified with this close link between thought and action. (Lewin, 1984; Deming, 1992; Schein, 1987; Argyris and Schon, 1978, Kim, 1993.) This thought and action relationship is similar to the thought and action between team members in product development. Piaget 1970, concluded that learning lies in the mutual interaction of accommodation (adapting our mental concepts based on our experience in the world) and assimilation (integrating our experience into existing mental concepts). Kolb 1994 commented, learning is the process whereby knowledge is created through the transformation of experience. Kim 1993, stated that both parts of the definition are important: what people learn (know-how) and how they understand and apply that learning (know-why). These two types of learning, operational (work integration) and conceptual (knowledge integration) are both critical drivers of new product development success. Team members must be working together and be sharing appropriate levels of knowledge on the product development team.

Experimental learning theory is the stream of literature that best accommodates these two aspects of learning: work planning and work doing.

(Kolb, 1994). Lewin 1984, described individual learning as a process in which a person continually cycles through a concrete experience, making observations and reflections on that experience, forming abstract concepts and generalizations based on those reflections, and testing those ideas in a new situation, which leads to another concrete experience. Various authors have modeled this relationship of experimental learning:

Table 2.4 Literature review of experimental learning models

Experimental Learning Models		
Area	Model Description	Author
Organizational Learning	Lewinian Experiential Learning Model	Lewin, 1984
TQM	Quality Control: Plan-do-check-act	Deming, 1992
TQM	Refers to Shewhart cycle: Plan-do-study-act	Deming, 1992
Organizational Development	observation-emotional-reaction-judgment-intervention cycle	Schein, 1987
Organizational Development	discovery-invention-production-generalization cycle	Argyris and Schon, 1978
Organizational Learning	observe-assess-design-implement cycle	Kofman, 1992
Organizational Learning	OADI-individual mental models (IMM) cycle	Kim, 1993

Kim's 1993 work built upon the Operational and conceptual learning model (OADI) cycle which preserves the salient features of the versions mentioned above, but the terms have clearer connections to activities conducted in the organizational context. In this cycle, people experience events and actively observe what is happening in the product development team. They assess (consciously or subconsciously) their experiences by reflecting on their observations and then design or construct an abstract concept that seems to be an appropriate response to the assessment. Team members will test the design by implementing it in the concrete world, which leads to a new concrete experience, commencing another cycle. In addition to the OADI cycle, Kim 1993, also address the role of memory which is represented in individual mental models.

The concept of mental models differs from the traditional notion of memory as static storage because mental models play an active role in what an individual (team) sees and does. Mental models are deeply held internal images of how the world works, which have a powerful influence on what we do because they also affect what we see (Senge, 1990). Mental models represent a person's view of the world including explicit and implicit understandings. Mental models provide the context in which to view and interpret new material, and they determine how stored information is relevant to a given situation. This research is an extension of Kim's operational and conceptual learning model (OADI), and applied to cross functional work in the product development team.

The two aspects of learning, operational and conceptual, can be related to mental models. Operational learning represents learning at the procedural level, where one learns the steps in order to complete a product development project. This know-how could be related to the process of product development, ideas in the fuzzy front end, drawing designs, determining customer specifications, forecasting demand, operational capacity, etc. Companies are adopting integrated approaches to identify, manage, share, and capitalize on the know-how, experience, and intellectual capital of employees (Steyn, 2002; Martensson, 2000). Work integration in IPD has the cycle of implemental and observational learning (Hong, 2000). The implementation cycle of product development is devising optimum workflows. Not only does operational learning accumulate and change routines, but routines affect the operational learning process as well. The arrows going in both directions in the diagram below represent this mutual influence. Conceptual learning is reflecting on why various routines are done in the first place sometimes challenging the very nature or existence of prevailing conditions, procedures, or conceptions and leading to new frameworks in the mental model. These new frameworks, can open up opportunities for discontinuous steps of improvement by reframing a problem in radically different ways. Thus, the team is working together and knowledge is being shared across functions. Kim's 1993, OADI model, which is shown below, highlights the importance of both types of integration. Work integration and knowledge integration need to be present in order for a successful product to occur. If team members are working together but not sharing knowledge, tasks are being performed with no real integrated understanding of the process. Glitches, delays, and increased costs will occur. Likewise, if the team has conceptual learning but has low levels of operational learning, only interfunctional knowledge is being shared and thus integrated optimal solutions are not achieved. This cycle of conceptual (work planning) and operational (work doing) learning by Kim 1993, adds very powerful support for this research work and can be seen in figure 2.1.

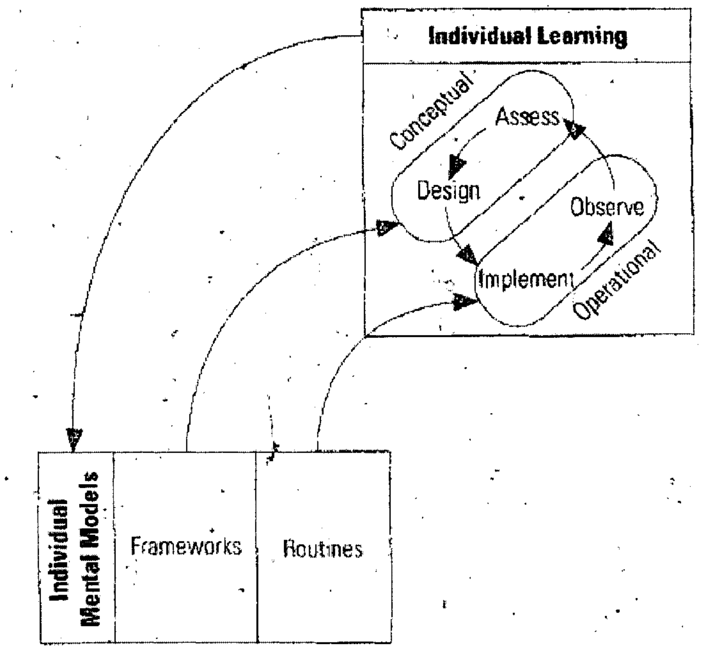


Figure 2.1 **Kim's Simple model of Individual Learning: OADI-Individual Mental Models (IMM) Cycle**

2. 6 Missing Link: Integration of Work Integration & Knowledge Integration:

The above bodies of literature emphasize the importance of integration in product development. Various authors have researched the need for integration (i.e. in the fuzzy front end, between product and process engineering, through cross functional teams, and in organizational learning). However, a gap exists in the product development literature identifying the need to integrate work integration and knowledge integration. This is similar to the work planning – work doing model in organizational learning and also can be extracted through other areas of integration such as the usage of engineering checklists at Toyota. Through checklists, standardization and knowledge established a close link at Toyota. Together, these mechanisms give Toyota a tightly linked productive development system that achieves cross-functional coordination while still building functional expertise (shared knowledge). This balance allows the company to achieve integration across projects and over time, capture learning in the product development process.

In Ettlie's (1995), article supporting product-process integration, he writes "when new product and new process are at the center of strategies for manufacturing, this reorganization to focus resources on development is more likely to impact organizational performance." In particular, Lee (1992), concludes that "the most important outcome of concurrent engineering (simultaneous design and product and process) is the emergence of an integrated knowledge base that is product / market focused rather than functionally oriented."

It is this integration between work integration and knowledge integration that this research attempts to explore. It identifies a current gap in the integration literature in product development, and adds empirical support to the field on knowledge in product development.

Chapter 3

Theory Development

3.1 Introduction into work integration

Product development is a critical means by which members of organizations diversify, adapt, and even reinvent their firms to match evolving market and technical conditions (Schoonhoven et al, 1990). IPD is a potential source of competitive advantage for many firms (Brown & Eisenhardt, 1995). Brown and Eisenhardt (1995), organized the empirical literature on product development into three streams: product development as a rational plan, a communication web, and as a disciplined problem solving approach. From an IPD perspective, NPD as a rational plan can fall into work integration, where as knowledge integration seems to be more suitable to be categorized in the other two streams,(i.e. communication web and disciplined problem solving). These streams are described below:

The rational plan builds on the Meyers and Marquis (1969) study which involved 567 successful product development projects. It focuses on a very broad range of determinants of financial performance of the product and helps to broadly define the relevant factors for product development research. According to this stream of research, successful product development is the result of rational planning and execution. Meyers and Marquis, 1969 first stated that market pull was substantially more important to the success of the products than technology push. In their study of 567 successful product development projects, they concluded a cross-functional view of PD was a key component of product success. Cooper and Kleinschmidt (1987), found the most important determinate of product success was product advantage (i.e. intrinsic value of the product, including unique benefits to customers, high quality, attractive cost, and innovative features). Additionally, Cooper and Kleinschimidt found the predevelopment planning phase (ie fuzzy front end) of IPD to be another critical success factor. IPD teams that developed a well defined target market, product specifications, clear product concept, and extensive preliminary market and technical assessments were found to be more successful. Furthermore, teams that consisted of cross-functional skills and their synergies with existing firms' competencies were also found to aid product success. Lastly, firms with favorable market conditions (entering an attractive market, low overall intensity of competition) were also found to be more successful.

Zirger and Maidique (1990), found that excellent internal organization, top management commitment, synergy with corporate strengths, product factors, and market factors were prescriptions for successful product development launches. Other authors have also provided antidotal evidence of successful product development: speed (Cordero, 1991; Mabert et al, 1992), predevelopment planning (Dwyer & Mellor, 1991), accelerating product development pace (Gupta and Wilemon, 1990) importance of early cross functional teams, customer involvement, supplier involvement, and top management support. The rational plan model stresses that successful products are more likely when the product has marketplace advantages, is targeted at an attractive market, and is well executed through carefully planned development activities. Well coordinated cross functional teams drive this effort with support from top management.

The communication web complements the rational plan literature by including the information-processing aspects of product development. Some of the early work was focused on the flow of information in product development groups. Today, the interaction of integrated product development team members (ie. work integration) and the level of information flow (ie. knowledge integration) are key factors for success in a product development project.

The communication web begins with the early work of Allen 1971, who concluded that communication among project team members with suppliers and customers stimulates the performance of the development team. Allen also researched the importance of gatekeepers, product managers, that gathered and translated external information to team members. The most successful product development teams engaged in a comprehensive external communication strategy, that helped these teams to secure resources, gain task related information (shared knowledge), and thus enhance success (Ancona and Caldwell, 1992). Teams with a strong vision (Keller, 1986) also increased communication internally among team members and led to increased performance. High levels of internal communication among team members is important in order to share deep rooted functional knowledge in a highly interactive, iterative fashion (Dougherty, 1990). Communication increased the amount and variety of internal information flow and improved the development-process performance. The communication web summarizes that frequent and appropriately structured task communication (both external and internal) leads to more comprehensive and varied information flow to team members and thus to higher performing development processes.

The third stream is disciplined problem solving which evolved from studies of Japanese product development practices in the mid 1980s. Successful product development is seen as a balancing act between relatively autonomous problem solving by the project team and the discipline of the heavyweight leader, strong top management, and an overarching project vision. The result is a fast, highly successful productive development process. Studies by Imai, 1985; Quinn, 1985; and Takeuchi & Nonaka, 1986 laid the groundwork for this stream of research. Imai 1985, studied seven product development projects in Japan and found that strong formal ties to suppliers and R & D networks were very important to the product development process. Such networks can yield high levels of technical skill which allows the supplier to contribute timely and valuable information to the NPD team. Additionally, cross functional teams permitted the overlap of development phases, which also quickened the pace of product development when knowledge was shared among team members. Studies by (Clark, 1987; Clark and Fujimoto, 1991) also replicated earlier findings. They reported that extensive supplier networks coupled with overlapping product development phases, communication, and cross functional groups, improved the performance of development teams. These authors also noted the importance of a heavyweight manager to gain resources, improve communications by breaking down traditional functional allegiances, and also build a strong product vision.

The disciplined problem solving stream also stressed the importance of managing predevelopment activities. Hayes 1988, concluded that by resolving issues / conflicts upstream in the product development effort, a clear vision was established which subsequently sped up the development process. In summary, this stream of research envisions successful product development as a disciplined problem solving approach. Successful product development involves relatively autonomous problem solving by cross functional teams with high levels of communication and the organization of work according to the demands of the development task (Brown and Eisenhardt, 1995). Below is a holistic view of the stages of this product development process.

3.2 Product Development Stages: The following stages are the most common stages in a product development process (Bingham and Quigley, 1990).

Stage 1 Idea generation: Information from existing or potential markets is obtained by marketing research and directed for evaluation. Information concerning new methods, materials, and technologies is obtained by engineering. This information may be obtained from external sources such as suppliers, competitors, customers, or obtained from internal sources, particularly manufacturing (Heiko, 1998). The heavyweight will integrate the information flows with the strategic directives of the organization.

Stage 2 Idea screening: The idea-screening stage focuses upon narrowing the range of ideas into subgroups based upon their probability of success and the time horizon for implementation. Information is exchanged through IPD team members, to assess market success, technical feasibility, production resources, distribution, and cost issues. To accelerate this stage of the process, it is accomplished in conjunction with idea generation.

Stage 3 Conceptual development and testing: Product ideas emerge into well-formulated sets of attributes designed to appeal to specific sets of consumers. These attributes must be transformed into detailed design blueprints. Product designs are made available to manufacturing, market acceptance studies are performed, consumer segments are identified, and target markets are selected.

Stage 4 Business analysis: An idea that seems appropriate to the company mission and strategy thrust is forwarded to research and development, where the new product concept is translated into a concrete, tangible entity.

Stage 5 Product development: At this stage, the idea has completed its transformation into a physical product. Technical and design problems are resolved and consumer reaction is gauged in order to develop entry strategies.

During this stage, emphasis within the team shifts from technical to market concerns as the product approaches commercialization.

Stage 6 Test market: Prototypes that survive the product development stage but do not yet meet the criteria to proceed to commercialization enter the test market stage.

Stage 7 Product introduction: The idea generated regarding the new product when it has reached its final stage. A full scale production and commercialization of the new product takes place.

Table 3.1 Work integration variables in IPD

Variables	Definition	Literature-base
Supplier Involvement	The extent to which suppliers are actively involved in the new product development process. Good suppliers not only provide parts, they provide process knowledge and product component innovation.	(Koufterous, 1995; Willaert Graff and Minderhoud, 2001)
Customer Involvement	The extent to which customers are actively involved in the new product development process. Involving customers early in the new product development process ensures that the customer's needs are being met.	(Koufterous, 1995; Hong, 2000; Clark and Fujimoto, 1991; Zirger and Maidique, 1990; Mabert et al., 1992)
Heavyweight team manager	Senior managers that have substantial power and influence to reassign people and reallocate resources to direct the project team.	(Koufteros et a. 2002; Shilling and Hill, 1998).
Concurrent Engineering	The early involvement of a cross functional team to simultaneously plan product, process, and manufacturing activities	(Koufterous, 1995)

3.3 Heavyweight Manager

"The heavyweight manager creates a drive to create products that fire the imagination, that surprise and delight the customer" (Clark and Fujimoto, 1991 p.59).

For this study, a heavyweight manager has been operationalized as:

Heavyweight managers are senior managers that have substantial power and influence to reassign people and reallocate resources to direct the project team" (Shilling and Hill, 1998).

Product development teams driven by a heavyweight manager are critical aspects of effective integrated product development (Koufterous, 1995, Lundqvist et al, 1996; Lee, Lee, and Souder, 2000; Thieme, Song, and Shin, 2003). Heavyweight managers facilitate concurrent engineering which involves customers, suppliers, and functional specialists. A heavyweight product manager possesses both position and seniority along with specific skills and experience developed while working in an organizational context that includes a structure and system to support a strong product focus, multifunctional teams of broadly skilled people, and extensive cross-functional communication and influence (Clark and Fujimoto, 1991). Japanese firms had already established the heavyweight manager product systems in the mid 1980s and US and European countries later utilized this effect some time after the late 1980s.

Heavyweight managers are responsible not only for internal coordination, but also for product planning and concept development. As external integrators, heavyweight product managers cultivate direct and continuous contact with customers. They supplement the "cooked" market information they receive from the marketing group with "raw" market information gathered directly from existing and prospective customers (Clark and Fujimoto, 1991). The emphasis placed on many Japanese heavyweight managers is to visit engineering, plant people, dealers, and customers. This gives them a better understanding of the new product. Of all the decisions management makes in managing NPD, none is more crucial to success that the choice of a project manage (Smith and Reinersten, 1991; Lee et al, 2000).

According to a study of 244 manufacturing firms by Koufterous, Vonderembse, and Doll, 2000, heavyweight product development managers drive the application of concurrent engineering and computer usage. They provide expertise and organizational authority that facilitates this cross functional process as well as the application of technology. The need for heavyweight product development managers entails the use of computers. Research framework illustrates how a firm's internal context, shaped by a key structural decision, i.e., heavyweight product development manager (Clark and Fujimoto, 1991; Maidique, 1980; Roberts, 1977), facilitates its effort to achieve cross-functional integration, (i.e. concurrent engineering; Barkan, 1992; Langowitx, 1988; Millson et al, 1992).

Heavyweight managers play a critical role in communication within the IPD team and to senior management. They can communicate with upper management in a language it understands (Pawar et al, 1994). Heavyweight managers are integrators (Daft and Lengel, 1986). Effective heavyweight managers must be "multilingual"; they must be fluent in the languages of customers, marketers, engineers, and designers. An example to illustrate this point could involve designing of a new sports car. Setting a target like "a sports car which can compete effectively in Europe", is too abstract and ambiguous for engineering, but the heavyweight could translate the target into clear and specific objectives such as "maximum speed 250km/hr, drag under 0.3 and so forth." A heavyweight manager who has internalized an equivocal product concept must translate it into unequivocal expressions in each of the downstream languages in order for all members of the team to understand it (Clark and Fujimoto, 1991).

Conditions favorable to assigning a heavyweight can include internal conditions such as high environmental uncertainty, increased levels of timely pressures, internal conditions of high resource requirements, and high levels of strategic fit with company goals. Environmental uncertainty involves the nature of markets sought for the developing project, the types of markets their firms targeted, market size and potential, market growth, the competitive situation, stage of the product life cycle, and market newness to and synergy with the firm (Cooper, 1984). Time based competition measures the pressures to enter the product into the market. Companies with short cycle times can continually upgrade their products and incorporate new state of the art technologies when they become available. This allows substantial gains in customer value, brand loyalty, and also to develop more products in niche type markets (Shilling and Hill, 1998). Firms entering new markets with high growth potential and uncertainty will need a heavyweight manager to help coordinate and manage the new product development effort. Additionally, firms that are developing projects with time based competitive pressures will need someone to coordinate the activities and ensure deadlines and launch times are being met.

Resource requirements involve the extent to which capital, labor, and time requirements / investments are needed for the particular project. Projects that have high capital requirements have an increased need for someone to oversee and manage this complicated process. Strategic fit products are products of high value to the firm which are aligned with the corporate strategy. Wheelwright and Clark (1992), suggest formulating a product map to oversee the current project development process. This rates projects on the extent of product and process change. Projects can then be identified as Enhancements, Next Generation, or Breakthroughs. Important projects to the company require someone to direct, oversee, and manage the project for the firm. Such projects may serve as high value for the firm and a heavyweight manager would direct this effort. Below are the four main types of projects described by Shilling and Hill, 1998 in the NPD process.

NDP teams can be formed for a number of various projects. Schilling and Hill, 1998, discuss four main types of projects based on the project map of Wheelwright and Clark, 1992. These four types of projects are as follows:

Derivative projects: involve incremental changes in products and or processes.

Platform projects: fundamental improvements in the cost, quality, and performance of a technology over preceding generations.

Breakthrough projects: development of products that incorporate revolutionary new product and process technologies.

Advanced R&D Projects: Precursor to commercial development projects and are necessary to develop cutting edge strategic technologies.

Schilling and Hill, 1998 argued that the use of a heavyweight team manager would be appropriate for platform and breakthrough projects. This is characterized by a high degree of cross-functional integration and a high degree of fit with existing organizational practices. The heavyweight manager would be given authority and influence over the rest of the team and be able to acquire necessary resources in order to carry out the project.

Assigning heavyweights to project teams helps firms cope with uncertainty and equivocality in the environment by providing a champion in the product development process, improving knowledge sharing through teams / concurrent engineering, and increasing information availability and flow. They help the IPD team share a common vision of the product. These practices seem to be central to the enhancement of product quality, product innovation, premium pricing, and profitability. (Koufteros et al, 2002)

3.4 Supplier Involvement

The next work integration variable is supplier involvement. For this study, supplier involvement has been operationalized as:

Supplier involvement is the extent to which suppliers are actively involved in the new product development process. (Koufterous, 1995).

Good suppliers not only provide parts, they provide process knowledge and product component innovation. Today companies must contend with increased pressures to reduce costs and cope with increased numbers of product and process technologies (Huang and Mak, 2000), The central argument of the literature is that individual organizations can no longer rely on their own resources to compete in today's world (Sobrero, 2002). Moreover, external sourcing of technology and technological knowledge (in the form of products, processes, and services) from suppliers and other providers is increasing (Chatterji, 1996) .This is a result of companies focusing in their core competences (Hamel, 1994) and the need to be responsive to the changing and less predictable markets at both national and global levels (Miffin, 2001). These factors expand the range of development options open to companies and increase the importance of the role of suppliers in the product development process. In a cross national study of twenty-nine NPD projects (Clark, 1989), it was found that much of the Japanese advantage in concept-to-market time was attributed to supplier involvement in the NPD process. Japan resulted in a higher fraction of unique parts and found that suppliers were an integral part of the development process; they were involved early, assumed significant responsibilities, and communicated extensively and directly with product and process engineers. Overall, greater supplier involvement accounts for roughly one-third of the Japanese advantage in engineering hours and 4-5 months of their lead time advantage (Sobrero and Roberts, 2002)

Suppliers may deliver valuable insights into the integration of the NPD and production phases ensuring a higher overlap between the stages in the product development process (i.e. by testing the innovation and developing prototypes in collaboration). At the concept design stage, suppliers can assist in identifying the latest technologies to be incorporated into the product. Additionally suppliers can participate in detailed design by providing solutions to component and part designs and by providing the selection of the most suitable materials and components. During the production planning phase, suppliers can contribute to strategic make or buy decisions when production design begins. Internally suppliers provide the most capable tooling, fixturing, and equipment. Bonaccorsi and Lipparini 1994, reported benefits of supplier involvement which include:

reduced development costs, early availability of prototypes, consistency between design and supplier's process capabilities, reduced engineering changes, higher quality with fewer defects, reduced time to market, early identification of technical problems, acquisition of suppliers' production capacity and improved supplier innovations. The rational is that suppliers frequently possess vital product and process technologies that can lead to improvements in product design and in the new product development process itself.

3.5 Customer Involvement

For this study, customer involvement has been operationalized as:

Customer involvement is the extent to which customers are actively involved in the new product development process" (Koufterous, 1995).

Customers are continually demanding innovative products with exceptional quality at a competitive cost. Companies are forced to either quickly deliver high valued products to customers or face the consequences in today's unforgiving competitive environment. A product which is not manufactured in accordance with the customer needs and hits the market late or is too expensive cannot be successful. Involving customers early in the NPD process ensures that customer needs are being met.

Kusar et al 2004, noted that for successful product development, customers should have representation on the product development team. According to Clark and Fujimoto 1991, a shared understanding of concept and customer expectations are critical to the integrity of the product. Even though customer partnerships are an integral part of the project development process, many companies fail to include them in their project planning (Wheelwright and Clark, 1992). Adding customers to the team from the beginning of product development, is the best way to understand the customer. (O' Neal, 1993). By involving a multi-disciplined team in the development process, it improves the translation from the customer's needs and wants to the completed product.

In an article by McDonough, Kahn, and Barczak, 2001, they recognize the movement towards global teams. Global teams are comprised of individuals who work and live in different countries and are culturally diverse. Companies are creating global teams because they realize the importance of closely identifying with global consumers. These teams understand the needs of consumers who may be located in different countries, who speak different languages, who have different sets of cultural beliefs, and who express their preferences in different ways.

Another practice, Quality function deployment (QFD) has been used in product development to help understand customer needs. QFD is a system to assure that customer needs drive the product design and production process. (Sullivan, 1986). Typically a QFD system can be broken down into four interlinked phases to fully deploy the customer needs phase by phase (Sullivan, 1986; Day 1993; Eureka, 1994; Hauser, 1988). The four QFD phases include:

Phase I: to translate customer needs into product design attributes (technical measures).

Phase II: to translate important technical measures into parts characteristics

Phase III: to translate important parts characteristics into process operations

Phase IV: to translate key process operations into day to day production requirements (Chan and Wu, 2005).

Most QFD articles stress the importance of the first phase, which is usually referred to as the house of quality. In this first phase, the voice of the customer is closely listened to among all IPD team members. Analysis of the voice of the customer includes the customer's need for the product and the customer's perceptions on the relative importance of these needs. Addtionally, it also includes the relative performance of the producing company and its main competitors on the needs (Chan and Wu, 2005). With increased levels of shared knowledge among IPD team members, the project will closely fit customer requirements, and contribute higher value for customers. This leads to better success in the marketplace (Gruner and Homburg, 2000).

3.6 Concurrent Engineering

For this study, concurrent engineering (CE) has been operationalized as:

Concurrent engineering (CE) is defined as: "the involvement of a cross functional team in a process to plan product, process, and manufacturing activities simultaneously (Koufterous, 2002)."

Successful product development requires structures and processes that generate and retrieve new ideas, knowledge, and information and then integrate this intellectual material into collective action (Sheremata, 2000). The market to develop new products is filled with uncertainty, as teams try to cope with the fuzziness of their task environment and there by try to enact a shared team vision more quickly (Gupta, 1986). Concurrent engineering has been cited as the main reason for the rapid new product introductions by Japanese firms (Willaert and Minderhoud, 1998). Many companies have turned to concurrent development which reduces uncertainty by improving communication between departments. Cross functional teams provide an avenue for constituents to express concerns, a mechanism for capturing learning, and an opportunity to reduce equivocality. Research suggests that cross-functional teams have become an important tool used in the development of new products (Cooper and Kleinschmidt, 1994; Griffin, 1997; McDonough, 2000; McDonough et al, 2001; Thieme, Song, and Shin, 2003). Companies that have embraced this approach have reduced their average development times by 30% to 50% due to the following reasons: activities run in parallel, team members meet regularly which allows for fast and efficient exchange of information, and teams are held responsible for all product development features (Kusar, 2004). Examples include Harley Davidson, Hewlett-Packard, Motorola, GE, GM, and AT&T (Stalk, 1988).

Through concurrent engineering, design characteristics such as manufacturability, complexity, and design for quality can be improved through greater cross functional involvement, shorter manufacturing lead times in the product life cycle, premium pricing, and better quality (Putman, 1985; Putman, 1988; Raturi et al, 1990; Fleischer and Liker, 1992; Ulrich et al, 1993). In a study by Koufterous and colleagues (2000), firms seeking to implement CE should focus on developing the three dimensions that form the CE construct: concurrent work flow, product development teams, and early involvement of relevant constitutes such as suppliers, customers, and cross functional team members. Koufterous's 2000, study supports the formation of cross functional teams at the beginning of the product development efforts. The results support the claim that CE practices lead to high levels of product innovation, quality (indirect), and premium pricing.

CE has also been linked to aspects of knowledge integration in product development. Several researchers have described NPD as a knowledge intensive activity (Eder, 1997; Iansiti and MacCormack, 1997; Nonanka and Takeuchi, 1995; Song and Weiss, 1998; Hong, 2000). NPD requires integration of knowledge of the cross functional team members in order to solve complex problems during the design and development phases. Through CE, cross functional teams can function as a flexible learning mechanism that encourages meaningful transformation of knowledge (Meyers and Wilemon, 1989). These lateral decision processes cut across functional authority and allow communication and information sharing in the NPD effort (Henke, 1997). Integrative practices (CE) help the team members acquire environmental information, exchange views, interpret the task environment, resolve cross functional conflicts, and reach a mutual understanding of the development task (Koufteros, 2000).

3.7 Knowledge Integration

The first attempt in the direction of integrating knowledge in new product development can be framed at the beginning of the 80's with the introduction of the concept of concurrent engineering (CE). CE was trying to address the problem of integrating different product development phases at the single project level (Nonaka, 1990; Dowlatshahi, 1994). Overlapping ongoing activities by means of multifunctional teams has rapidly become a common practice in product development and an implicit means of addressing knowledge integration issues across different phases of the process.

At the beginning of the nineties, the literature started to focus on how to improve the performance of teams suggesting solutions such as the *heavyweight* project manager (Wheelwright and Clark, 1992). The heavyweight project manager integrates knowledge and development efforts within teams. Moreover, the literature began to emerge that the creation of teams did not by itself solve the knowledge integration problems along two dimensions: space and time. Literature on the multi-project management (Cusumano and Nobeoka, 1992), the role of product families (Meyer and Utterback, 1993), the role of product architecture (Henderson and Clarks, 1990), and the importance of developing long term product plans (Wheelwright and Sasser, 1989) has tried to address both the spatial and temporal problem moving the focus of knowledge integration from the individual project level to the company level. As a consequence, from an organizational point of view, new managerial roles developed such as the product manager, platform and program managers. In the nineties, moreover, there was also a strong emphasis on the role of external sources of innovation such as suppliers and customers in product development (Von Hippel, 1988; Clark, 1989; Cusumano and Takeishi, 1991; Nishiguchi, 1994). Hence, the integration problem began to move from the intra to the inter-company dimension. The most common solution to address the integration problems here, was the use of *guest engineering* (Nishiguchi, 1994). Guest engineering involves the exchange of technical personnel between organizational actors in a supplier network (Lewis et al. 2001). Some literature, in this respect, suggests the importance of heavyweight managers (Clark and Fujimoto, 1991) to interact with the external sources of knowledge.

A further step of the literature is linked to the re-interpretation of concepts such as component modularity (Whitney, 1988; Ulrich and Eppinger, 1995;

Sanchez, 1994). The design strategies that hinge on modularity have been demonstrated to have an impact beyond the engineering aspects. The co-ordination of different actors (i.e. R&D centers, OEMs, suppliers, engineering firms) does not hinge only on the hierarchical power but also it is based on the design interfaces themselves that should act as a co-ordination mechanism.

Table 3.2 Knowledge integration variables and IPD outcomes in product development

Constructs	Definition
Team Vision	Team Vision is the extent of a shared understanding of the project mission, strategic fit and the project target for product development.
Mutual Trust	Mutual Trust is the mutual expectation among product development team members that everyone will work together in good faith.
Mutual Influence	Mutual Influence is the symmetrical power relationships among members of the product development team.
Shared Knowledge	Shared Knowledge is the shared understanding of customers, suppliers, internal capabilities, and process in cross-functional product development team.
IPD Outcomes	IPD Outcomes are product outcomes and process outcomes.

3.8 Team Vision

For this study, team vision has been operationalized as:

Team vision is the extent of a shared understanding of the project mission, strategic fit, and the project targets for product development. (Hong, 2000).

In IPD, team vision is a shared purpose and plan of action that clarifies mission, strategic fit, and sets of project targets that are consistent with the firm's internal capabilities and the marketplace realities (Rosenthal and Tatikonda, 1990; Clark and Wheelwright, 1993; Marquart and Reynolds, 1996; and Hong, 2000). Team vision is a critical linkage between role changes and shared knowledge to bring about positive product development outcomes (Hong, 2000). Importance of team purpose and objectives are discussed by Colenso (2000). Teams fail because of confused goals and unresolved roles (Robbins and Finley, 1996). According to Katzenbach and Smith (1993), in jointly developing clear goals and approaches, teams establish communications that support real-time problem solving and initiative.

There are three variables of team vision: shared purpose and mission, strategic fit of project targets, and clarity of project targets (Hong 2000). The first two variables (shared purpose and strategic fit) relate project characteristics to broad organizational or program goals, while the last variable, clarity of project targets, examines project specific characteristics. Shared purpose and mission describe the future state associated with project success. Strategic fit of project targets is for use in identifying important factors that assess and compare a project's ability to achieve overall strategic goals. Lastly, clarity of project targets evaluates alternatives among existing and potential projects and decides exactly what the project is to accomplish among the set of targets.

Throughout the literature there is support to show that a clear vision that is shared and agreed upon by others on the team are recurring themes for successful innovation (Leonard-Barton et al, 1994). Sharp and colleagues (2000), purpose that shared vision, purpose, goals, and direction are among key enablers for a high performance team. One such concept is collective ambition development, which (Weggeman, 1995) is described as an intervention technique designed for knowledge intensive organizations. Collective ambition refers to a shared view of the organization's mission, goals, and strategy among IPD team members. When team members develop a collective ambition, the IPD team members share the same set of goals. Team members also attempt to see each others behavior in an important decision making process. Thus, teams that jointly develop clear goals and approaches establish communication that supports real time problem solving and initiative.

Successful teams were committed to the vision of the project, while unsuccessful teams were misdirected with blurred vision or a vision conflict among team members (Bowen et al, 1994; Lynn, 1998). One such example is the concept of goal incongruity. Goal incongruity is defined as the basic difference within the firm between marketing's goals and values and those of the R&D and manufacturing departments. An empirical study by (Pinto, Pinto, and Prescott, 1993), has shown that a high level of goal incongruity leads to a high level of cross function conflict and open hostility. Thus marketing perceives other functions, goals, and objectives to conflict with its own and therefore it has little incentive to cooperate. In this type of environment, there is a decrease in motivation to share knowledge and to develop collective wisdom among team members. This results in confused goals, unresolved roles, and a lack of a shared vision (Lynn, 1998) which are major causes of team project failure.

Table 3.3 Team Vision in IPD

Variables	Definition	Literature
Mission	The extent of plan of action for product development.	Hong, 2000; Rosenthal, 1992; McComb, Green and Compton, 1999 etc.
Strategic Fit	The extent of alignment between team's mission and overall business, technology, and product strategy.	Hong, 2000; Cooper, 1983; Cooper and Kleinschimidt 1987; Engulund and Graham, 1999 etc.
Project Targets	The extent of project targets specification and the extent of communication and understanding of project goals.	Hong et al, 2005; Lundqvist et al, 1996; Schein, 1996; Clark and Wheelright, 1993; Gupta and Klaus, 1992; Prabuddha et al, 1995; Rosenau, 1989 etc.

3.8.1.1 Mission

Mission refers to the extent of a plan of action for product development. It is the extent of a shared understanding of the project purpose, the project mission, the project goals, work plan, and the product concept for product development (Hong, 2000). Project purpose is used to answer the fundamental question of why the project is important. Project mission is used to define what the project is really about (Tjosvold, 1989; Rosenthal, 1992). Project goals are what the project intends to accomplish (Rosenthal and Tatikonda, 1992, 1993). Project work plan is the sequence of how the project is to be implemented. Finally, product concept is an elaborated version of the idea expressed in meaningful consumer terms (Khurana and Rosenthal, 1997; Kotler, 1999). In innovation, there is talent, there is ingenuity, and there is knowledge; but when all is said and done, what innovation requires is hard, focused purposeful work (Drucker, 1998).

3.8.1.2 Strategic Fit

Strategic fit is the extent of alignment between the team's mission and overall business, technology and product strategy (Hong, 2000). Those companies that optimize their R&D and marketing investments, define the right new product strategy for the firm, select the winning new product projects, and achieve the ideal balance of projects, will win in the long run (Cooper et al, 1999). Strategic fit is the extent to which a firm's overall business, product, and technology guide the product development contents and processes (Cooper, 1983; Cooper, 1985; Cooper and Kleinschmidt, 1987; Wheelwright and Clark, 1992). Team members should understand the linkage of what they specifically do (e.g., design of new products, setting project targets) with the overall firm's policy directions. Senior management's role is to support overall direction and assist necessary resource allocation (Rosenthal and Tatikonda, 1992; Rosenthal and Tatikonda, 1993)

According to Cooper et al 1999, companies should critically consider the portfolio management (of NPD) whereby decision processes of active products is constantly evaluated, selected and prioritized. If a particular product concept fits the overall strategic direction, it has a better chance of being selected (i.e., the product moves faster), accepted (i.e., better team coordination) and executed (i.e., less cost) among team members (Crawford, 1991; Crawford, 1992; Song and Parry, 1997). Project targets that have a high degree of strategic fit tend to receive quicker top management support and get easier access to internal resources. It would also accelerate the project process to attain strategic advantages in the marketplace. Therefore, a project that has a high level of strategic fit may enhance teamwork (Trygg, 1993), time to market (Mabert et al,1992), manufacturing cost (Cusumano and Nobeoka, 1992), improved return on investment, and improved productivity (Wheelwright and Clark, 1992).

3.8.1.3 Project Targets

Project targets in the case of IPD can have two dimensions of clarity and tradeoffs. Clarity of project targets relates to the extent of communication and understanding of a set of project goals that guide development efforts (Hong et al, 2005). Knowing clear project targets enable members to focus the resources faster and more effectively. This can improve cycle time (time to market), teamwork, and overall process productivity (Murmann, 1994). In an empirical study by Hong et al 2004, results from the structural model suggest that uncertain project environments influences the nature of project targets which in turn affects the levels of teamwork.

Project targets relate to all entities in IPD. For IPD team members, clarity of project targets requires unambiguous definition, rich communication, and common understanding (Gupta and Klaus, 1992; Marquandt and Reynolds, 1996) Effective targets are based on realistic customer requirements (Rosenau, 1989), and good understanding of competitive situations and technical risks (Clark and Wheelwright, 1993). Targets also need to be consistent with manufacturing capabilities, suppliers' capabilities, and resources (Clark and Wheelwright, 1993).

Tradeoffs refer to the extent of project target's specifications in term of performance, cost, quality, and time (Hong et al, 2005). In IPD, time-cost trade off is about the overall product development time compared with its associated cost. If an organization aims to speed up the new product development effort it will incur additional hidden costs (Crawford, 1992). Complexity and technology also impact projects as increased levels necessitate more time. (Karisson and Ahistrom, 1999). Finally, cost-quality tradeoffs compares the cost of the resources vs. the quality of the product to the final customer. As companies engage more heavily in time based competition, defining, communicating, and understanding the tradeoff between time and cost, time and quality, and quality and cost become more critical. Timely determination of tradeoffs may facilitate and enhance development productivity.

3.9 Mutual Trust

"Trust is after all the single most important precondition for knowledge exchange." (Rolland & Chauvel, 2000).

In this study, mutual trust is operationalized as:

Mutual trust is the mutual expectation among product development team members that everyone will work together in good faith (Rauniar, 2005).

Within the knowledge management literature, trust is often discussed as an important element for successful knowledge management ventures (Bukowitz and Williams, 1999; Rolland and Chauvel, 2000; Roberts, 2000). One of the most salient factors in the effectiveness of complex IPD social systems is the willingness of one or more individuals in a social unit (team) to be trusted and to trust – this is referred to as mutual trust. In order for people to be willing to share their knowledge, they must have trust (Davenport & Prusak, 1998; Kramer, 1999, Lee et al, 2000). Rotter, 1967 noted the efficiency, adjustment, and even survival of any social group depends upon the presence or absence of such trust. Greater cooperation, higher effectiveness, and fewer wasted resources are results of higher trusting teams (Betz, 1986).

New product development is about problem solving in a complex uncertain environment that requires continuous streams of information and knowledge.

This knowledge sharing can take two forms, tacit and explicit knowledge. Of these two forms, researchers have noted that tacit knowledge, knowledge that resides in individuals through personal experiences, is the most challenging. Uzzi, 1996, has found that trust acts as the governance mechanism of embedded relationships and facilitated the exchange of especially tacit knowledge related capabilities and information. Tacit knowledge resides in the individual, and in order to share such information, individuals must be able to trust each other.

Trust has also been noted by Cooper 1993, as an important factor in knowledge sharing. As companies strive to bridge the gap between functional areas, information critical to the product's formation and function can get withheld, misunderstood, or lost. Members of the IPD team can withhold this information because of a lack of trust among functions, suppliers, and customers. This lack of trust can damage and undermine the outcome of a product development project. Urban and Hauser 1980, commented, "vested interests can prevent effective progress on a good project." High levels of trust, will enhance information sharing and new product development success. Common goals and interests (Ford et al, 1986) will bind all parties in a common interest or shared purpose and influence interactions by encouraging either party to make sacrifices for the sake of the relationship.

Trust must be mutual among IPD team members. Trust based on mutuality among team members ensures that knowledge can be openly shared in good faith. Mutual trust is necessary in cross functional IPD teams because the higher interdependency between disciplines means that team members must rely upon the functional expertise of each other for timely and accurate information, view points, and decisions.

3.10 Mutual Influence

In this study, mutual influence is operationalized as:

Mutual influence is the extent of symmetrical power relationships among members of the product development team (Rauniar, 2005).

Influence refers to the degree to which information offered by participants in the NPD process leads to change in behavior, attitudes, and or actions of the recipient (Kohli, 1989). Influence ensures the legitimacy of the team member in the knowledge exchange process. Influence is germane in new product development because, at its core, NPD is about risk, ambiguity, and uncertainty and is replete with functional conflicts caused by differences in perceptions and self interest (Frost and Egri, 1991; Ruekert and Walker, 1987).

IPD involves reciprocal interdependence in which each member involved depends on the other for accurate and truthful information. Interdependence can be considered a defining characteristic of all teams (Sundstrom et al, 1990). This interdependence is critical in achieving goals for novel, important, and complex NPD projects (Adler, 1995; Pfeffer and Salancik, 1978). Naturally, the information negotiation behavior should involve parties in the information transaction that are open to give and accept information with proper feedback. Mutuality in situations or reciprocal interdependence reduces uncertainty for the parties (Thompson, 1967). Information is exchanged and accepted in an open mutual environment and provides a basis for joint decision making thus, bridling opportunistic behavior of the NPD team members, suppliers, and customers.

If knowledge is to be exchanged to solve complex problems amidst the uncertainty, mutual influence will ensure that the exchanging parties appreciate and understand the knowledge offered by others.

3.11 Shared knowledge

"Communication that is rich, bilateral, and intense is an important, even essential, element of integrated problem solving" (Wheelwright and Clark, 1992).

For this study, shared knowledge has been operationalized as:

Shared knowledge is the understanding of customers, suppliers, internal capabilities, and process in cross-functional product development teams.

Knowledge has been differentiated into two main types: explicit and tacit knowledge (Nonaka and Takeuchi, 1995). Explicit knowledge is knowledge that can be easily explained and codified into text, diagrams, etc (Nonaka, 1991). Tacit knowledge can be very difficult to articulate and codify (Matusik and Hill, 1998); it is learned from experience. Both tacit and explicit knowledge are considered not to be in dichotomous states of knowledge, but mutually dependent and reinforcing qualities of knowledge: tacit knowledge forms the background necessary for assigning the structure to develop and interpret explicit knowledge (Polyani, 1975). The inextricable linkage of tacit and explicit knowledge suggests that only individuals with a requisite level of shared knowledge can truly exchange knowledge. If tacit knowledge is necessary to the understanding of explicit knowledge, then in order for individual B to understand individual A's knowledge, there must be some overlap in their underlying knowledge bases or a shared knowledge space (Ivari and Linger, 1999; Tuomi, 1999).

The discussion of knowledge sharing is very much influenced and dominated by two "models": (1) the SRMC (source, recipient, message, and channel) derived from the communication theory and, (2) the distinction between explicit and tacit knowledge (see chapter 2). These two models or perspectives highlight a lot of barriers and problems for sharing knowledge that has been identified and discussed in other literatures, such as the stickiness of knowledge (Szulanski, 2003), where to find the knowledge (O'Dell and Grayson, 1998), the tacit dimension of knowledge (Nonaka and Takeuchi, 1995), the relationship between the sender and receiver of knowledge (Osterloh and Frey, 2000), organizational units that hinder or enables knowledge sharing (Brown and Duguid, 2001), and identification of knowledge worth sharing (Gupta and Govindarajan, 2000).

Davenport & Prusak 1998, have classified knowledge processes into four categories: knowledge generation (creation and knowledge acquisition), knowledge codification (storing), knowledge transfer (sharing), and knowledge application. Knowledge generation in an IPD team involves the discovery and resolution of opportunities or problems (Gray and Chan 2000; Matusik and Hill, 1998). Knowledge acquisition is acquiring and integrating knowledge from external sources such as customers and suppliers (Davenport and Prusak, 1998). Codification is the translation of knowledge into text, drawings, etc. Knowledge transfer is the sharing of knowledge between IPD team members. Finally, knowledge application is the use of knowledge to gain a competitive advantage in the marketplace (Alavi and Leidner, 2000).

Effective communication sharing of meaningful and timely information, is essential for an IPD team (Anderson and Narus, 1994). Close and frequent interactions on an IPD team lead to project effectiveness because of timely integration of knowledge across organizational boundaries (Clark and Fujimoto, 1991; Leonard-Barton and Sinha, 1993; Henderson and Cockburn, 1994; Eisenhardt and Tabrizi, 1995; Szulanski, 1996). Persons from different functions are able to solve problems through open and fruitful informal contacts (Lundqvist, 1996). Sharing knowledge is both about combining existing knowledge and securing that existing knowledge that is distributed across the organization to prevent “Reinventing the wheel” (Grant, 1996).

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. This research model builds on the pioneering works of Khurana and Rosenthal (1997, 1998), Kim (1993), Paashuis (1998), Hoopes and Postrel, (1999) and Hong (2000) in regard to the importance of shared learning and knowledge. Table 3.6 identifies four variables of shared knowledge, their definition and their relevant literature base of each variable. Shared knowledge affects product development performance outcomes (Zack, 1999).

Table 3.4 Shared Knowledge in IPD

Variables	Definition	Literature
Shared Knowledge of Customers	The extent of a shared understanding of current customer needs and future value to customer creation opportunities among IPD team members.	Hong et al, 2004a; Clark and Wheelright, 1993; Dolan, 1993; Day, 1990; Cordell, 1997 etc.
Shared Knowledge of Suppliers	The extent of a shared understanding of supplier's design, process, manufacturing capabilities among IPD team members.	Hong et al, 2004a; Sobrero and Roberts, 2002; Evans and Lindsay, 1996; Hartley, 1997, Slade 1993;Fischer et al, 2002
Shared Knowledge of Internal Capabilities	The extent of a shared understanding of firm's internal design, process, and manufacturing capabilities among IPD team members.	Hong et al, 2004a; Adler et al., 1996; Moorman, 1997; Kim and Mauborgne, 1997 etc.
Shared Knowledge of Process	The extent of a shared understanding of firm's product development process among IPD team members.	Krishnan and Ulrich, 2001; Haho et al., 2000; PMBOK, 2002 etc.

3.11.1.1 Shared Knowledge of Customers

"A key of product development success is how much other product development team members understand the customer needs, requirements, use, and value attributes in the early stages of the product development process" (Clark and Wheelwright 1993).

Shared knowledge of customers refers to the extent of a shared understanding of current customers' needs and future value to customer creation opportunities among product development team members (Hong et al, 2004a; Narver and Slater, 1990; Griffin and Hauser, 1991; Calantone et al, 1995; Calantone et al, 1996). Meeting regularly with customers allows the integrated product development team to share a common understanding of customer needs (Dougherty, 1992). Through interactions with customers, the information content of the communications is improved, which allows IPD team members to develop a common understanding of the customer while working together (Brown and Eisenhardt, 1995). Several studies have shown that firms can acquire knowledge from their customers, which can be used for further market entry and expansion (Hertz, 1993; Lee, 1991). Project development teams with high levels of contact with customers will understand the changing needs of customers (Holak and Lehmann, 1990; Slater and Narver, 1994; Slater and Narver, 1995), the value of customer attributes (Slater and Narver, 1994), and the achieve high levels of customer satisfaction. (Gatignon and Robertson, 1991; Day, 1993; Gale, 1994).

Additionally, teams that have high levels of contact with customers may improve the quality and knowledge of customers (Dougherty, 1992; Brown and Eisenhardt, 1995; Jaworski and Kohli, 1993) along with improved levels of assessing characteristics of target customers (Cooper, 1983; Cooper, 1984; Cooper, 1992; Wheelwright and Clark, 1992).

3.11.1.2 Shared Knowledge of Suppliers

The product development team may involve other structures such as a value-added chain or a distribution channel (Hakansson and Snehata, 1995). Relationships with these actors (i.e. distribution channels) are the most important assets of the firm (Sharma and Johanson, 1987). According to Clark 1989, much of the advantage in the man hours and lead times for new projects is attributed to the developing firm's supplier networks. This relationship allows the firm to benefit from the supplier's know how and to capture it more effectively in the design of the product and in the conduct of the development process. Moreover, the use of collaborative arrangements allowing for mutual access to internal processes will facilitate both development and the transfer of tacit knowledge (Sobrero and Roberts, 2002; Hamel, 1991; Gulati, 1998). Dowlatshahi 1998, developed a framework for implementing early supplier involvement, which addressed the stages and interactions among procurement, manufacturing, marketing, and design during the product development process for qualified suppliers.

Shared knowledge of suppliers refers to the extent of the shared understanding (i.e., know-why) of suppliers' design, and process and manufacturing capabilities among product development team members (Hahn et al, 1990; Slade, 1993). Since suppliers are actively involved in key processes of IPD, the knowledge of suppliers' capabilities is essential for timely and cost-effective decision making in IPD (Evans and Lindsay, 1993). Shared knowledge of suppliers allows product development members to improve product performance (i.e., its technical and overall performance) and reduce manufacturing costs (i.e., cost of raw materials of the product supplied by the suppliers) because a substantial portion of their final product depends on suppliers' work. (Hong et al, 2004a).

3.11.1.3 Shared Knowledge of Internal Capabilities

Knowledge of internal capabilities resides usually among design and manufacturing team members. The key is how many different functional specialists (i.e., 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 (i.e., 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). For this study, knowledge of internal capabilities refers to the extent of a shared understanding (i.e., know-why) of the firm's internal design, process, and manufacturing capabilities among product development members (Hong et al, 2004a; Clark and Wheelwright, 1993; Garvin, 1993; Adler et al, 1996).

The more knowledge of internal capabilities is shared among product development members, the faster the team members start working on their project targets and increase development productivity. Knowledge of what other team members can do will enable team members to make better quality decisions that affect outcomes. Therefore, shared knowledge of internal capabilities might affect almost all performance outcomes because ultimately effective problem solving in IPD is the result of the effective decision making of all team members.

3.11.1.4 Shared Knowledge of Process

Shared knowledge of process it the extent of a shared understanding of a firm's product development process among IPD team members. A clear understanding of various stages, activities, and milestones enables IPD teams to co-ordinate projects and realize the task interdependencies among various tasks. Team members will thus have a clear knowledge of timing and sequence of development activities (Aitsahlia et al, 1995; Krishnan et al, 1997), project milestones and planned prototypes (Terwiesch and Loch, 1998), and the relative priority of development objectives (Ittner and Larcker, 1997; Cohen et al, 1996).

A shared understanding of the development process can help prevent difficulties such as persistent fire fighting from continuing. In the product development context, fire fighting describes the unplanned allocation of engineers and other resources to fix problems discovered late in a product's development cycle (Repenning, 2001). In his article Repenning described the importance of good aggregate resource planning, allocating slack development resources, and having integrity when screening projects in early stage phases (don't pass poor projects downstream to later play "catch up"). Preventing fire fighting requires the discipline to resist the natural tendency to focus on specific projects and instead target interventions at maintaining the integrity of the development process. Only by have development teams focus explicitly on the health and performance of its NPD system / process will an organization overcome the dynamics of fire fighting (Repenning, 2001).

A model which can add support to shared knowledge of process is the capabilities maturity model. The capabilities maturity model is a reference model for appraising software process maturity and a normative model for helping organizations progress along an evolutionary path from ad hoc, chaotic processes, to mature, disciplined software processes (Herbsleb et al., 1997). This model states that an organization should strive to reach upper levels of mature, very defined, and continuous process improvement to gain optimum benefits of productivity, reduction of rework, and improvement in cycle time (Butler, 1995; Dion, 1993; Humphrey et al, 1991; Wohlwend et al, 1994). At these upper levels of process maturity, activities are standardized, documented, and integrated into a standard process for developing products. Companies that achieve upper levels of maturity will be able to attain a shared knowledge of process more effectively than lower level companies.

Deschamp and Nayak, 1995, identified six basic management processes in product innovation: intelligence development process, idea management, resource management, technology and product development planning, project or program management, and product support management. Several studies have shown that the use of repeatable NPD process leads to successful new production outcomes (Cooper and Edgett, 1996; Cooper and Kleinschmidt, 1995; Rochford and Rudelius, 1997). Formal project planning tools, such as work breakdown structures, gantt chart and project-scheduling techniques such as PERT and CPM enjoy widespread use in planning the resources and timing sequences of various development activities and processes (Project Management Book of Knowledge, 2002; Eppinger et al, 1994). Careful management of overlapped activities in product development requires the detailed representation of information exchange between individual tasks and a deeper understanding of the properties of information (Krishnan et al, 1997; Loch and Terwiesch, 1998). Insights about the nature of development tasks offer the promise of fostering communication where it is most valuable (Moenaert and Souder, 1996; Griffin, 1992).

3.12 IPD Performance Outcomes

Performance measures serve as an integrative common control mechanism in the product development effort. They evaluate such performance objectives as cost, time, productivity, customer satisfaction, and overall product performance which demands that each function work together rather than separately to achieve its own goal. In many studies, it is reported that about half of the surveyed firms measure NPD performance (Gerwin and Barrowman, 2002; Griffin, 1997). Performance outcomes evaluate the behavior of the IPD system and are used to evaluate success in achieving the company's goals. IPD performance outcomes serve best if they are linked to the firm's overall strategy (Langfield-Smith, 1997).

Since this study focuses on the interaction between work integration and knowledge integration in an IPD environment, performance measures used here are a combination of measures in the two respected fields of work integration (Syamil, 2000) and knowledge integration (Hong, 2000). Syamil's research focused on eleven measurement factors: teamwork performance, engineering change time, product cost reduction, team productivity, manufacturing cost reduction, product integrity, suppliers' on time performance, suppliers' quality performance, suppliers' cost performance, product development time, and customer satisfaction. Hong's work in knowledge integration measured the success of the product development project in terms of teamwork, development productivity, time to market, manufacturability, manufacturing cost, value to customer, and product performance. Based upon these two works, in this study, IPD performance measures are classified into two broad categories of process outcomes and product outcomes.

Process outcomes measure the effectiveness of product development process (Hong, 2000). Accordingly, process outcome is measured in terms of engineering change time, teamwork, and productivity. Product outcomes are measures related with the product development characteristics and are measured using four factors: product cost reduction, manufacturing cost reduction, product development time, and customer satisfaction. The definition and literature base for each of the variables is provided in Table 3.5.

Table 3.5 NPD Performance Outcomes

	Definition	Literature-base
Process Outcome		
Engineering Change Time	The time required modifying product definition or documentation.	Syamil, 2000; Blackburn 1991; Fujimoto, 1989; Clark and Fujimoto, 1991 etc.
Teamwork	Degree of collaborative behavior of IPD team.	Hong, 2000; Clark and Fujimoto, 1991; Zirger and Maidique, 1990; Mabert et al., 1992 etc.
Productivity	Effectiveness of new product development –from product concept to commercialization.	Syamil, 2000; Hong, 2000; Clark and Fujimoto, 1991; Crawford, 1992; Adler, 1995 etc.
Product Outcome		
Product Cost Reduction	Success level of the development team to reduce product costs.	Syamil, 2000; Gupta et al., 1992; Clark, 1989 etc.
Manufacturing Cost Reduction	Cost of materials, labor, and overhead for the product.	Syamil, 2000; Hong, 2000; Gersbach et al., 1994; Mercer, 1994; Garrison and Noreen, 1997 etc.
Product Development Time	Time required from product concept to product introduction.	Syamil, 2000; Hong, 2000; Stalk, 1988;Bonnaccorsi and Lapparini, 1994; Murmann, 1994 etc.
Customer Satisfaction	satisfaction of the customer for the product designed in a certain target market	Syamil, 2000; Cooper and Kleinschmidt, 1987; Clark and Fujimoto, 1991; Koen and Kohli, 1998 etc.

3.12.1.1 Engineering change time:

Engineering change time involves the modification of some aspect of the product's definition or documentation (Blackburn, 1991). These changes can occur through mediums such as an engineering drawing or a bill of material. Engineering changes that occur early in the product development cycle can be very attractive to companies by allowing the company to match competitor innovation (Symil, 2000), incorporating new features in the product that were not considered earlier, new technology, new techniques, or for other reasons. However as the process flows towards downstream activities, engineering change time can become quite expensive and can disrupt manufacturing through obsolesce of certain components, inventory fluctuations, schedule changes, and production delays (Balakrishnan and Chakravarty, 1996). Engineering change orders is the number one cause of delays in the product development process (Barkan, 1992). Throughout the IPD process, projects with too many changes will be a signal that the particular process is one of poor development, and will ultimately result in a delay of product launch and commercialization target dates.

3.12.1.2 Teamwork

Teamwork is the degree of collaborative behavior of an IPD team (Hong, 2000; Clark and Fujimoto, 1991; Zieger and Maidique, 1990). Susman and Dean 1992, have argued that the cross functional nature of concurrent engineering improves the decision making effectiveness of the product development team by considering a problem from various perspectives. Indicators of a IPD team displaying high levels of teamwork include: timely conflict resolution (Zieger and Maidique, 1990; Clark and Fujimoto, 1991), effective decision implementation (Mabert et al, 1992), creative problem solving (Guftafson, 1994), effective communication (Brown and Eisehardt, 1995; Fisher, 1997) and high levels of coordination among activities (Heang, 1989; Griffin, 1993). A product development process that is not only integrated (customers, suppliers, and internal functions) but also shares their functional knowledge will display high levels of teamwork in IPD projects.

3.12.1.3 Team Productivity

Team productivity measures the effectiveness of a new product project from product conception to commercialization (Hong, 2000). Many companies such as Hewlett-Packard have developed screening criteria which describes the importance of each project such as customer value, business value, market conditions, resource requirements, etc. Thus, a project funnel is created with only the high value projects that remain. Projects which the company will ultimately develop will be assigned a high degree of the company's valuable resources (time, capital, labor, etc). It is critical that these remaining projects are very efficient, complete work quickly, reduce cost, and reduce engineering hours. Team productivity is measured by overall technical and team performance in terms of efficiency, budget, schedule, and innovation (Cooper and Kleinachmidt, 1987; Cooper and Kleinachmidt, 1995; Arcona and Coldwell, 1990; Cooper, 1999).

3.12.1.4 Product Cost Reduction

The success level of the development team to reduce product costs is measured by the product cost reduction (Clark, 1989). Low costs of products signify efficiency in the development of the product and position the project to be more competitive in the marketplace. Project costs can be reduced if functions work together to reduce direct and indirect costs in the IPD process. Symil 2000, noted that project or part complexity can be a proxy of product cost. A product that is designed, manufactured, or assembled in a more complex manner will lead to increased cost of that particular product. The IPD team members must be efficient in handling uncertainty and efficient in solving problems in the IPD process. Teams which are integrated in their work and knowledge sharing will be able to communicate effectively with IPD issues and utilize simpler solutions which lead to reduction in product cost.

3.12.1.5 Manufacturing Cost Reduction

Product development has a high degree of influence on the manufacturing cost over the life of the product. Up to 80% of the cost of products are designed-in during the development phase. Products which are costly to assemble, complex, use poor materials, etc can lead to high manufacturing costs over the entire life of the product. Manufacturing costs involve the cost of materials, labor, and overhead for the product. Upstream development is essential to downstream ease on the manufacturing floor. Knowledge which is shared among suppliers, customers, and internal capabilities can reduce manufacturing cost. Many companies such as Toyota have borrowed supplier expertise in their product development process (Sobeck et al, 1999; Sobeck et al, 1998) to aid the manufacturing process and reduce cost.

3.12.1.6 Product Development Time

"Victory often goes to the side that gets thar the fustest with the mostest." – Confederate General Nathan Bedford Forrest (Blackburn, 1991).

Product development time is the time required from product conception to product introduction (Stalk, 1988; Gupta, Brackhoff, and Weisendfeld, 1992; Hong, 2000). Product development time refers to how fast the firm completes product development projects from concept to market introduction (Takeuchi and Nanaka, 1986; Clark and Fujimoto, 1991; Gupta and Wilemon, 1990). The need for shortened product development lead times has especially been brought to attention over the past decade (Lundqvist et al 1996; Clark and Fujimoto, 1991). An IPD team that values time to market would strive to get products to market ahead of competitors, (Liberman and Montgomery, 1988; Stalk and Hout, 1990; Blackburn, 1991; Yossef, 1995), develop products on schedule, (Cohen, 1996; Ziger, 1996), and keep improving on the previous time to market (Mabert et al, 1992). Many studies have documented the importance of reducing product development time.

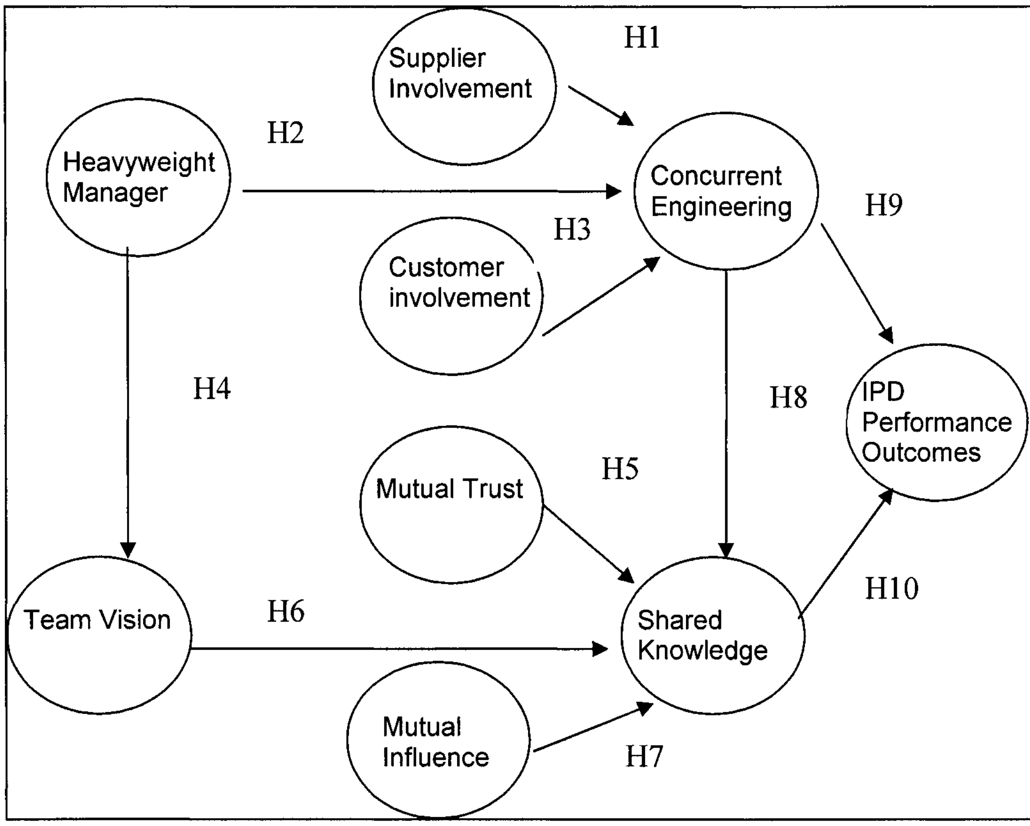
When reducing product development time, the challenge is to carry out the development task faster without sacrificing quality (Gupta and Wilemon, 1990; Karlsson and Ahlstrom, 1999). One of the biggest problems with time to market reduction programs is that firms often pursue speed without considering how faster product development or increased product turnover contribute to the fulfillment of their customer requirements. Hong 2000, noted that the extent of shared knowledge is related to the projects' time to market. Shared knowledge of customers is critical to ensure that the resulting products satisfy customer needs. Mabert et al 1992, stated that reducing time to market requires adequate knowledge of customers earlier in the process. Understanding suppliers and internal capabilities can also accelerate the time to market in understanding the earlier availability of prototypes, increased standardization of parts, consistency between designs and supplier's process capabilities, and reduced engineering changes (Bonaccorsi and Lapparini, 1994).

3.12.1.7 Customer Satisfaction

Customer satisfaction measures the satisfaction of the customer for the product designed in a certain target market (Cooper and Kleinschmidt, 1987). Customer satisfaction is important for many companies for several reasons. First, attracting new customers is more expensive than retaining existing customers. Satisfied customers mean lower handling cost in managing customer complaints, lower warranty cost, and can help the company to attract new customers (Syamil, 2000). The transaction cost can also be lowered if a company can take advantage of the economies of scale of the current customer base (Sharma et al., 1999).

Value to customer is measured in terms of the value of new products in meeting customer needs and expectations in the market place (Clark and Fujimoto, 1991; Clark & Wheelwright, 1993; Cordell, 1997). It is also reflected in the product success in the marketplace (Slater and Narver, 1995), its creation of value to customers in terms of highly perceived product quality (Clark and Wheelwright, 1992), customer's perceived value in terms of uniqueness (Zirger and Maidique, 1990), and the key commonalities in what customer's value (Kim and Mauborgne, 1997). Value to customers is enhanced through shared knowledge of customers (Koen and Kohli, 1998).

Figure 3.1 Proposed research model



3.14 Hypothesis

3.14.1 Development of hypothesis 1: Suppliers frequently possess vital product and process technologies for the developing project (Sobrero and Roberts, 2002; Huang and Mak, 2000; Willaert, 1998). In product development, suppliers drive the need for cross functional involvement because they expect integrated answers to questions involving engineering design, manufacturing, and the development process. Suppliers that fulfill requests, contribute valuable information and expertise, force an integrated team response to issues and opportunities they raise.

Hypothesis 1: The greater the extent of supplier involvement, the greater the extent of concurrent engineering.

3.14.2 Development of hypothesis 2: Of all the decisions management makes in managing NPD, none is more crucial to success that the choice of a project manager (Smith and Reinersten, 1991; Lee et al, 2000). Heavyweight managers serve as an authoritative figure that cut across functional boundaries and make the members work as a team (Daft and Lengel, 1986). Research framework illustrates how a firm's internal context, shaped by a key structural decision, i.e., heavyweight product development manager (Clark and Fujimoto, 1991; Maidique, 1980; Roberts, 1977), facilitates its effort to achieve cross-functional integration, (i.e. concurrent engineering; Barkan, 1992; Langowitx, 1988; Millson et al, 1992). Heavyweights possess power and authority to demand that key functional areas are represented on the team, that schedules are met among cross functional team members, and the necessary resources for the development team are provided (Thieme, Song, and Shin 2003; Shilling and Hill, 1988; Gupta 1986)

Hypothesis 2: The greater the influence (both formal and informal) of the heavyweight manager, the greater the extent of concurrent engineering.

3.14.3 Development of hypothesis 3: Kusar et al 2004, noted that for successful product development, customers should have representation on the product development team. Customer involvement forces the team to seek integrated answers for its demands in design and manufacturing. Customers need a central place to get a reaction. They expect integrated answers to their demands and force the development team to work together across functions. The involvement of a multi-disciplined team in the development process, improves the translation from the customers' needs and wants to the completed product. A shared understanding of concept and customer expectations are critical to the integrity of the product (Clark and Fujimoto, 1991) and is the best way to understand the customer (O Neal, 1993).

Hypothesis 3: The greater the extent of customer involvement, the greater the extent of concurrent engineering

3.14.4 Development of hypothesis 4: Heavyweight managers help the IPD share a common vision of the product (Koufteros et al, 2002; Lee, Lee, and Souder, 2000; Thieme, Song, and Shin, 2003). Effective product managers must be able to communicate to all customers, marketers, engineers, suppliers, and designers. A heavyweight manager who has internalized an equivocal product concept must translate it into unequivocal expressions in each of the downstream languages in order for all members of the team to understand it. (Clark and Fujimoto, 1991). This drives a common purpose and shared vision for the development project.

Hypothesis 4: The greater the extent of use of a heavyweight manager the greater the level of team vision for the project.

3.14.5 Development of hypothesis 5: In a concurrent work team there is a high need for interdependence between disciplines. The higher interdependence between disciplines means that team members must rely upon the functional expertise of each other for timely and accurate information, view points, and decisions. Cooper 1993, has noted that as a company strives to bridge the gap between functional areas, information critical to the product's formation and function can get withheld, misunderstood, or lost. Vested interests can prevent effective progress on a good project (Urban and Hauser, 1980). Lack of mutual trust will withhold information sharing that needs to take place for effective problem solving. In order for people to be willing to share their knowledge, they must have trust (Davenport & Prusak, 1998; Kramer, 1999, Lee et al, 2000).Thus trust is a critical ingredient for increasing shared knowledge on a development team.

Hypothesis 5: The greater the extent of use of a mutual trust the greater the level of shared knowledge

3.14.6 Development of hypothesis 6: Through team vision, teams develop clear goals and establish communications that support real-time problem solving (Katzenbach and Smith, 1993). The common goals that the IPD team members share will help the team to see the potential value of each others view points and benefit cooperation. Team members who share a vision will be more likely to share or exchange their critical knowledge resources (Orton and Weick, 1990; Tsai and Ghoshal, 1998). By having a shared vision of the project, team members know what information they want to share and find more valuable information to contribute to the project. A shared team vision contributes to a common purpose to share information and acts as a lens that is focused on the necessary kinds of information to share on the development team.

Hypothesis 6: The greater the extent of team vision the greater the level of shared knowledge.

3.14.7 Development of hypothesis 7: Influence is germane in new product development because, at its core, NPD is about risk, ambiguity, and uncertainty and is replete with functional conflicts caused by differences in perceptions and self interest (Frost and Egri, 1991; Ruekert and Walker, 1987). If knowledge is to be exchanged to solve complex product development questions, mutual influence will ensure that the exchanging parties appreciate and understand the knowledge offered by others. If there exists equal power among IPD members, each team member will have an equal opportunity to change others' views on a product development problem. Thompson, 1967) commented that mutuality in situations or reciprocal interdependence reduces uncertainty for the parties. Information is exchanged and accepted in an open mutual environment and provides a basis for sharing information and joint decision making.

Hypothesis 7: The greater the extent of mutual influence the greater the level of shared knowledge.

3.14.8 Development of hypothesis 8: Concurrent engineering is cross-functional. According to Wheelwright and Clark, 1992, NPD is a problem-solving activity, whereas, Clausing 1994, argues NPD is complex problem-solving activity. Increasing the level of work involvement and concurrent cross-functional activities allows the team to interact and share relevant knowledge better among team members (Koufterous 2002, Hong, 2004a; Hong, 2004b). By working on a team, joint problem solving skills will be enhanced and will lead to a greater extent of shared knowledge.

Hypothesis 8: The greater the extent of concurrent engineering, the greater the extent of shared knowledge.

3.14.9 Development of hypothesis 9: A large number of past studies demonstrate the positive effects of concurrent engineering on NPD success (Ettlie, 1997; Gupta and Wilemon, 1985; Kahn, 1996; Menon et al, 1997; Song and Parry, 1992; Song et al, 1997). Product development is an integrated problem solving activity. Involving cross functional team members early in the new product development process leads to better trade off decisions among alternatives, enhanced design, production, and allows the development team to achieve optimum solutions.

Hypothesis 9: The greater the extent of concurrent engineering the greater the extent of new product development performance.

3.14.10 Development of hypothesis 10: Several researchers have described NPD as a knowledge-intensive activity (Eder, 1997; Iansiti and MacCormack, 1997; Nonanka and Takeuchi, 1995; Song and Weiss, 1998; Hong, 2000). The absence of knowledge integration may lead to poor IPD performance, while the presence of knowledge integration may lead to better performance. Hong (2000), in his empirical study, found a positive relationship between shared knowledge and product performance outcomes. Having a lack of shared knowledge on a development team causes inappropriate trade off decisions where team members have different agendas and objectives for the project. This causes glitches in the development process.

Hypothesis 10: The greater the extent of shared knowledge the greater the extent of new product development performance.

Chapter Four

Research Methodology and Pilot Study

4.1 INTRODUCTION

The primary goal of this research is to assess the effects of work integration and knowledge integration and its determinates in new product development. Additionally, there has been no theoretical measure of shared knowledge of process. Developing a useful instrument will provide researchers with new insights into this topic and provide a tool for benchmarking the new product development process in practice.

A pilot study has been performed to assess the instruments used in this study. Many characteristics have to be tested such as: construct validity, content validity, convergent validity, discriminant validity, predictive validity, and reliability. These are briefly described below. Construct validity refers to an effective instrument that covers the content domain of each variable (Nunnally, 1978). Convergent validity is concerned with the extent to which multiple measures of the same construct agree with each other (Campbell and Fiske, 1959). Predictive validity refers to the extent to which scores of one variable are empirically related to the scores of other conceptually related variables. (Bagozzi et al, 1992). Discriminant validity is evident if items underlying each dimension load as different factors (Pitt et al, 1995). For each variable considering reliability, it should have a Cronbach's alpha level of at least .80 (Nunnally, 1978), and the instrument should be short and easy to use in practice. Additionally, the instrument should be generalizable across industries and firms of varying sizes (Koufteros et al, 1995).

These goals stated above were accomplished by basing the research process on commonly accepted methods for developing standardized instruments (Nunnally, 1978; Churchill, 1979). An extensive literature review ensured that the proposed research model was grounded in theory. Additionally, case studies and structured interviews with product development practitioners helped to define the domain of the variables and facilitated item generation. A pre-test was conducted to enhance content validity. A pilot study was conducted utilizing respondents similar to the target respondents. These steps were taken to ensure the measurement characteristics stated above were valid.

4.2 Item Generation

Since all items pertain to product development at the team level, the cross-functional development team is the unit of analysis for this study since all items pertain to product development at the team level. To ensure content validity, the following steps were taken for each variable. First, possible items were adapted from articles published in major journals in the fields of marketing, product development, manufacturing management, strategy, teamwork, organizational learning, team learning, individual learning, psychology, organizational behavior, knowledge, and project management. In addition, previous doctoral dissertations in the field of concurrent engineering and shared knowledge in the specific context of product development were studied. Additionally, the authors of these works were consulted to ensure items reflected strong content validity.

The goal of the literature review in Chapter Two is to generate a comprehensive list of items to match the domain of heavyweight team manager, supplier involvement, customer involvement, concurrent engineering team vision (3 variables), mutual trust, mutual influence, shared knowledge (4 variables), process outcomes (3 variables), and product outcomes (4 variables). A five-point Likert scale was used to solicit responses for each item where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. The item below is one of the items actually used in the pilot study.

Figure 4.1 Sample of web questionnaire

1. none or to a little extent	2. to some extent	3. to a moderate extent	4. to a great extent	5. to a very great extent

	1	2	3	4	5
Our suppliers were involved in the early stages of product development.	○	○	○	○	○

To provide additional support for the content validity, the items were grouped according to their theoretical variable and presented to three researchers and four product development project managers during structured interviews. For each variable, the researchers and the managers were asked to discuss the theories and practices as they related to concurrent engineering and shared knowledge. Their responses were then compared with the proposed variables and items for this study. The key questions were: (1) what did they think about the importance and relationship of work integration and knowledge integration in product development; (2) what aspects of concurrent engineering and shared knowledge were critical in the product development; (3) what is the role of a heavyweight team manager in new product development; (4) if they perceived the importance of promoting trust among the focal project team members and its relationship with team and/or product performance; (5) if they perceived the importance of sharing power among the focal project team members; and finally, (6) whether they could answer all the questions based on their personal experiences in a recent product development project. Their qualitative comments from the structured interviews were compared with the responses to items measuring each variable. This was done to verify that they understood the questions. Based on suggestions by these researchers and practitioners, items were added, modified, or even deleted for the reviewed instrument. Finally, the revised items were grouped into 21 variables as shown in Table 4.1.

Table 4.1. Variables of the Proposed Research Model

Variables	items	Code
Heavyweight Team Manager	(6 Items)	HM
Supplier Involvement	(6 Items)	SR
Customer Involvement	(5 Items)	CI
Concurrent Engineering	(10 Items)	CW
Team Vision		
	Mission (5 Items)	TM
	Strategic Fit (4 Items)	SF
	Project Target (4 Items)	PTT
Mutual Trust	(10 Items)	TR
Mutual Influence	(9 Items)	MI
Shared Knowledge (of)		
	Customers (4 Items)	CT
	Internal Capabilities (4 Items)	IT
	Suppliers (6 Items)	ST
	Process (5 Items)	TP
Process Outcome (NPD Performance)		
	Engineering Change Time (3 Items)	EC
	Team Work (3-Items)	TW
	Team Productivity (3 Items)	XTP
Product Outcome (NPD Performance)		
	Product Cost Reduction (4 Items)	PC
	Manufacturing Cost Reduction (5 Items)	MC
	Product Development Time (5 Items)	YPT
	Customer Satisfaction (6 Items)	CS

4.3 Pretest

A pretest was conducted to review the instrument for data collection and the variables in the study. Four individuals in the automotive industry (one program manager, two team leaders, and one team member) from the field of product development were selected as key informants for the pretest of this study. These members worked in product development areas with OEM, tier-1 and tier-2 auto part suppliers.

The four individuals that were selected as key informants for the pretest study were all representative of various positions of a new product development team. Their responses were based on the particular project they experienced with the other team members. In evaluating, it is important to have a knowledgeable informant to answer the survey regarding the extent of concurrent work flow and shared knowledge in the team. (Seidler, 1974). All four participates had experience at all levels of new product development and were able to share their views on current work flow and shared knowledge for the pretest.

Next, a knowledge ability test assessed the content of inquiry (Kumar, Stern and Anderson, 1993). The potential informants were asked about how knowledgeable they were about the content of information provided after answering the questionnaire. All the respondents reported being comfortable and confident in answering the questions. This ensured that the respondent with the appropriate position and knowledge answered the questionnaire. The very first page of the questionnaire clearly stated:

"A person who has been a project manager or team leader for a new product development project should answer the questionnaire below. The questions enable you to describe the extent that the focal project utilized key best practices in integrated product development."

Additional steps were taken to ensure content validity. Five academics and two doctoral students were ask to review the items and make suggestions to add, modify, or delete items. Representatives from organizational behavior and manufacturing management were included because the research variables involved both disciplines. Of the total 149 items, 27 were dropped. Where any experts suggested that the domain of a variable should be more adequately covered, modification and generation of items were carried out through further literature review and group discussion. The total number of items after the expert evaluation and revision for the pilot study was 121.

4.4 Pilot Study Instrument

After the pilot questionnaire was reviewed, a web based questionnaire was created. The questionnaire can be located at http://www.wjdoll.utoledo.edu/pdpsurvey/PDPPilot.html and is also located in the appendix portion of this dissertation. Construction of the web questionnaire for the internet-based survey was aided by consultation with researchers with experience in this field. Proper format, color combination, and appropriate links were discussed to ensure that data collection would be effective. Multiple test runs were conducted by two doctoral students to ensure all the responses for each item were technically functioning. Once a respondent completed the survey and clicked on the "Submit" button at the end of the questionnaire, the web page created and e-mailed a text file capturing item codes and corresponding answers to the item.

The beginning of the survey provided information to the respondent on the goal and purpose of the research, the name and background of the researchers, and the requirements to participate in the study. This ensured the appropriate target audience was captured by the research instrument. Also included was the length of time the respondent required to complete the survey.

The survey itself provided the next section of the web instrument. The items were grouped according to variables. The first section of the survey consisted of work integration practices, followed by the second section of team vision, mutual trust, and mutual influence. The third section of the web survey involved the level of shared knowledge (i.e. knowledge integration of customers, suppliers, internal capabilities, and process) in the new product development team. Section four contained items that reflected process outcomes and section five listed items that referred to product outcomes.

Both process outcomes and product outcomes represented measures for new product development performance.

For each section in the pilot study, items were mixed randomly to insure each respondent paid close attention, reading each item before filling the responses. Thus, items for variables of heavyweight team manager, customer involvement, supplier involvement, and concurrent engineering were mixed randomly in the first section of the web survey.

The final portion of the web survey was reserved for demographic questions. These were specific questions about the industry type, size of the firm, knowledge intensity of the product development, product complexity, process complexity, and position in the supply chain (OEM or suppliers).

The instrument was purified in SPSS 11.0 by examining the corrected-item-total-correlations (CITC), of the items with respect to a particular variable (strategic fit). This method is recommended by Churchill 1979. The item inter-correlation matrices were used to drop items if they did not strongly contribute to Cronbach's alpha (minimum 0.80) for the variable under consideration (Flynn, Schroeder, and Sakakibara, 1995; Hong, 2000). However, if an item had a lower CITC (less than .60) but its contribution to the research was considered important, the item was retained.

In exploratory factor analysis, the internal consistency (i.e., the dimensionality) of the remaining variables were used to eliminate items that were not factorially pure. In some instances, phrases in each item may have sounded unclear or ambiguous, in these cases recommendations may have been made to re-word the item for the large scale study. Principle component analysis was used as for the means of extraction and verimax and oblimin rotation were used to rotate the factors. Items which loaded below 0.60 were generally eliminated, but if the item fell below this limit provided a contribution to the research, it was retained (Dillon & Goldstein, 1985). Reliability of the remaining items were then evaluated.

External consistency for each variable (team vision) was measured by submitting the remaining items to exploratory factor analysis to uncover significant cross-loadings. Principle component and oblimin were used as the means of extraction and method of rotation. Eigenvalues were chosen to list factors above 1.0. Loadings for items below 0.30 were not reported. Additionally, the Kaiser-Meyer-Olkin (KMO) measure lists KMO measures: in the 0.90's as outstanding, 0.80's very good, 0.70's as average, 0.60's as tolerable, in the 0.50's as poor and below 0.50 unacceptable. Before the large-sample administration, the variables were examined with respect to the research objectives and the overall pilot study results. Modification or addition of items was performed as reflected by the results of the pilot study process.

4.5 Pilot Study Result

Out of the 40 selected respondents that were contacted, 38 responses were received from the internet survey. Four of the responses could not be included in the study as they contained multiple missing items. Table 4.2 summarizes the response rate for the pilot study conducted.

Table 4.2 Response Rate

Phase	1
Total Contacted	40
Usable Response	34
Response Rate	85%

Zikmund, 1994 cautioned that even with the limited sample size of a pilot study, it remains important to demonstrate the reliability and validity. The remaining 34 responses were a large enough sample to perform some initial statistical analysis for the proposed research model. In this way, the pilot test could provide means for assessing the preliminary reliability and convergent validity of the instrument. Reliability was assessed by calculating Cronbach's alpha, and convergent validity was assessed by simple factor structure and high factor loading (>0.75).

All 34 respondents were full time employees in the product development field in the auto-industry. Company sizes for the respondents were measured by the number of employees working in the company. 58% of the companies had over 10,000 employees, 15% had employees in the range of 5000-9000, another 15% had employees in the range of 1000-4,999, 13% had employees in the range of 500-999, and 9% of the companies had employees in the range of 1-499. The demographical information of the companies for which each respondent worked is summarized in Table 4.3.

Table 4.3 Demography of the Respondent Company

Number of Employee				
	0-499		9%	
	500-999		13%	
	1000-4999		15%	
	5000-9999		15%	
	over 10000		58%	
Total				100%
Focal Product Manufactured				
	Body Exterior		0	
	Body Interior		0	
	Powertrain		3%	
	Body Component		6%	
	Chasis		82%	
	Electrical/Electronic Component		6%	
	Other		3%	
Total				100%
Company Position				
	OEM		26%	
	Auto Part Suppliers		71%	
		First-tier supplier (86%)		
		Second-tier supplier (7%)		
		Third-tier supplier (7%)		
		Other	3%	
Total				100%

In the following section, Concurrent Engineering and its determinates (heavyweight team manger, supplier involvement, customer involvement) along with Shared Knowledge and its determinate (team vision, mutual trust and mutual influence), and finally NPD Performance are examined one by one.

4.5.1 Heavyweight team manager

The variable of heavyweight team manager and its items were taken from an earlier study in work integration (Koufteros, 2000) which was empirically supported. Heavyweight team manager had a total of six items as reliability and factor analysis were performed. Table 4.4 shows the initial factor loadings and corrected item total correlations (CITC) generated for the variable of heavyweight team manager. Cronbach's alpha is also reported for the analysis and given if an item was to be dropped. During this stage, it was decided to inspect and or drop / modify items which showed poor CITC (less that 0.60). As evident from the results, all but six items except HM3 had a CITC > 0.60. Additionally, Cronbach's alpha for the variable of heavyweight team manager was .91 which indicated the high reliability of these measurements. Additionally, if HM3 is deleted, Cronbach's alpha rises to .92. After inspection of HM3, it was decided to delete the item because of the phrase "expert knowledge" which may have been unclear to the respondent.

After running factor analysis, the results showed that all items loaded on one single factor. All items had a high factor loading, except HM3, which again illustrates why this item was deleted.

Table 4.4 Heavyweight team manager-Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Heavyweight team manager					
Items	**Descriptions**	**CITC**	**Alpha if Item Deleted**	**Initial Factor Loading**	**Retained Factor Loading**
HM1	product development managers are given "real authority over personal	0.8256	0.8783	0.894	0.914
HM2	product development managers have enough influence to make things happen	0.8384	0.8779	0.898	0.909
HM3	product development managers derive their influence From expert knowledge of manufacturing processes	0.5434	0.9177	0.654	
HM4	product development managers have a final say budget decisions	0.6575	0.9022	0.756	0.759
HM5	product development managers have a final say in product design decisions	0.7718	0.8861	0.853	0.876
HM6	product development managers have broad influence across the organization	0.8505	0.8746	0.902	0.884
	Cronbach's Alpha = 0.9177 **Extraction Method: Principal Component Analysis** **1 Component Extracted, KMO = 0.849**				

All items were retained for heavyweight team manager except HM3 which had a poor CITC loading and contained the phrase "expert knowledge" which may have confused respondents. One item was added which became the new HM3 for the large scale study: "Product requirements are solicited, consolidated, and fed back to potential customers." Thus, the remaining items proposed for the large scale study can be seen below in table 4.5.

Table 4.5 Heavyweight items for large scale study

Items	Descriptions	Comment
HM1	product development managers are given "real" authority over personnel	No change
HM2	product development managers have enough influence to make things happen	No change
HM3	product development managers derive their influence from expert knowledge of manufacturing processes	Deleted
HM4	product development managers have a final say in budget decisions	No change
HM5	product development managers have a final say in product design decisions	No change
HM6	product development managers have broad influence across the organization	No change

4.5.2 Supplier Involvement

Items for supplier involvement were used from a previous work integration study (Koufteros, 2000) in product development. Supplier involvement consisted of six items. The same procedure was used to evaluate supplier involvement. A test for reliability was performed in SPSS and is reported in table 4.6. One item, SR5, was modified in the large scale study, it was removed from this analysis. All other items had a CITC of over .67. Overall Cronbach's alpha was good (>0.90). Additionally, all the items loaded on a single factor that were above 0.79. The Kaiser-Meyer-Olkin test reported a value of .808 which is very good.

Table 4.6 Supplier Involvement -Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Supplier Involvement						
Items	**Descriptions**	**CITC**	**Alpha if Item Deleted**	**Initial Factor Loading**	**Retained Factor Loading**
SR1	our suppliers do the product engineering of component parts for us	0.8148	0.8692	0.88	0.904
SR2	our suppliers develop component parts for us	0.8425	0.8644	0.904	0.919
SR3	our suppliers develop whole subassemblies for us	0.6725	0.8962	0.770	0.794
SR4	our suppliers are involved in the early stages of product development	0.7052	0.887	0.797	0.790
SR5	we ask our suppliers for their input on the design of component parts	0.5988	0.9007	0.712	
SR6	we make use of suppliers' expertise in the development of our products	0.7775	0.8762	0.856	0.840
	Cronbach's Alpha = 0.9007 **Extraction Method: Principal Component Analysis** **1 Component Extracted, KMO = .834**				

Item SR 5 was removed because it had a poor CITC loading (below .60) and also had the lowest contribution to the factor in analysis in SPSS. All other items were retained and shown to have strong loadings on the factor. The item list can be seen below in table 4.7.

Table 4.7 Supplier involvement items for large scale study

Items	Descriptions	Comment
SR1	our suppliers do the product engineering of component parts for us	No change
SR2	our suppliers develop component parts for us	No change
SR3	our suppliers develop whole subassemblies for us	No change
SR4	our suppliers are involved in the early stages of product development	No change
SR5	we ask our suppliers for their input on the design of component parts	Dropped
SR6	we make use of suppliers' expertise in the development of our products	No change

4.5.3 Customer Involvement

Five items were constructed for customer involvement, which were used from Koufteros', 2000 work integration study. Two items were dropped, CI2 and CI4, which left three items remaining for a Cronbach's alpha of .8219. CI4 was dropped because of its low CITC loading which may be a result of the word "study". Suppliers may not necessarily "study" how customers use their products. Often, designs are given or need slight modification from the customer. Thus, this may have contributed to item CI4 being a poor item. CI4 also had a slight cross load with CI2. CI2 was deleted because of a high error loading and also a low CITC. The KMO is .636 for the remaining three items which measure customer involvement. This is tolerable, but the author went back to literature and gathered four more items which were used from another research work to measure customer involvement and were included in the large scale survey.

Table 4.8 Customer Involvement -Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Customer Involvement					
Items	**Descriptions**	**CITC**	**Alpha if Item Deleted**	**Initial Factor Loading**	**Retained Factor Loading**
CI1	we involve customers in the early stages of product development	0.6042	0.7221	0.778	0.851
CI2	in developing the product concept, we listen to our our customer's needs	0.6386	0.7294	0.771	
CI3	we visit our customers to discuss product development issues	0.5746	0.7329	0.739	0.804
CI4	we study how our customers use our products	0.3263	0.8084	0.527	
CI5	our product development people meet with customers	0.7097	0.6777	0.858	0.926
	Cronbach's Alpha = 0.8219 **Extraction Method: Principal Component Analysis** **1 Component Extracted, KMO =.636**				

Customer involvement had two items eliminated in the pilot stage, CI2 and CI4, because of a low CITC. The remaining three items loaded had a high factor loading (all above 0.80) and had a Cronbach's alpha of .8219. Additional items were researched and three new items were proposed for the large scale study to add to these prior three. These items were used from a New Product Development Best Practices and Maturity Survey (Dooley et al, 1996). The scales for the analysis in this survey have been validated and four of the seven items proposed for customer involvement were found to fit well with the research definition for customer involvement. These added items can be seen in table 4.9.

Table 4.9 Customer involvement items for large scale study

Items	Descriptions	Comment
CI1	we involve customers in the early stages of product development	No change
CI2	in developing the product concept, we listen to our customer's needs	Dropped
CI3	we visit our customers to discuss product development issues	No change
CI4	we study how our customers use our products	Dropped
CI5	our product development people meet with customers	No change
	New Items Added to large scale	
CI2	during the requirements definition, potential customers are involved continuously and interactively	Add
CI4	product performance is verified by testing of prototypes by customers	Add
CI6	product improvements/redesigns occur because improvement ideas from customers are solicited	Add

4.5.4 Concurrent Engineering

Concurrent Engineering was measured by ten items. Item CW2 was dropped because of a low CITC and after review it was determined to be confusing to the respondent. Since there were many other strong items, (high factor loadings above 0.80), CW2 was deleted. The remaining nine items had a Cronbach's alpha of .9460, and the Kaiser-Meyer-Olkin measure of .897 which is very good.

Additionally, a factor analysis was performed after the poor items were deleted or removed. Running factor analysis with heavyweight team manager (all items except HM3), supplier involvement (all item except SR5) and customer involvement (items CI1, CI3, and CI5), it was shown that all items loaded on their own separate factor. All factors had eigen values above 1.0 and all items except one had loadings above .73. These results are reported in table 4.10. In table 4.11 and 4.12, factor analysis was performed between work integration variables. The results of the pattern matrix showed strong loadings on respective factors.

Table 4.10 Concurrent Engineering -Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Concurrent Engineering					
Items	**Descriptions**	**CITC**	**Alpha if Item Deleted**	**Initial Factor Loading**	**Retained Factor Loading**
CW1	Product and process designs are developed concurrently by a team of employees from various departments	0.7697	0.9396	0.814	0.802
CW2	Much of process designs is done concurrently with product designs	0.6281	0.9460	0.694	
CW4	Product development group members represent a variety of disciplines	0.7692	0.9395	0.818	0.827
CW5	Various disciplines are involved in product development From the early stages	0.7544	0.9402	0.804	0.819
CW6	Process engineers are involved from the early stages of product development	0.7802	0.9390	0.828	0.823
CW7	Manufacturing engineers were involved from the early stages of product development	0.824	0.9375	0.861	0.847
CW8	The team consisted of cross-functional members of the organization	0.8043	0.9381	0.845	0.865
CW9	The team simultaneously planned the product, process and manufacturing activities of the project	0.8841	0.9343	0.912	0.904
CW10	The entire project team was involved since the early stages of the project	0.8494	0.9358	0.890	0.902
CW11	All necessary functions of the organization were represented in the project team	0.6884	0.9436	0.745	0.752
	Cronbach's Alpha = .9460 **Extraction Method: Principal Component Analysis** **1 Component Extracted, KMO = .897**				

Table 4.11 Factor Analysis for drivers of Concurrent Engineering

Factor Analysis for all Determinates of Concurrent Engineering
Final Result
Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.792			
Items	**Factor 1**	**Factor 2**	**Factor 3**
CI1			0.796
CI3			0.857
CI5			0.882
SR1	0.944		
SR2	0.902		
SR3	0.696		
SR4	0.732		
SR6	0.875		
HM1		-0.893	
HM2		-0.899	
HM4		-0.800	
HM5		-0.881	
HM6		-0.748	
Eigen Value	5.557	2.58	1.818
% of Variance	42.747	19.844	13.988
Cumulative % of variance	42.747	62.591	76.578

Table 4.12 Factor Analysis: Heavyweight team manager and concurrent engineering

Factor Analysis: Heavyweight team manager and Concurrent Engineering

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.878		
Items	**Factor 1**	**Factor 2**
HM1		0.919
HM2		0.889
HM4		0.71
HM5		0.955
HM6		0.667
CW1	0.589	
CW4	0.751	
CW5	0.675	
CW6	0.919	
CW7	0.894	
CW8	0.749	
CW9	1.022	
CW10	0.882	
CW11	0.71	
Eigen Value	8.406	1.97
% of Variance	60.04	14.07
Cumulative % of Variance	60.04	74.11

Extraction Method: Principal Component Analysis
2 Components Extracted
Cross loads above .35 not reported
Rotation Method: Oblimin with Kaiser Normalization

Only one item was dropped from concurrent engineering due to a low CITC, CW2 as can be seen in table 4.13. Looking at loadings for these items, CW 11 loaded at .752 on the factor, every other item loaded above .80. Additionally, items for concurrent engineering loaded only on this construct when compared to heavyweight team manager. Cronbach's alpha is .946 for the factor which is very good.

Table 4.13 Concurrent Engineering items for large scale study

Concurrent Engineering		
Items	Descriptions	Comment
CW1	Product and process designs are developed concurrently by a team of employees from various departments	No Change
CW2	Much of process designs is done concurrently with product designs	Dropped
CW4	Product development group members represent a variety of disciplines	No Change
CW5	Various disciplines are involved in product development from the early stages	No Change
CW6	Process engineers are involved from the early stages of product development	No Change
CW7	Manufacturing engineers were involved from the early stages of product development	No Change
CW8	The team consisted of cross-functional members of the organization	No Change
CW9	The team simultaneously planned the product, process and manufacturing activities of the project	No Change
CW10	The entire project team was involved since the early stages of the project	No Change
CW11	All necessary functions of the organization were represented in the project team	No Change

4.5.5 Team Vision

Team Vision was conceptualized as having three variables (i.e. Mission, Strategic Fit, and Project Targets). All the items for these three variables were used from Hong (2000) and were empirically proven to be highly reliable.

Each variable had 4-5 items. Reliability analysis and factor analysis for each of the three variables was carried out first. Table 4.14 shows the initial factor loadings and corrected item total correlations (CITC) generated for each item related to a particular variable of Team Vision. It also gives the initial Cronbach's alpha for each scale and alpha value if items were to be dropped. During this stage, it was decided to drop items, which showed poor CITCs (<0.60). As evident from the result, the CITC for all 13 items of Team Vision had CITC >0.60. Further, Cronbach's alpha for all three variables is

0.96, 0.88, and 0.92, which indicates the high reliability of these measurements.

When factor analysis was conducted for all three variables separately, a single component was extracted. Except for PTT2, the factor loadings for all remaining twelve items are above .80. For PTT2, the factor loading is 0.76 which is still above the tolerance level. Thus, at this stage, all of the thirteen items of Team Vision were retained.

Table 4.14 Mission, Strategic Fit, and Project Target -Items, Description Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
Mission					
TM1	The project purpose was well understood by the entire team	0.8886	0.9586	0.929	0.929
TM2	The project mission was well communicated to all team members	0.8424	0.966	0.898	0.898
TM3	The project mission was well defined for all team members	0.916	0.9544	0.948	0.948
TM4	The product development team has a well defined mission.	0.9253	0.9527	0.954	0.954
TM5	The project mission was well understood by the entire team.	0.9373	0.9519	0.961	0.961
Cronbach's Alpha = 0.9651					
Extraction Method: Principal Component Analysis, 1 Component Extracted					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.849					
Strategic Fit					
SF1	Our firm's overall technology strategy guided a setting of the project targets	0.7812	0.845	0.883	0.883
SF2	The project target were consistent with our overall business strategy	0.731	0.8657	0.849	0.849
SF3	Project targets reflected the competitive situation	0.7048	0.8769	0.83	0.83
SF4	Our firms overall product strategy guided a setting of project targets	0.8115	0.8326	0.904	0.904
Cronbach's Alpha = 0.8875					
Extraction Method: Principal Component Analysis, 1 Component Extracted					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.819					
Project Target					
PTT1	The project targets clearly specified tradeoffs between performance and cost	0.8841	0.8847	0.919	0.919
PTT2	The relative priority of each project target was clear	0.7311	0.9353	0.764	0.764
PTT3	The project targets clearly specified tradeoffs between time and cost	0.8216	0.9095	0.92	0.92

Next, all thirteen items were included for exploratory factor analysis to investigate if three components could be extracted corresponding to Mission, Strategic Fit, and Project Target. The result of this step is presented in Table 4.15.

Table 4.15 Factor Analysis for all Team Vision Variables Retained Items, Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.773			
Items	**Factor 1**	**Factor 2**	
TM1	1.057		
TM3	0.925		
TM2	0.912		
TM5	0.891	**Team Mission**	
SF2	0.869		
TM4	0.867		
SF1	0.781	**Strategic Fit**	
PTT2	0.764		
SF3	0.741		
SF4	0.631		
PTT3		0.92	
PTT1		0.919	**Project Targets**
PTT4		0.853	
Eigen Value	12.287	2.17	
% of Variance	64.669	11.42	
Cumulative % of variance	64.669	76.089	

Extraction Method: Principal Component Analysis
2 Components Extracted

Rotation Method: Oblimin with Kaiser Normalization

As presented in the pattern matrix in Table 4.15, two components were extracted using the minimum Eigen Value of 1.0 from thirteen items for Team Vision. Items representing Team Mission and Strategic Fit resulted a single factor as opposed to expectations. PTT3, PTT4 and PTT1 represented Project Targets and constitute the second factor. PTT2, however, was found to be loading in factor 1.

The small sample size of 34 responses could be yet another possible reason that there were only two components being extracted. With high sample size of 205 respondents empirical work on Team Vision resulted in four distinct factors that the study identified as Shared Team Purpose and Mission, Strategic Fit, Clarity of Project Targets and Tradeoff of Project Targets (Hong, 2000). All the items showed high factor loadings (> 0.75) with no cross loadings.

As shown in Table 4.15, there are no cross-loadings and the factor 1 (Mission and Strategic Fit) and factor 2 (Project Target) discriminated clearly from each other. Factor loadings for all the thirteen items in the two components are higher than 0.74 and mostly in 0.80s and 0.90s. The factor loading for SF4 is 0.63 and is the lowest. All the items were retained at this stage.

4.5.6 Mutual Trust

Mutual Trust represents a single variable with a total of ten items. Table 4.16 displays item codes, item description, factor loadings, CITCs, Cronbach's alpha and the alpha value if the item was deleted. The Cronbach's alpha was 0.97 signifying very high reliability of the instrument. The CITC for each item was also very high, mainly in 0.80s and 0.90s, except for TR5 which has a CITC value of 0.73. There is no significant improvement to Cronbach's alpha if any of the items is omitted. Thus, all the items for Mutual Trust were retained at this stage.

During factor analysis, a single factor was extracted. The factor loadings for all the items for Mutual Trust (except for TR5) are high in 0.80s and 0.90s. For TR5, the factor loading reported is 0.774. Because of high reliability and high factor loadings, all 10 items for Mutual Trust were retained during this phase.

Table 4.16 Mutual Trust -Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Trust					
Items	**Descriptions**	**CITC**	**Alpha if Item Deleted**	**Initial Factor Loading**	**Retained Factor Loading**
TR1	There was mutual trust among team members	0.884	0.970	0.908	0.908
TR2	The team members trusted each other enough to share all relevant information	0.854	0.971	0.882	0.882
TR3	The team members were willing to share sensitive information	0.854	0.971	0.882	0.882
TR4	Team members trusted each other	0.943	0.968	0.956	0.956
TR5	The team members shared the belief that all members were acting in good faith	0.729	0.975	0.774	0.774
TR6	The team shared a belief that all members were honest	0.882	0.970	0.904	0.904
TR7	The team members were confident they could trust each other	0.968	0.967	0.976	0.976
TR8	Team members relied on each other for the truthfulness of the information shared	0.840	0.972	0.872	0.872
TR9	The team members trusted each other to share accurate information	0.932	0.968	0.946	0.946
TR11	Team members trusted each other enough to share sensitive information	0.857	0.971	0.885	0.885
Cronbach's Alpha = .973 **Extraction Method: Principal Component Analysis, 1 Component Extracted** **Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0. 873**					

4.5.7 Mutual Influence

Mutual Influence also represents a single variable with a total of nine items. Table 4.17 displays item codes, item description, factor loadings, CITCs, Cronbach's alpha and the alpha value if the item was deleted. The Cronbach's alpha is reported to be 0.9360 signifying very high reliability of the instrument. The CITC for each item is also high, mainly in 0.80s and 0.70s, except for MI1 which has the lowest CITC value of all of 0.6297. There is no significant improvement to Cronbach's alpha if any of the items are omitted.

During the factor analysis, a single factor was extracted. The factor loading of all the items was > 0.80s. MI1 reported the lowest factor loading of

0.694. Because of high reliability and high factor loadings, all nine items for Mutual Influence were retained during this phase.

Table 4.17 Mutual Influence -Items, Description
Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Mutual Influence					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
MI1	Mutual influence was broadly spread among the team	0.630	0.936	0.694	0.694
MI2	Everyone on the team had some power to influence others	0.787	0.778	0.842	0.842
MI3	Power was broadly shared among team members	0.758	0.702	0.808	0.808
MI4	Each team member had some ability to affect the decisions of others	0.739	0.641	0.800	0.800
MI5	Each team member had at least some control over the decisions of the team	0.755	0.740	0.810	0.810
MI6	Each team member had some power to affect team decisions	0.823	0.850	0.867	0.867
MI7	Influence was shared among team members	0.826	0.819	0.867	0.867
MI8	All team members had at least some ability to persuade each other	0.778	0.824	0.835	0.835
MI9	All team members had some authority to influence team decisions	0.791	0.714	0.842	0.842
Cronbach's Alpha = .9360 Extraction Method: Principal Component Analysis, 1 Component Extracted Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.857					

4.5.8 Mutual Trust and Mutual Influence –Factor Analysis

To investigate further, it was decided to conduct factor analysis using all the retained ten items of Mutual Trust and all the retained nine items of Mutual Influence. The objective was to statistically check if any cross loadings appear between the two variables and if these two variables discriminated from each other. The result of exploratory factor analysis is presented in Table 4.18.

As expected, the two variables discriminantly loaded separately in two factors. Factor 1 represents items for Mutual Trust and factor 2 represents items for Mutual Influence. No cross loading between the two variable was reported and the factor loadings for all the items were above 0.70 except for MI7 and MI1 with factor loading of 0.69 and 0.527 respectively. No item purification was carried out in this stage either.

Table 4.18 Factor Analysis for Mutual Trust and Mutual Influence
Initial Result / Final Result
(Pattern Matrix)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.773			
Items	**Factor 1**	**Factor 2**	
TR6	1.021		
TR5	0.956		
TR7	0.869		
TR4	0.854		
TR2	0.847		**Mutual Trust**
TR9	0.825		
TR11	0.805		
TR11	0.734		
TR3	0.721		
TR8	0.72		
MI8		0.948	
MI6		0.881	
MI5		0.841	
MI2		0.817	
			Mutual Influence
MI3		0.789	
MI4		0.784	
MI9		0.741	
MI7		0.69	
MI1		0.527	
Eigen Value	12.287	2.17	
% of Variance	64.669	11.42	
Cumulative % of Variance	64.669	76.089	

Extraction Method: Principal Component Analysis
2 Components Extracted
Rotation Method: Oblimin with Kaiser Normalization

4.5.9 Team Vision, Mutual Trust, and Mutual Influence –Factor Analysis

Next, all the proposed drivers for Shared Knowledge –Team Vision, Mutual Trust, and Mutual Influence were tested to verify if all three discriminate into three clear factors. During this stage, all the variables and corresponding items were submitted simultaneously for exploratory factor analysis using principal component analysis as the extraction method with the Eigen value as 1.0 and oblimin rotation. The objective was to further examine if any cross loadings occurred between variables. The initial result from the pattern matrix is presented in Table 4.19.

Table 4.19 Factor Analysis for Team Vision, Mutual Trust, and Mutual Influence Initial Result

(Pattern Matrix)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = Not Reported					
Items		**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
TR6		0.991			
TR5		0.966			
TR11		0.813			
TR7	**Mutual Trust**	0.813			
TR4		0.795			
TR9		0.777			
TR2		0.758			0.41
TR1		0.691			
TR3		0.679	0.351		
TR8		0.629			0.318
TM2		0.578	0.478		
SF1			0.966		
PTT2			0.851		
TM3			0.828	**Mission and**	
SF4			0.776	**Strategic**	
TM4			0.759	**Fit**	
TM5			0.671		
SF2			0.616		
TM1		0.319	0.563	0.33	
SF3			0.447	0.381	
MI8				0.982	
MI6				0.891	
MI2			**Mutual**	0.886	
MI9			**Influence**	0.858	
MI5				0.751	
MI3				0.744	
MI4				0.675	
MI7				0.587	
PTT1				**Project**	0.743
PTT3				**Target**	0.67
PTT4			0.5		0.631
MI1				0.43	0.55
Eigen Value		19.424	3.591	2.113	1.251
% of Variance		60.702	11.221	6.603	3.909
Cumulative % of Variance		60.702	71.923	78.734	82.435

Extraction Method: Principal Component Analysis

4 Components Extracted

Rotation Method: Oblimin with Kaiser Normalization

As evident from the Table 4.19; the factor analysis resulted in four components. Factor 1 mostly represented items for Mutual Trust (TR); Factor Three represented items mostly of Mutual Influence (MI); Factor 2 and Factor 4 represented items mostly of Team Vision. Factor 3 consisted of items for Mission (TM) and Strategic Fit (SF) and Factor 4 consisted of items from Project Target (PTT). Clearly, some of the items demonstrated cross loadings.

TR2 and TR8 were found to have cross loading with Factor 4 and TR3 with Factor 2. Similarly, TM1 was found to have cross loadings with Factor 1 and Factor 3, and SF3 had cross loading with Factor 3. Except for MI1, all the items of Mutual Influence loaded discriminantly in Factor 3. MI1 had cross loading in Factor 4. Except for PTT2, all the items of Project Target had discriminant loading in Factor 4. PTT2 loaded in Factor 2 with no cross loadings to any other factors.

Next, it was required to conduct item purification with all the items that had cross loadings. This was conducted using Exploratory Factor Analysis, eliminating one item at a time, with the highest factor cross loading first. The final result of this is provided in Table 4.20.

Table 4.20 Factor Analysis for Team Vision, Mutual Trust, and Mutual Influence Final Result
(Pattern Matrix)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.559					
Items		**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
TR5		1.026			
TR6		1.001			
TR7		0.799			
TR4	**Mutual Trust**	0.786			
TR9		0.775			
TR11		0.761			
TR1		0.697			
TR3		0.675			
TR8		0.621			
TM2		0.566			
SF1			0.937		
SF4			0.923	**Mission and Strategic Fit**	
SF2			0.738		
TM3			0.59		
TM5			0.515		
MI8				-0.985	
MI6				-0.925	
MI2			**Mutual Influence**	-0.872	
MI9				-0.852	
MI5				-0.776	
MI3				-0.743	
MI4				-0.707	
MI7				-0.601	
PTT1					0.967
PTT3				**Project Target**	0.891
PTT4					0.874
Eigen Value		15.506	2.734	1.995	1.221
% of Variance		59.637	10.515	7.671	4.694
Cumulative % of Variance		59.637	70.152	77.823	82.518

Extraction Method: Principal Component Analysis
4 Components Extracted
Rotation Method: Oblimin with Kaiser Normalization

4.5.10 Shared Knowledge

Shared Knowledge consists of four variables (i.e. Shared Knowledge of Customers, Internal Capabilities, Suppliers, and Process). Except for the Shared Knowledge of Process, all three variables and items are used directly from the empirical study of Hong 2000, on Shared Knowledge in new product development. Items for Shared Knowledge of Process were developed as described in Chapter Two and Three. The results from reliability analysis and initial factor loadings for all the four variables are presented in Table 4.21.

Table 4.21 Shared Knowledge of Customers, Internal Capabilities, Suppliers, and Process- Item Description, Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Shared Knowledge of Customers					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
CT1	customer requirements	0.6497	0.8421	0.912	0.912
CT2	what our customers wanted	0.8287	0.7633	0.826	0.826
CT3	Which features were most valued by target customers	0.6764	0.8336	0.817	0.817
CT4	current customer needs.	0.6769	0.8317	0.802	0.802
	Cronbach's Alpha = 0.852 **Extraction Method: Principal Component Analysis, 1 Component Extracted** **Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.713**				
Shared Knowledge of Internal Capabilities					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
IT1	The capabilities of the process technologies we used	0.7988	0.773	0.904	0.904
IT2	The strengths of our engineering development capabilities	0.5653	0.8665	0.884	0.884
IT3	The capabilities of our engineering staff	0.779	0.7878	0.813	0.813
IT4	The strengths of our manufacturing facilities	0.6801	0.6906	0.745	0.745
	Cronbach's Alpha = 0.8551 **Extraction Method: Principal Component Analysis, 1 Component Extracted** **Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.616**				
Shared Knowledge of Suppliers					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
ST1	Our suppliers' process capabilities	0.9087	0.8824	0.943	0.943
ST2	Our suppliers design capabilities	0.5645	0.9274	0.9	0.9
ST3	Our suppliers' manufacturing facilities	0.7834	0.9006	0.896	0.896
ST4	Our suppliers' capabilities to meet cost requirements	0.8381	0.8938	0.858	0.858
ST5	Our suppliers' capabilities to meet time requirements	0.6778	0.9147	0.77	0.77
ST6	Our suppliers' capabilities to meet quality requirements	0.8942	0.8911	0.667	0.667
	Cronbach's Alpha = 0.9178 **Extraction Method: Principal Component Analysis, 1 Component Extracted** **Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.871**				
Shared Knowledge of Process					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
TP4	The process of product development	0.7682	0.8593	0.993	0.993
TP5	the activities in the product development process that were on the critical path	0.631	0.889	0.86	0.86
TP6	how our firm should develop products	0.7405	0.869	0.839	0.839
TP7	each other's roles in the product development process	0.8889	0.8316	0.795	0.795
TP8	Key decision points in the product development process	0.6733	0.8802	0.755	0.755
	Cronbach's Alpha = 0.8907 **Extraction Method: Principal Component Analysis, 1 Component Extracted** **Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.754**				

CITC for all the items of Shared Knowledge was at least of acceptable value. IT2 and ST2 had the lowest CITC values of 0.5653 and 0.5645 which is less than the minimum desired value of 0.60. However, because of practical significance of these two items, they were retained. Reliability test for all the four variables reported high Cronbach's alpha; 0.8582, 0.8551, 0.9178, and 0.8907 for Shared Knowledge of Customer, Internal Capabilities, Suppliers, and Process respectively. Since dropping any item could not contribute significantly to Cronbach's alpha, all the items for each variable were retained. Once high reliability for all these four variables of Shared Knowledge was established, separate factor analysis for each of the four variables was performed to investigate initial loadings and to verify if a single component could be extracted. As shown, all the variables reported single component extraction with high factor loadings; in the range between 0.70 and 0.90. ST6, however, reported the lowest factor loading of 0.667. All 19 items for Shared Knowledge were retained during this stage.

Next, factor analysis for all the 19 items was conducted to investigate if the four variables discriminate from each other in four distinct components. Further, it was also desirable to check if any items cross loaded, in which case item purification was required. The initial result of factor analysis of all the 19 items is shown in Table 4.22.

Table 4.22 Factor Analysis for all Shared Knowledge variables
Initial Result / Final Result
Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.73				
Items	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
IT4	0.968			
IT1	0.907			
TP4	0.837			
ST4	0.791			0.305
ST6	0.731			
TP7	0.678	0.387		
TP6	0.654	0.335	-0.361	
ST1	0.563			0.525
ST5	0.477		-0.31	0.464
TP5		0.913		
IT2		0.861		
TP8		0.812		
CT3		0.671	0.53	
IT3		0.619	0.308	
CT1			0.838	
CT2			0.79	
CT4		0.359	0.628	-0.35
ST2				0.923
ST3	0.383			0.485
Eigen Value	10.102	2.181	2.075	1.207
% of Variance	53.168	11.478	10.919	6.354
Cumulative % of variance	53.168	64.646	75.565	81.919
Extraction Method: Principal Component Analysis **4 Components Extracted** **Rotation Method: Oblimin with Kaiser Normalization**				

The result of factor analysis extracted four components as expected, however many items cross loaded on various components. Furthermore, no clear grouping of items in single component was evident. The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.73 which is higher than the minimum value of 0.5 mentioned in the SPSS 11.0 manual indicating the result of the factor analysis is probably useful.

After the result was investigated, items for each variable were examined for revision for the large scale study. The empirical study of Hong 2000, resulted into five distinct factors that were identified as Shared Knowledge of Customers, Suppliers, Competitors, Internal Capabilities, and Product. The study reported Kaiser-Meyer-Olkin Measure of Sampling Adequacy to be 0.86. Cronbach's alpha for each variable was larger than 0.80 except for Shared Knowledge of Product. Shared Knowledge of Product was reported to be the weakest in terms of reliabilities and overall factor loadings. For this reason, this research study proposed not to use this variable, but based on other literature, Shared Knowledge of Process was developed and utilized in the pilot study.

4.5.11 IPD Performance Outcomes

Two variables have been proposed to represent NPD performance outcomes, one of process and one of product. Process outcomes are made up of engineering change time, team work, and team productivity while product outcomes are measured by product cost reduction, manufacturing cost reduction, product development time, and customer satisfaction.

4.5.12 Process Outcome (NPD Performance)

Process Outcome is one of the two variables for NPD Performance. Process Outcome was represented by three variables; Engineering Change Time, Team Work, and Team Productivity. All the items on these variables were used from the empirical study in the field of new product development (Syamil, 2000; Hong, 2000). Each variable has three items. Table 4.23 shows results of individual variables on reliability analysis and factor analysis.

Table 4.23 Engineering Change Time, Team Work, and Team Productivity -Item Description, Initial Factor Loading, CITC, Cronbach's Alpha and Alpha if Item Deleted

Engineering Change Time

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
EC2	finished engineering change orders on time	0.938	0.933	0.972	0.972
EC3	delivered engineering change notices on time	0.938	0.936	0.972	0.972
EC4	Met engineering change deadline regularly	0.899	0.965	0.954	0.954

Cronbach's Alpha = 0.9632
Extraction Method: Principal Component Analysis, 1 Component Extracted
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.769

Team Work

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
TW2	communicated effectively	0.667	0.878	0.916	0.916
TW4	resolved design conflicts on time	0.776	0.781	0.905	0.905
TW5	coordinated design activities effectively	0.795	0.762	0.840	0.840

Cronbach's Alpha = 0.8653
Extraction Method: Principal Component Analysis, 1 Component Extracted
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.710

Team Productivity

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
XTP1	Was productive	0.853	0.798	0.939	0.939
XTP2	completed work quickly	0.773	0.871	0.897	0.897
XTP3	worked on product improvements successfully	0.761	0.879	0.892	0.892

Cronbach's Alpha = 0.8954
Extraction Method: Principal Component Analysis, 1 Component Extracted
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.721

Engineering Change Time shows high reliability with Cronbach's alpha of .9362. The CITC for all three items are also in the range between 0.89 and 0.93. Since omitting any items will not improve alpha, all the three items were retained. Factor analysis resulted in a single component extraction with high factors loadings of 0.972, 0.972 and 0.974. All the items for Engineering Change Time were retained at this stage.

The Cronbach's alpha for second variable, Team Work, was 0.8653 which is high. CITC for the three items were reported as 0.6665, 0.7757, and 0.7949; all were above the average acceptance value of 0.60. Although TW5 could be argued for otherwise, comparison of Cronbach's alpha for Team Work versus individual items if they are dropped does not improve the reliability significantly. However, because of practical significance, all the three items were retained. Next, factor analysis resulted in a single component, and the factor loadings were all above 0.84. All the items for Team Work were retained at this stage.

The third variable for Process Outcome is Team Productivity for which the Cronbach's alpha reported was 0.8954. CITC for all three items of Team Productivity were in the range between 0.76 and 0.85. Omission of any item at this stage did not lead to any significant improvement in Cronbach's alpha. Thus, all of the three items were retained. Factor analysis resulted in a single component structure, with factor loadings higher than 0.89. Therefore, all the items were retained at this stage.

Next factor analysis for all the items for Process Outcome, which were grouped into Engineering Change Time, Team Work, and Team Productivity, was conducted to investigate the pattern structure and cross loadings of the items. The result is presented in Table 4.24.

Table 4.24 Factor Analysis for all Process Outcomes Variables
Initial Result / Final Result
Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.891	
Items	**Factor 1**
EC4	0.921
TW5	0.906
EC3	0.902
TW4	0.899
EC2	0.899
XTP2	0.84
XTP1	0.839
TW2	0.78
XTP3	0.755
Eigen Value	6.686
% of Variance	74.29
Cumulative % of Variance	74.29

Extraction Method: Principal Component Analysis
Only One Component Extracted
The solution cannot be rotated

All the items reported to be loading on a single factor. The KMO value was reported to be 0.891 and significance level was 0.00 that showed the items used were significant for factor analysis. Probably the small sample size of 34 could be one possible reason why a single factor was extracted instead of three factors.

With a larger sample size of 205, Hong 2000, has empirically demonstrated that Process Outcome of new product development results in three factors representing Team Work, Development Productivity, and Time

To Market. Development Productivity and Time To Market discriminated clearly from one another with no cross loadings, high Cronbach's alpha (0.81 and 0.91), and high loadings (mostly in the range of 0.70s and 0.95). However, of five items representing Team Work, 4 items for Team Work reported high (>0.81) cross loading with Development Productivity and 1 item reported to have high (0.88) cross loading with Time To Market. At this point, all the items for Process Outcome were retained.

4.5.13 Product Outcome (NPD Performance)

Product Outcome is the second variable for NPD Performance and contains four variables: Product Cost Reduction, Manufacturing Cost Reduction, Product Development Time, and Customer Satisfaction. All the items for each of the variables were borrowed from empirical work on new product development by Hong (2000) and Syamil (2000).

Each of these four variables has 4 to 6 items. The result of Reliability test and factor analysis is presented in Table 4.25.

Table 4.25 Product Cost Reduction, Manufacturing Cost Reduction, Product Development Time, Customer Satisfaction - Item Description, Initial Factor Loading, CITC, Cronbach's Alpha, and Alpha if Item was Deleted

Product Cost Reduction

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
PC1	simplified the design successfully	0.502	0.877	0.914	0.914
PC2	reduced product costs successfully	0.835	0.738	0.900	0.900
PC3	reduced material costs successfully	0.807	0.754	0.815	0.815
PC4	reduced the number of parts successfully	0.668	0.823	0.683	0.683

Cronbach's Alpha = .849

Extraction Method: Principal Component Analysis, 1 Component Extracted

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.694

Manufacturing Cost Reduction

Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
MC1	successfully reduced assembly cost	0.892	0.897	0.910	0.910
MC2	reduced equipment cost successfully	0.796	0.902	0.891	0.891
MC3	reduced manufacturing cost successfully	0.718	0.917	0.887	0.887
MC4	reduced production tooling costs successfully	0.816	0.899	0.878	0.878
MC5	reduced the number of manufacturing steps effectively	0.851	0.889	0.809	0.809

Cronbach's Alpha = .919

Extraction Method: Principal Component Analysis, 1 Component Extracted

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.876

Product Development Time					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
YPT1	launched product to the market faster	0.809	0.864	0.928	0.928
YPT2	enabled our company to start volume production faster	0.721	0.885	0.884	0.884
YPT3	brought product to the market before our competitors	0.681	0.892	0.820	0.820
YPT4	developed product from concept to commercial production faster	0.870	0.850	0.797	0.797
YPT5	made better progress in reducing total product development time	0.682	0.892	0.792	0.792
	Cronbach's Alpha = 0.899				
	Extraction Method: Principal Component Analysis, 1 Component Extracted				
	Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.768				

Customer Satisfaction					
Items	Descriptions	CITC	Alpha if Item Deleted	Initial Factor Loading	Retained Factor Loading
CS1	satisfied customers better	0.850	0.880	0.918	0.918
CS2	fit target customers better	0.834	0.884	0.911	0.911
CS3	has more loyal customers	0.769	0.894	0.905	0.905
CS4	generated more new customers	0.625	0.916	0.840	0.840
CS5	was more highly valued by customers	0.854	0.884	0.760	0.760
CS6	was more successful in the marketplace	0.661	0.907	0.717	0.717
	Cronbach's Alpha = 0.910				
	Extraction Method: Principal Component Analysis, 1 Component Extracted				
	Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.892				

Cronbach's alpha for Product Cost Reduction was reported to be 0.85. CITC for PC1 was reported to be .5017, which was less than the desired minimum value of 0.60. However, no item purification was done at this stage. All the four items resulted in a single factor with high factor loadings. All four items were retained at this stage.

Manufacturing Cost Reduction has five items and reported Cronbach's alpha of 0.912. Further CITC for all the five items were in the range of 0.70s and 0.80s. No significant improvement in reliability would result if any item was to be dropped. All the items were retained at this stage. Factor analysis yielded in a single component extraction with high factor loadings for each item. All the items, thus, was retained for Manufacturing Cost Reduction.

Product Development Time is the third variable of Product Outcomes and it contains five items. Cronbach's alpha was reported to be 0.90 with CITC value for each item above 0.69. Further, dropping any item did not lead to any improvement in the reliability for Product Development Time. All the five items were retained at this stage. Factor Analysis resulted in a single component with higher loadings between 0.79s and 0.90s.

The Cronbach's alpha for the fourth variable, Customer Satisfaction, was reported to be 0.9104. It has 6 items and CITC for each of these items were reported to be greater than 0.60. Further, dropping any these items would not result any significant improvement in reliability. Factor analysis resulted in a single component with high loadings (between 0.70 and 0.90). All six items were retained at this stage.

Next, factor analysis for all the items of Product Outcomes was performed. The result is presented in Table 4.26.

Table 4.26 Factor Analysis for all Product Outcomes
Initial Result
Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.656			
Items	**Factor 1**	**Factor 2**	**Factor 3**
MC4	0.888		
PC2	0.878		
MC5	0.852		
MC1	0.834		
PC3	0.815		
MC2	0.814		
MC3	0.805		
PC1	0.558	0.442	
PC4	0.556		
CS2		0.905	
CS5		0.902	
CS1		0.874	
CS6		0.788	
CS3		0.752	
YPT3			-0.876
YPT2			-0.75
YPT4			-0.726
YPT1		0.324	-0.654
YPT5		0.361	-0.626
CS4		0.508	-0.543
Eigen Value	8.95	3.723	1.868
% of Variance	44.751	18.613	9.33
Cumulative % of variance	44.751	63.363	72.694

Extraction Method: Principal Component Analysis
3 Components Extracted
Rotation Method: Oblimin with Kaiser Normalization

All 20 items for the Product Outcomes when subjected to factor analysis resulted into 3 separate components. Items from first two constructs – Product Cost Reduction and Manufacturing Cost Reduction loaded in single factor, Factor 1. Instead of having two constructs, maybe the result suggested a single construct which could be labeled as Cost Reduction. Factor loadings of both PC1 and PC4 were lower than 0.6; and in addition, PC1 had cross loadings on Factor 2. Factor 2 consisted of all the items of fourth construct, Customer Satisfaction. However, CS4 was found to have cross loadings on Factor 3. All the items of Product Development Time loaded on Factor 3. YPT1 and YPT5 were found to have cross loadings with Factor 2.The overall KMO was reported to be 0.656; above the suggested value of 0.60.

The final pattern matrix after item purification from above factor analysis for all the items of Product Outcomes is presented in Table 4.27. PC1 and CS4 were dropped at this point. While there was a significant improvements in factor loadings of all the items, YPT1 and YPT5 still were found to have a cross loading on Factor 2. Because of small sample size and on the basis of practical significance, both the items were retained at this stage.

Table 4.27 Factor Analysis for all Product Outcomes Variables
Final Result
Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.723				
Items		**Factor 1**	**Factor 2**	**Factor 3**
MC4		0.907		
PC2	**Product Cost and Manufacturing Cost Reduction**	0.885		
MC1		0.853		
MC5		0.84		
MC2		0.84		
PC3		0.815		
MC3		0.799		
PC4		0.553		
CS2			0.932	
CS5			0.901	**Customer Satisfaction**
CS1			0.898	
CS6			0.802	
CS3			0.757	
YPT3				-0.901
YPT2				-0.799
YPT4		**Product Development Time**		-0.753
YPT1			0.325	-0.693
YPT5			0.374	-0.627
Eigen Value		8.347	3.445	1.672
% of Variance		46.372	19.14	9.288
Cumulative % of variance		46.372	65.511	74.799

4.6 Methodological Limitations (Bias)

One of the most frequent criticisms in research is the *provincialism* introduced by way of the researcher. Each researcher applies the constructs and methodologies typical to the academic domain in which he or she was trained or the corporate environment he or she works within (Roberts and Boyacigiller, 1984). The researcher in this case has post-secondary degrees in business and engineering which allows for a broader perspective in research methodologies. The primary researcher had taken doctoral level courses in product development, manufacturing systems, information system, research theory and methodology, and organizational behavior that are directly related with the domain of this research. In addition, the advising and research committee included expert members and researchers in the field of organizational behavior, NPD, operations management, sales and marketing, and advance statistics. Further, professionals in the field of product development were consulted on this research topic to provide insights in product development practices. The additional 'insider' working knowledge should be considered as an asset rather than a liability.

A further methodological limitation relates to *random and system error.* Random error (RA) occurs because of chance variation in the scientific selection of sampling units and will be handled statistically during the large scale study in Chapter 5. Systematic errors result from some imperfect aspect of the research design or from a mistake in the execution of the research.

The two main sources of systematic error are administrative and respondent derived (De Vaus, 1995; Zikmund, 1994). Administrative error results from improper administration of the research task. Data processing sourced error is associated with the accuracy of data entry and subsequent computer generated aspects of processing the data. Frequency analysis within SPSS 11.0 was run to verify all data existed within the assigned Likert scale range. Each analysis step was carefully quality checked to minimize this type of error.

Respondent error includes error introduced through non-response and error introduced when respondents tend to answer in a certain direction. Due to the high rate of response, the issue of non-response is treated as negligible. The criteria of anonymity and confidentiality were specifically included in the research design to minimize the deliberate falsification of responses by employees as a result of their attempts to portray a particular image, e.g. more team productivity, better customer satisfaction, etc.

4.7 Recommendations for large scale study

After the pilot study, the overall proposed model for this dissertation remains unchanged. However, items of some variables (e.g. customer involvement, Mutual Trust, Mutual Influence, Shared Knowledge etc.) need to be modified, dropped, and/or added. All the variables and the constructs, however, remain as proposed.

The suggestions and proposal made here is largely based upon the statistical results of pilot study, literature reviews, and comparison of the pilot study results with previously conducted large scale study result of same variables from the doctoral dissertations of (Kouteros, 2000; Hong, 2000; and Syamil, 2001). Essentially, because of the limited sample size of the pilot study, the data analysis was limited to issues surrounding reliability and validity only. Nevertheless, the pilot study result provided some useful insights on the behavior of some of the items of the research model that should be investigated closely during both the exploratory analysis and the confirmatory analysis of the large-scale study. In doing so, special attention was focused on the variables that had one or more of the following characteristics – poor factor loading, presence of high cross loadings with other factors, and low reliability. The conclusion of the items after the pilot study of the proposed model for new product development is presented in Table 4.28.

During the factor analysis of all the items of team vision, mutual trust and mutual influence, TM1, and SF3 reported to have the cross loading with mutual influence. Similarly, PTT2 had factor loading on items belonging to TM and SF. MI1 and MI7 cross-loaded with items belonging to MT.

Although no clear factors were noted for shared knowledge construct, ST2 and ST6 in particular reported to have low CITC and factor loading. A close observation of ST2 revealed resemblance in meaning with item ST1. IT1 was reworded from "engineering development" capabilities to its original form as used in Hong 2000, study to "engineering design" capabilities. Following the theory provided at http://www.npd-solutions.com/pdforum.html and PMBOK (2002), TP1, TP2, and TP3 were added to the instruments for the shared knowledge of process.

Table 4.28 Summary of all items in pilot study

Items	Remarks
HM3	low CITC
SR5	low CITC
CI2	low CITC
CI4	low CITC
CI2, CI4, CI6	Added new items
HM3	Added new item
CW2	low CITC
TM1	Cross loading with MI
SF3	Cross loading with MI
PTT2	Cross loading with SF and TM items
MI1	Cross loading with MT items
MI7	Cross loading with MT items
ST2	Low CITC, Similar to ST1
ST6	Low factor loading
IT2	Low CITC, reworded to previously used item from Hong(2000) study
TP1, TP2, TP3	Added
ALL EC	Loaded in single factor with all items of TW and TPO
ALL TW	Loaded in single factor with all items of EC and TPO
ALL TPO	Loaded in single factor with all items of TW and EC
PC1	Low CITC, Cross loading with CS
PC4	Low factor loading
ALL MC	Loaded with all items of PC
PTO1	Cross loading with items of CS
PTO5	Cross loading with items of CS
CS4	Low factor loading, Cross loading with items of PTOs

Because of complications associated with third order factor analysis in Structural equation modeling for Confirmatory factor analysis, process outcomes and product outcomes were proposed to be consolidated in single factor for New Product Performance Outcomes (NPPO). PC1 was reported to have low CITC and had cross loading with CS. Similarly PC4 had a low factor loading during the factor analysis. Moreover, all the items for product cost reduction (PC) and manufacturing cost reduction (MC) loaded on a single factor. From a theoretical significance perspective, it was decided to assess in the large-scale study if PC and MC could be treated as a single factor as Product Cost Reduction (PC) instead of two separate factors. PTO1 and PTO5 had cross loading with CS items. And CS4 had low factor loading along with cross loading with items of PTO.

The problems associated with above items were expected generally to be because of low sample size and it was thus decided not to drop any items from the large scale. Since the field of knowledge management in the context of new product development is new, the entire research was to be considered exploratory in nature. Thus it was recommended to conduct exploratory data analysis followed by the confirmatory approach of SEM in the large-scale study for this research. The final list of all the items recommended for the large-scale study for knowledge integration in new product development is presented in Table 4.29.

Table 4.29: Recommended Measures for Large Scale Study

Constructs	Variables (Factors)	Items	Description
Heavyweight Manager (HM)			
		HM1	Product Development managers were given "real" authority over personnel
		HM2	Product development managers had enough influence to make things happen
		HM3	Product requirements are solicited, consolidated, and fed back to potential customers
		HM4	Product development managers had a final say in budget decisions
		HM5	Product development managers had a final say in product design decisions
		HM6	Product Development managers have broad influence across the organization
Supplier Involvement (SR)			
		SR1	Our suppliers did the product engineering of component parts for us
		SR2	Our suppliers developed component parts for us
		SR3	Our suppliers developed whole assemblies for us
		SR4	Our suppliers were involved in the early stages of product development
		SR6	We made use of suppliers' expertise in the development of our projects
Customer Involvement (CI)			
		CI1	We involved customers in the early stages of product development
		CI2	Our suppliers developed component parts for us
		CI3	Our suppliers developed whole assemblies for us
		CI4	Product performance is verified by testing of prototypes by customers
		CI5	Our product development team met with customers
		CI6	Product improvements / redesigns occur because improvement ideas from customers are solicited
Concurrent Engineering (CW)			
		CW4	Product development team members represented a variety of disciplines
		CW5	Various disciplines were involved in product development from the early stages
		CW6	Process engineers were involved from the early stages of product development
		CW7	Manufacturing engineers were involved from the early stages of product development
		CW8	The team consisted of cross functional members of the organization
		CW9	The team simultaneously planned the product, process, and manufacturing activities of the project
		CW10	The entire project team was involved since the early stages of the project
		CW11	All necessary functions of the organization were represented in the project team
Team Vision (TV)			
	Mission (TM)	TM1	The project purpose was well understood by the entire team
		TM2	The project mission was well communicated to all team members
		TM3	The project mission was well defined for all team members
		TM4	The product development team has a well defined mission
		TM5	The project mission was well understood by the entire team
	Strategic Fit (SF)	SF1	Our firm's overall technology strategy guided a setting of the project targets
		SF2	The project target were consistent with our overall business strategy
		SF3	Project targets reflected the competitive situation

	SF4	Our firms overall product strategy guided a setting of project targets
Project Targets (PTT)	PTT1	The project targets clearly specified tradeoffs between performance and cost
	PTT2	The relative priority of each project target was clear
	PTT3	The project targets clearly specified tradeoffs between time and cost
	PTT4	Project targets clearly specified tradeoffs between quality and cost
Mutual Trust (MT)		
	TR1	There was mutual trust among team members
	TR2	The team members trusted each other enough to share all relevant information
	TR3	The team members were willing to share sensitive information
	TR4	Team members trusted each other
	TR5	The team members shared the belief that all members were acting in good faith
	TR6	The team shared a belief that all members were honest
	TR7	The team members were confident they could trust each other
	TR8	Team members relied on each other for the truthfulness of the information shared
	TR9	The team members trusted each other to share accurate information
	TR11	Team members trusted each other enough to share sensitive information
Mutual Influence (MI)		
	MI1	Mutual influence was broadly spread among the team
	MI2	Everyone on the team had some power to influence others
	MI3	Power was broadly shared among team members
	MI4	Each team member had some ability to affect the decisions of others
	MI5	Each team member had at least some control over the decisions of the team
	MI6	Each team member had some power to affect team decisions
	MI7	Influence was shared among team members
	MI8	All team members had at least some ability to persuade each other
	MI9	All team members had some authority to influence team decisions
Shared Knowledge of (SK)		
Customer (CT)	CT1	customer requirements
	CT2	what our customers wanted
	CT3	which features were most valued by target customers
	CT4	current customer needs
Internal Capabilities (IT)	IT1	the capabilities of the process technologies we used
	IT2	the strengths of our engineering design capabilities
	IT3	the strength of our engineering staff
	IT4	the strengths of our manufacturing facilities
Suppliers (ST)	ST1	our suppliers' process capabilities
	ST2	our suppliers design capabilities
	ST3	our suppliers' manufacturing facilities
	ST4	our suppliers' capabilities to meet cost requirements
	ST5	our suppliers' capabilities to meet time requirements
	ST6	our suppliers' capabilities to meet quality requirements
Process (TP)	TP4	the process of product development
	TP5	the activities in the product development process that were on the critical path
	TP6	how our firm should develop

		products
	TP7	each other's roles in the product development process
	TP8	key decision points in the product development process
	TP1	the steps in the product development process
	TP2	The points in the product development process where information needed to be exchanged
	TP3	where key deliverables in the product development process were essential to subsequent activities
NPD Perf Outcomes (NPPO)		
Engineering Change Time (EC)	EC2	finished engineering change orders on time
	EC3	delivered engineering change notices on time
	EC4	met engineering change deadline regularly
Team Performance (PERF)	TW2	communicated effectively
	TW4	resolved design conflicts on time
	TW5	coordinated design activities effectively
	TPO1	was productive
	TPO2	completed work quickly
	TPO3	worked on product improvements successfully
Product Cost (PC)	PC1	simplified the design successfully
	PC2	reduced product costs successfully
	PC3	reduced material costs successfully
	PC4	reduced the number of parts successfully
	MC1	successfully reduced assembly cost
	MC2	reduced equipment cost successfully
	MC3	reduced manufacturing cost successfully
	MC4	reduced production tooling costs successfully
	MC5	reduced the number of manufacturing steps effectively
Product Development Time (PTO)	PTO1	launched product to the market faster
	PTO2	enabled our company to start volume production faster
	PTO3	brought product to the market before our competitors
	PTO4	developed product from concept to commercial production faster
	PTO5	made better progress in reducing total product development time
Customer Satisfaction (CS)	CS1	satisfied customers better
	CS2	fit target customers better
	CS3	has more loyal customers
	CS4	generated more new customers
	CS5	was more highly valued by customers
	CS6	was more successful in the marketplace

4.8 Conclusion

From this point the research moved into the large scale study which is described in Chapter Five. The pilot study was of benefit to screen potential items and make recommendations to enhance the reliability and validity of the constructs. Although some items have been removed and likewise some have been added based on theory, the overall model proposed has remained unchanged.

Chapter Five

Large Scale Study

The pilot study as discussed in Chapter Four provided substantial support to conduct the large-scale study for the hypothesized model of work integration and knowledge integration in new product development. The objective of this study is to empirically test the propositions through large-scale data collection from a wider community of product development professionals. For the large scale study, instruments proposed at the end of the pilot study were used. In this section, the large scale study, exploratory data analysis and confirmatory factor analysis were conducted first. Second order constructs, which are the building blocks of the proposed model, were tested next. Finally, the entire model was tested using structural equation modeling (SEM) methodology for all the proposed hypotheses.

5.1 Large Scale Survey Method

The questionnaire for the large scale study for integrated product development was based on the items recommended from the pilot study. A total of 107 items were utilized to test the proposed model of this research. The Society of Automotive Engineers (SAE) provided the mailing list of active product development professionals. SAE mailing lists have been used in past doctoral researches in the product development, and have been found to have a good response rate (i.e. Hong, 2000; Syamil, 2000). However, the response rate in the research stream of business has declined over the years. In order to improve the response rate, it was decided to use both the mail-in survey and internet survey as the methods of collecting the data. By nature, product development managers are usually not located in their home offices for the majority of their time, so it was thought best to offer them access to the instrument by both a hard copy questionnaire and the internet.

A structured, self-administered survey questionnaire with self-addressed envelopes was mailed to a total of randomly selected 3000, product development professionals provided by the SAE. The respondents were given option to respond either using the mail-in survey, or using the on-line Internet survey. Respondents also had the option to request the report of the research findings. These efforts were added to increase the instrument's rate of response.

A total of 132 responses were received in the first three weeks after the dispatch of the first round of questionnaire. Out of 132, 20 responses had multiple items missing and thus were excluded from the study. Another 73 responses were received following a second round of questionnaire mailed along with email and telephone call requests made to participate in the study. Out of 73, only 58 responses were considered complete and suitable to be included in the large-scale study. Thus out of 205 total responses received, 170 responses were used for the large scale data analysis making the response rate for this study to be 5.6 %. This low response rate is to be considered in the context of continuous decrease in survey responses (Kathuria, 2000). The detail of the responses received is presented in Table 5.1 and considered in the following data analysis.

Table 5.1: Response Methods

	Mail	Internet	Total
Early	80	32	112
Late	23	35	58
Total	**103**	**67**	**170**

A chi-square test for mail versus internet survey and early versus late respondents was performed using company size (number of full time employees). Result of chi-square tests is presented in Table 5.2.

Table 5.2 Respondent Bias: Mail vs. Internet

Size of Company	**Mail**	**Internet (Observed)**	**Early**	**Late**
1-499	31	17	35	7
500-599	6	8	9	4
1000-4999	25	16	27	11
5000-9999	15	6	13	7
over 10,000	26	18	35	10
Total	103	65	119	39
Calculated Chi Square: **6.45**			Chi Square	**5.30**
df: 4			df: 4	
Chi Square critical (alpha .05): 9.48			Critical:	9.41

Since the calculated chi-square was less than the critical chi-square at alpha .05, there was no significance difference between either mail versus internet respondents or early versus late respondents based upon the company size.

Similarly, at alpha = .05, as presented in Table 5.3 a chi-square was used to test on industry position. Calculated chi-square for early versus late respondents was 5.31, which was less than the critical chi-square, 7.81 and calculated chi-square of 6.31 was less then critical chi-square of 7.81. This signifies no difference between the early / late or mail / internet respondents based upon company position in the industry.

Table 5.3 Respondent Bias: Early vs. Late

Company Position	Early	Late (Observed)	Mail	Internet
First Tier	85	32	71	46
Second Tier	20	3	18	6
Third Tier	2	2	1	2
Other	5	1	3	3
Total	112	38	93	57
Calculated Chi Square:		**5.32**	Chi Square	**6.31**
df: 3			df: 3	
Chi Square critical (alpha 05):		7.81		7.81

Sample demographics of the surveyed sample are presented in Table 5.4. Information in the table is presented on number of employess, focal product manufactured, company status, supplier ownership, and supplier level.

Table 5.4 Sample Demographics

Demographics	Percentage	Total
Number of employees		
up to 499	28%	
500-999	8%	
1,000-4,999	24%	
5,000-9999	12%	
over 10,000	27%	
		100%
Focal Product Manufactured		
Body Exterior	4%	
Body Interior	14%	
Powertrain	25%	
Body Component	9%	
Chassis	27%	
Electrical / Electronic Component	9%	
Other	14%	
		100%
Company Status		
OEM	24%	
Supplier	67%	
Other	9%	
		100%
Supplier Ownership		
Owned by OEM	10%	
Independent	90%	
		100%
Supplier Level		
First tier	78%	
Second tier	15%	
Third tier	3%	
Other	4%	
		100%

5.2 Research Methods

From the exploratory data analysis for the proposed model, results from the 170 responses were analyzed with several objectives in mind: purification, reliability, and simplicity of factor structure and discriminant validity. Next, confirmatory factor analysis or the measurement model for the first order variable was conducted using SEM methodology with AMOS 5.0. SEM is a statistical methodology that takes a confirmatory (i.e. hypothesis-testing) approach to the analysis of a structural theory bearing on some phenomenon (Byrne, 2001). Second order factor analysis was also conducted for team vision, shared knowledge, and new product performance outcomes. Finally, the structural model was tested for all the proposed hypotheses. The structural model test would either validate or fail to validate the hypotheses proposed for this study.

Item purification was performed using corrected-item-total-correlation (CITC) analysis with SPSS 12.0. Items were eliminated if their CITC was less than 0.60 unless the items were thought to hold a high value of theoretical significance. The reliability of all the scales was examined using Cronbach's alpha. In general, reliabilities above 0.80 would indicate that the scale performs well (Nunnally, 1978).

All instruments were then factor analyzed. Exploratory factor analysis is designed for the situation where links between the observed and latent variables (factors) are unknown or uncertain. DeVellis (1991) provides three reason for using factor analysis: 1) to determine how many latent variables underlie a set of items (or other variables); 2) to provide a means of explaining variation among relatively many original variables using relatively few newly created variables (i.e. factors); and 3) to define the substantive content or meaning of the factors (i.e. latent variables) that account for the variation among a larger set of items. This is accomplished by identifying groups of items that covary with one another and appear to define meanings that underlie latent variables. If anticipated item groupings are identified prior to factoring, a factor analytic solution that is consistent with these groupings provides some evidence of factorial validity (Comrey, 1988). The numbers of factors to extract in this research were based on Kaiser's Eigen values greater than 1.0 (Nunnally, 1978).

To achieve a stable factor structure, it is suggested that the ratio of the respondents to items should be at least between 5 to 10 (Tinsley and Tinsley, 1987). Items with factor loading below 0.60, as in the pilot study, and/or cross loading of 0.30 or above were to be deleted. Exploratory factor analysis was then conducted because a few new items had been created after the pilot study for the large scale instrument. This was performed using SPSS 12.0.

Discriminant validity, using AMOS methodology, was assessed for those variables (i.e. factors) or constructs that seemed to be similar. Using AMOS methodology, models were constructed 1) with the correlation between the latent variables fixed at 1.0, and 2) with the correlation between the latent variable free to assume any other value. The difference in chi-square values for the fixed and free solutions would indicate whether a uni-dimensional model would be sufficient or not (Koufteros, 1995).

First order and second order measurement models of knowledge integration were to be tested using the confirmatory factor analysis (CFA) methodology of AMOS (Byrne, 2001). In contrast to exploratory factor analysis, CFA is appropriately used when the researcher has some knowledge of the underlying latent variable structures. Because the CFA model focuses solely on the link between factors and their measured variables, within the framework of SEM, it represents what has been termed measurement model.

In contrast to the measurement model, the full latent variable model allows for the specification of regression structure among the latent variables. The researcher can hypothesize the impact of one latent construct on another in the modeling of casual directions and thus the model is termed complete because it comprises both a measurement model and a structural model where the structure model depicts the links among the latent variables (Byrne, 2001).

Structural relations of the hypothesized knowledge integration model were tested using SEM methodology for which AMOS 5.0 was used. As mentioned before, SEM is a statistical methodology that takes a confirmatory (i.e. hypothesis-testing) approach to the analysis of a structural theory bearing on some phenomenon (Byrne, 2001). The structural relation was tested for both the hypothesized model and for any alternate models generated.

The aim in SEM, is to specify a model such that it meets the criterion of overidentification. AMOS methodology automatically assigns a single arrow when drawing the path diagram which is related to the issue of model identification (Byrne, 2001). Linked to the issue of identification is the requirement that every latent variable has its scale determined. This requirement arises because these variables are unobserved and therefore have no definite metric scale, which is accomplished in AMOS where an unmeasured latent variable is mapped onto its related observed indicator variable. This scaling requisite is satisfied by constraining to some non-zero value (typically 1.0). As discussed earlier in Chapter Three and Four, the option of generating alternate model was left open should one or more hypotheses be rejected.

5.3 Results of exploratory data analysis (Item purification, reliability, and construct validity)

In this section, the data was analyzed for each variable for item purification (CITC), reliability (Cronbach's alpha) and simple factor structure (exploratory factor analysis) using SPSS 12.0 as discussed earlier in Chapter Four.

5.3.1 Heavyweight team manager (HM)

The assessment of this construct had six items (HM1-HM6). The analysis begins with Cronbach's alpha, CITC, and factor loading. HM3 was dropped because of a low CITC value (<.60) which resulted in five remaining items. The cronbach alpha reported for HW is .843 with all CITC values above .60. All items loaded on a single factor and had a high factor loading; above .70. The eigen value was reported to be 3.101, and percent of variance is 62.017%

Table 5.5 Heavyweight – reliability, item purification, and factor validity

Heavyweight Manager			
Items	CITC	Alpha if Items Deleted	Factor Loading
HM1	0.71	0.795	0.834
HM2	0.695	0.803	0.82
HM4	0.607	0.823	0.747
HM5	0.623	0.819	0.761
HM6	0.632	0.816	0.772
Cronbach's Alpha: .843			
Extracted Method: Principal Component Analysis			
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .854			

5.3.2 Supplier Involvement

The result of reliability, item purification, and factor analysis is presented in table 5.6 for supplier involvement. Five items went into the analysis, one item (SI4) was dropped due to a low CITC value (<.60), which resulted in four remaining items. The Cronbach alpha reported for supplier involvement is .858 with all CITC values above .60. All items loaded on one factor and had a high factor loading > .70. Eigen values was reported to be 2.812, and percentage of variance exlpanied is be 70.294%.

Table 5.6 Supplier Involvement – reliability, item purification, and factor validity

Supplier Involvement			
Items	CITC	Alpha if Items Deleted	Factor Loading
SI1	0.708	0.817	0.842
SI2	0.797	0.778	0.899
SI3	0.674	0.833	0.817
SI6	0.638	0.845	0.792
Cronbach's Alpha: .858			
Extracted Method: Principal Component Analysis			
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .805			

5.3.3 Customer Involvement

Next customer involvement was analyzed for reliability, item purification, and factor analysis in table 5.7. Item CI4 was removed due to a poor CITC (< .60), which resulted in five items. The resulting Cronbach alpha for the remaining four items is .821. All items had a factor loading above .80. The Eigen value for customer involvement is 2.947 and percentage of variance explained is 58.95%.

Table 5.7 Customer involvement – reliability, item purification, and factor validity

Customer Involvement			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
CI1	0.615	0.703	0.832
CI2	0.621	0.695	0.836
CI3	0.616	0.705	0.832
Cronbach's Alpha: .779			
Extracted Method: Principal Component Analysis			
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .839			

Factor analysis was performed below for all work integration variables in table 5.8. All variables loaded separately on their respected factors with no cross loadings reported.

Table 5.8 Factor analysis for Heavyweight Manager, Customer Involvement, and Supplier Involvement

Factor Analysis for all Determinates of Concurrent Engineering Final Result Pattern Matrix

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.792			
Items	**Factor 1**	**Factor 2**	**Factor 3**
CI1			0.841
CI2			0.808
CI3			0.847
HM1	0.785		
HM2	0.873		
HM4	0.708		
HM5	0.829		
HM6	0.732		
SR1		-0.836	
SR2		-0.931	
SR3		-0.797	
SR6		-0.767	
Eigen Value	4.209	2.054	1.809
% of Variance	35.07	17.12	15.07
Cumulative % of variance	35.07	52.19	67.28

5.3.4 Concurrent Engineering (CW)

Concurrent engineering was analyzed for reliability, item purification, and factor analysis in table 5.9. Item CW4, CW7, and CW11 were dropped due to a low CITC value. Also item CW8 had a poor factor loading, which resulted in four remaining items. Two items (CW5 and CW 10) displayed lower CITC values but were retained because of their theoretical significance they were retained. The resulting Cronbach alpha for the remaining four items is .787. All items had a factor loading above .73. The Eigen value for concurrent engineering is 2.449 and percentage of variance explained is 61.24%.

Table 5.9 Concurrent Engineering – reliability, item purification, and factor validity

Concurrent Engineering			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
CW5	0.537	0.765	0.731
CW6	0.647	0.707	0.819
CW9	0.635	0.714	0.809
CW10	0.575	0.746	0.768

Cronbach's Alpha: .787

Extracted Method: Principal Component Analysis

Kaiser-Meyer-Olkin Measure of Sample Adequacy: .748

5.3.5 Team Vision (TV)

Team vision was conceptualized with three variables: mission (TM), strategic fit (SF), and project targets (PTT). First, Cronbach's alpha and CITC were computed for each item for each of the three variables for team vision. The result of this test is presented in Table 5.10.

Table 5.10 Reliability, Item Purification, and Factor Validity

Mission			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
TM2	0.762	0.926	0.844
TM1	0.818	0.914	0.889
TM5	0.825	0.912	0.891
TM4	0.828	0.911	0.892
TM3	0.855	0.906	0.913
Cronbach's Alpha: .93 **Extracted Method: Principal Component Analysis** **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .89**			
Strategic Fit			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
SF3	0.348	0.834	0.532
SF2	0.616	0.719	0.8
SF4	0.706	0.667	0.869
SF1	0.714	0.661	0.874
Cronbach's Alpha: .784 **Extracted Method: Principal Component Analysis** **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .723**			
Project Targets			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
PTT2	0.452	0.861	0.632
PTT4	0.703	0.76	0.849
PTT3	0.73	0.746	0.867
PTT1	0.745	0.738	0.876
Cronbach's Alpha: .828 **Extracted Method: Principal Component Analysis** **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .79**			

The reliability of TM, SF, and PTT was reported to be .93, .784 and .828 respectively. CITC for all the items were good except for SF3, PTT2 and SF2. CITC for SF3, PTT2, and SF2 were reported to be .348, .452, and .616. If SF3 was to be dropped, the Cronbach's alpha for remaining items were reported to be .827 with CITC for SF1, SF2, and SF4 to be .888, .802, and .895. Similarly, if PTT2 was to be dropped, the new Cronbach's alpha was reported to be .861 with CITC for PTT1, PTT3, and PTT4 to be .89, .885, and .879 respectively.

An exploratory factor analysis was then conducted separately for all the three variables using principal components as the means of extraction and oblimin as the method of rotation. Factor loading for each item in each variable was reported to be high except for SF3 (.532) and PTT2 (.632).

Next, all the 13 items of team vision were subjected to the factor analysis without specifying the numbers of factors. The ratio of respondents (170) to items (13) was 13.0 and met the general guidelines. The final results of the factor analysis are presented in Table 5.11.

Table 5.11 Factor Analysis for Team Vision

Final Result Pattern Matrix			
Items	**Factor 1**	**Factor 2**	**Factor 3**
TM2	0.792		
TM4	0.844		
TM3	0.891		
TM1	0.912		
TM5	0.929		
SF3			0.703
SF1			0.876
SF4			0.933
PTT3		0.845	
PTT1		0.88	
PTT4		0.898	
Eigen Value	5.321	1.912	1.367
% of Variance	48.375	17.383	12.426
Cumulative %	48.375	65.758	78.184
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .858 **Extraction Method: Principal Component Analysis** **Rotation Method: Oblimin with Kaiser Normalization**			

Eigen values for the three factors were reported to be 5.321, 1.921, and 1.367. The cumulative variance explained by the three factors was 78%. All items, in the final analysis loaded in their respective factors with dropping of SF2 and PTT2, which also had problems associated with their respective CITCs. Factor loading for each item was greater than 0.60, which was desirable.

Overall, based upon the reliability, item purification, and factor analysis, two items (SF2 and PTT2) were deleted at this stage with reliabilities and the factor loading of the remaining items were high.

5.3.6 Mutual Trust (MT)

The assessment of this construct with 10 items (TR1-9, and TR 11) begins with analysis of Cronbach's alpha, CITC, and factor loading. The result is presented in Table 5.12.

The Cronbach's alpha for MT was reported to be .958 with high CITC for each of the items. Similarly, all the items had high factor loading; above 0.60. The eigen value was reported to be 7.292 and percentage of variance explained is 72.9%.

Table 5.12 Reliability, Item Purification, and Factor Validity

Mutual Trust			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
TR8	0.678	0.959	0.731
TR5	0.766	0.956	0.809
TR11	0.796	0.955	0.835
TR9	0.807	0.954	0.846
TR1	0.81	0.954	0.848
TR6	0.837	0.953	0.871
TR3	0.844	0.953	0.876
TR2	0.851	0.953	0.882
TR7	0.861	0.952	0.891
TR4	0.914	0.95	0.934
Cronbach's Alpha: .958			
Extracted Method: Principal Component Analysis			
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .948			

At this stage, all the items for MT were retained.

5.3.7 Mutual Influence (MI)

The result of reliability, item purification, and factor analysis is presented in Table 5.13.

Table 5.13 Reliability, Item Purification, and Factor Validity

Mutual Influence			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
MI2	0.663	0.934	0.727
MI5	0.717	0.93	0.783
MI1	0.734	0.93	0.789
MI7	0.775	0.927	0.826
MI3	0.777	0.927	0.829
MI4	0.787	0.926	0.839
MI9	0.789	0.926	0.842
MI6	0.796	0.926	0.845
MI8	0.802	0.926	0.853
Cronbach's Alpha: .936			
Extracted Method: Principal Component Analysis			
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .931			

Eigen value for MI was reported to be 5.988 and percent of variance explained is 66.53 %. Because of high CITC, high Cronbach's alpha, and high factor loading, all the items of MI were retained.

In order to investigate the factor validity, all the items for MT and MI were subjected to the factor analysis without specifying the number of factors. During the factor analysis, the pattern matrix resulted with MI1 having cross loading of .35 with factor 1 representing items for MT. Moreover, MI1 had a factor loading of .579 in factor 2 representing MI. The final result of the factor analysis, after deleting MI1, is presented in Table 5.14.

Table 5.14 Factor Analysis for Mutual Trust and Mutual Influence

Final Result Pattern Matrix		
Items	Factor 1	Factor 2
MI2		0.587
MI3		0.654
MI7		0.737
MI5		0.85
MI8		0.853
MI6		0.881
MI4		0.883
MI9		0.921
TR8	0.726	
TR9	0.786	
TR1	0.803	
TR5	0.821	
TR11	0.826	
TR3	0.869	
TR2	0.879	
TR6	0.893	
TR7	0.915	
TR4	0.956	
Eigen Value	10.486	2.973
% of Variance	54.948	16.304
Cumulative %	54.948	71.252
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .944		
Extraction Method: Principal Component Analysis Rotation Method: Oblimin with Kaiser Normalization		

5.3.8 Shared Knowledge (SK)

Shared Knowledge was conceptualized to consist of four variables; shared knowledge of customer (CT), shared knowledge of internal capabilities (IT), shared knowledge of suppliers (ST), and shared knowledge of process (TP). The result of corresponding reliability, item purification, and independent factor analysis is presented in Table 5.15.

For CT, Cronbach's alpha was reported to be .827 with CITC value for CT3 to be .459. If CT3 was to be dropped, the new Cronbach's alpha was reported to be .876, which is a considerable improvement. In addition, CT3 was reported to have the lowest factor loading of .634. Based on these results, CT3 was removed from the CT factor.

For IT, Cronbach's alpha was reported to be .71. All the items had low CITC, with IT4 being the lowest at .414. The factor loading of IT4 was also the lowest compared to all the other three items for IT at .639. Thus, IT4 was removed from the IT factor.

Table 5.15 Reliability, Item Purification, and Factor Validity

Shared Knowledge of Customer			
Items	CITC	Alpha if Items Deleted	Factor Loading
CT3	0.459	0.876	0.634
CT1	0.688	0.769	0.852
CT2	0.746	0.738	0.884
CT4	0.758	0.734	0.891

Cronbach's Alpha: .827
Extracted Method: Principal Component Analysis

Kaiser-Meyer-Olkin Measure of Sample Adequacy: .789

Shared Knowledge of Internal Capabilities			
Items	CITC	Alpha if Items Deleted	Factor Loading
IT4	0.414	0.697	0.639
IT3	0.485	0.655	0.738
IT1	0.521	0.634	0.746
IT2	0.581	0.6	0.807

Cronbach's Alpha: .710

Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .693

Shared Knowledge of Suppliers			
Items	CITC	Alpha if Items Deleted	Factor Loading
ST2	0.628	0.928	0.724
ST3	0.731	0.915	0.811
ST4	0.793	0.906	0.865
ST5	0.837	0.9	0.896
ST6	0.841	0.9	0.897
ST1	0.844	0.9	0.901

Cronbach's Alpha: .923
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .903

Shared Knowledge of Process			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
TP6	0.537	0.892	0.648
TP1	0.593	0.887	0.684
TP7	0.595	0.886	0.689
TP4	0.682	0.879	0.753
TP3	0.691	0.879	0.754
TP2	0.693	0.879	0.774
TP5	0.679	0.88	0.776
TP8	0.707	0.877	0.793

Cronbach's Alpha: .893
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .886

Similarly, for ST, the Cronbach's alpha was reported to be .923. Based on the high CITC and factor loading, all the items are retained.

For TP, the Cronbach's alpha was reported to be .893 with TP1 reported to be the lowest CITC value of .593 and the lowest factor loading among all the items at .684.

Next, all the items for shared knowledge were subjected to factor analysis. Multiple items had cross loading, and after dropping such items, the final result of the factor analysis is presented in Table 5.16.

Table 5.16 Factor Analysis for all Variables of Shared Knowledge

Final Result

Pattern Matrix

Items	Factor 1	Factor 2	Factor 3	Factor 4
CT4			0.866	
CT2			0.885	
CT1			0.902	
IT2				0.751
IT3				0.87
ST3		-0.725		
ST6		-0.856		
ST5		-0.871		
ST1		-0.926		
ST4		-0.934		
TP1	0.628			
TP4	0.664			
TP8	0.762			
TP3	0.809			
TP2	0.882			
IT1	0.62			
Eigen Value	0.6685	2.941	1.528	1.132
% of Variance	39.321	17.299	8.991	6.658
Cumulative %	39.321	56.62	65.611	72.269

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .887
Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization

In the final analysis, IT1 (.62) still ended up loading with TP. However, because IT had only three items left, IT1 was decided to be included in CFA.

5.3.9 New Product Performance Outcomes (NPPO)

NPPO was conceptualized to have two variables, product outcomes and process outcomes with seven variables combined. However, considering problems with a third order factor and as recommended in the pilot study for the sake of simplicity of running CFA, NPPO was re-conceptualized of having seven factors: engineering change time (EC), product cost reduction (PC), manufacturing cost reduction (MC), team work (TW), team productivity (TPO), product development time (PTO), and customer satisfaction (CS). The initial results of the data analysis are presented in Table 5.17.

Table 5.17 Reliability, Item Purification, and Factor Validity

Engineering Change Time			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
EC2	0.845	0.901	0.931
EC4	0.849	0.898	0.933
EC3	0.863	0.887	0.94
Cronbach's Alpha: .928 *Extracted Method: Principal Component Analysis* **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .765**			
Team Work			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
TW2	0.598	0.804	0.811
TW4	0.651	0.753	0.849
TW5	0.74	0.66	0.897
Cronbach's Alpha: .811 **Extracted Method: Principal Component Analysis** **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .682**			
Team Productivity			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
TPO3	0.516	0.751	0.774
TPO2	0.573	0.712	0.814
TPO1	0.703	0.553	0.887
Cronbach's Alpha: .757 **Extracted Method: Principal Component Analysis** **Kaiser-Meyer-Olkin Measure of Sample Adequacy: .646**			
Product Cost			
Items	**CITC**	**Alpha if Items Deleted**	**Factor Loading**
PC4	0.6	0.794	0.772
PC1	0.621	0.784	0.789
PC3	0.665	0.764	0.825
PC2	0.687	0.753	0.839

Cronbach's Alpha: .821
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .757

Manufacturing Cost

Items	CITC	Alpha if Items Deleted	Factor Loading
MC4	0.577	0.87	0.712
MC2	0.65	0.854	0.775
MC1	0.739	0.832	0.846
MC3	0.748	0.83	0.852
MC5	0.768	0.825	0.865

Cronbach's Alpha: .871
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .817

Product Development Time

Items	CITC	Alpha if Items Deleted	Factor Loading
PTO3	0.725	0.934	0.817
PTO2	0.812	0.918	0.881
PTO1	0.843	0.912	0.904
PTO5	0.851	0.911	0.91
PTO4	0.872	0.907	0.923

Cronbach's Alpha: .932
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .85

Customer Satisfaction

Items	CITC	Alpha if Items Deleted	Factor Loading
CS4	0.655	0.893	0.752
CS1	0.677	0.888	0.785
CS2	0.721	0.882	0.819
CS3	0.735	0.88	0.821
CS6	0.757	0.876	0.834
CS5	0.829	0.865	0.892

Cronbach's Alpha: .899
Extracted Method: Principal Component Analysis
Kaiser-Meyer-Olkin Measure of Sample Adequacy: .854

All the variables had high Cronbach's alpha, above .80, except for TPO that reported to be .757. Also, all the items had high factor loading and CITC was also reported to be high for each item within each variable. MC4, however, reported to have the lowest CITC value of .57 and was removed from the MC factor.

Next, all the items for NPPO were subjected for factor analysis. The final factor analysis results from the five separate factors for NPPO resulted in Table 5.18.

Table 5.18 Factor Analysis for all Variables of New Product Performance Outcomes

Final Result

Pattern Matrix

Items	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
EC2	0.921				
EC3	0.885				
EC4	0.888				
TW2					0.491
TW4	0.818				
TW5	0.669				0.315
TPO1					0.648
TPO2	0.545			-0.373	
TPO3					0.582
PC1			-0.669		
PC4			-0.735		
MC1			-0.741		
PC3			-0.781		
MC2			-0.783		
MC5			-0.798		
MC3			-0.844		
PC2			-0.85		
PTO3				-0.739	
PTO5				-0.769	
PTO4				-0.839	
PTO1				-0.919	
PTO2				-0.926	
CS1		0.687			
CS4		0.701			
CS2		0.739			
CS6		0.798			
CS5		0.869			
CS3		0.876			
Eigen Value	11.347	3.403	2.893	1.628	1.094
% of Variance	40.523	12.153	10.333	5.814	3.909
Cumulative %	40.523	52.676	63.009	68.823	72.732

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .908
Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization

Instead of seven separate factors, only five factors were extracted. In the final analysis, PC and MC again loaded on a single factor (factor 3).The final cost of a product is a factor dependent on various cost elements, for example, material, labor, expenditures, tooling, machinery and equipment (M&E), and investment, of which manufacturing cost is only one element, which generally becomes a subject of study for design-for-manufacturing. From product development and manufacturing stand point of view, the cost of product may include upfront cost (design cost, tooling design and fabrication cost), production setup cost, and production cost (component production cost, assembly cost, quality cost etc.) (http://www.octs.com/inventhelp/mfrcost.html, 2000). However, since this study addresses a more generic cost objective from a strategic focus, product cost and manufacturing cost could be treated as a single factor for performance objectives. This is also evident from the data from both pilot study as well as the large scale.

Thus, factor 1 represented EC, factor 2 represented CS, factor 3 represented PC (PC and MC consolidated in one factor), factor 4 represented PTO.

Items for TW and TPO did not result in a simple stable factor. Based upon the items' wording and practical significance, it was decided to consolidate TPO and TW into a single factor that can be interpreted as team performance (PERF) with items TW2, TPO1, and TPO3. TW5, although loaded on factor 5, the loading was low (.315) and had a very high cross loading with factor 1 (.669). It was thus decided to exclude TW5 from factor 5.

5.3.10 Conclusion

Based upon the above exploratory results, it was decided from the subsequent data analysis to:

1. drop HM3 from the Heavyweight manager
2. drop CI4, CI6 from the Customer Involvement
3. drop SI4 from the Supplier Involvement
4. drop CW4, CW7, CW8, CW11 from the concurrent engineering
5. drop MI1 from Mutual Influence
6. drop SF2 and PTT2 from Team Vision
7. retain all the items for Mutual Trust
8. drop MI1 from Mutual Influence
9. drop CT3, IT4, ST2, TP5, TP6, TP7 from Shared Knowledge
10. drop MC4, consolidate MC and PC items in single factor PC; drop TPO3, TW4, and TW5 ; consolidate TW and TPO items in a single factor PERF for New Product Performance Outcomes.

It was recommended to delete PTT2, MI1, and ST2 during the pilot study. In addition, the pilot study had also recommended consolidating PC and MC in one single factor. For a subsequent data analysis, the final list of items to be used is presented in table 5.19.

Table 5.19: Recommended Measures for Structural Model

Constructs	Variables (Factors)	Items	Description
Heavyweight Manager (HM)			
		HM1	product development managers are given "real" authority over personnel
		HM2	product development managers had enough influence to make things happen
		HM4	product development managers have a final say in budget decisions
		HM5	product development managers have a final say in product design decisions
		HM6	product development managers have a broad influence across the organization
Supplier Involvement (SI)			
		SR1	our suppliers do the product engineering of component parts for us
		SR2	our suppliers develop component parts for us
		SR3	our suppliers develop subassemblies for us
		SR6	we make use of suppliers' expertise in the development of our products
Customer Involvement (CI)			
		CI1	we involve customers in the early stages of product development
		CI2	in developing the product concept, we listen to our customer's needs
		CI3	we visit our customers to discuss product development issues
Concurrent Engineering (CW)			
		CW5	various disciplines are involved in product development from the early stages
		CW6	process engineers are involved from the early stages of product development
		CW9	the team simultaneously planned the product, process, and manufacturing activities of the project
		CW10	the entire project team was involved since the early stages of the project
Team Vision (TV)			
	Mission (TM)	TM1	The project purpose was well understood by the entire team
		TM2	The project mission was well communicated to all team members
		TM3	The project mission was well defined for all team members
		TM4	The product development team has a well defined mission
		TM5	The project mission was well understood by the entire team
	Strategic Fit (SF)	SF1	Our firm's overall technology strategy guided a setting of the project targets
		SF3	Project targets reflected the competitive situation
		SF4	Our firms overall product strategy guided a setting of project targets
	Project Targets (PTT)	PTT1	The project targets clearly specified tradeoffs between

		performance and cost
	PTT3	The project targets clearly specified tradeoffs between time and cost
	PTT4	Project targets clearly specified tradeoffs between quality and cost
Mutual Trust (MT)		
	TR1	There was mutual trust among team members
	TR2	The team members trusted each other enough to share all relevant information
	TR3	The team members were willing to share sensitive information
	TR4	Team members trusted each other
	TR5	The team members shared the belief that all members were acting in good faith
	TR6	The team shared a belief that all members were honest
	TR7	The team members were confident they could trust each other
	TR8	Team members relied on each other for the truthfulness of the information shared
	TR9	The team members trusted each other to share accurate information
	TR11	Team members trusted each other enough to share sensitive information
Mutual Influence (MI)	MI2	Everyone on the team had some power to influence others
	MI3	Power was broadly shared among team members
	MI4	Each team member had some ability to affect the decisions of others
	MI5	Each team member had at least some control over the decisions of the team
	MI6	Each team member had some power to affect team decisions
	MI7	Influence was shared among team members
	MI8	All team members had at least some ability to persuade each other
	MI9	All team members had some authority to influence team decisions
Shared Knowledge of (SK)		
Customer (CT)	CT1	customer requirements
	CT2	what our customers wanted
	CT4	current customer needs
Internal Capabilities (IT)	IT1	the capabilities of the process technologies we used
	IT2	the strengths of our engineering design capabilities
	IT3	the strength of our engineering staff
Suppliers (ST)	ST1	our suppliers' process capabilities
	ST3	our suppliers' manufacturing facilities
	ST4	our suppliers' capabilities to meet cost requirements
	ST5	our suppliers' capabilities to meet time requirements
	ST6	our suppliers' capabilities to meet quality requirements
Process (TP)	TP4	the process of product development
	TP8	key decision points in the product development process
	TP1	the steps in the product development process

	TP2	The points in the product development process where information needed to be exchanged
	TP3	where key deliverables in the product development process were essential to subsequent activities
New Product Development Performance Outcomes (NPPO)		
Engineering Change Time (EC)	EC2	finished engineering change orders on time
	EC3	delivered engineering change notices on time
	EC4	met engineering change deadline regularly
Team Performance (PERF)	TW2	communicated effectively
	TPO1	was productive
	TPO3	completed work quickly
Product Cost (PC)	PC1	simplified the design successfully
	PC2	reduced product costs successfully
	PC3	reduced material costs successfully
	PC4	reduced the number of parts successfully
	MC1	successfully reduced assembly cost
	MC2	reduced equipment cost successfully
	MC3	reduced manufacturing cost successfully
	MC5	reduced the number of manufacturing steps effectively
Product Development Time (PTO)	PTO1	launched product to the market faster
	PTO2	enabled our company to start volume production faster
	PTO3	brought product to the market before our competitors
	PTO4	developed product from concept to commercial production faster
	PTO5	made better progress in reducing total product development time
Customer Satisfaction (CS)	CS1	satisfied customers better
	CS2	fit target customers better
	CS3	has more loyal customers
	CS4	generated more new customers
	CS5	was more highly valued by customers
	CS6	was more successful in the marketplace

5.4 Discriminant Validity

Tables 5.20 and 5.21 list all latent variables of shared knowledge and product outcomes showing correlation in triangle, chi-square test of discriminant validity between each pair of latent variables, reliability, and average variance extracted on the diagonals. Means and standard deviations are also listed for each latent variable below.

Reliability is a function of the number of items that define the scale and the respective reliabilities of those items. Coefficient alpha is perhaps the most widely used metric for gauging the reliability of scale items (Cronbach, 1951). Reliability for each variable is above the general recommendation of alpha .70 (Nunnally, 1978). In fact all but two variables (IT =.70, PERF = .77) are greater than .80 which suggests that the underlying items are sufficiently representative of their respective factors.

Discriminant validity is assessed by estimating an alternative model where the correlation between variables is constrained to unity or zero. Discriminant validity is demonstrated when a measure does not correlate very highly with another measure from which it should differ (Venkatraman, 1989). The difference in chi-square values between restricted and freely estimated models provides statistical evidence of discriminant validity (Segars, 1997). This was performed for each variable and the difference in chi-square values in reported for each set of variables in the table. For all variables the change is chi-square was significant at $p < .01$. This highly significant difference suggests that the factors are distinct and that their underlying scales exhibit the property of discriminant validity.

To fully satisfy the requirement for discriminant validty, average variance extracted (AVE) should be greater than the squared correlation between factors. Such results suggest that the items share common variance with their respective factor than any variance the items share with other factors (Fornell and Larcker, 1981). If AVE is less than .50, then the variance due to measurement error is larger than the variance captured by the respective factor. Subsequently, the validity of the individual indicators, as well as the factor, is suspect (Segars, 1997). From the table above, AVE for each factor is above the .50 requirement, the lowest AVE in the table is TP with a value of .5649. All other values are above AVE > 0.63. Additionally, the AVE for each factor is greater than the squared correlation between factors. Both of these additional tests (AVE and AVE compared to the squared correlation) indicate discriminant validity for factors of shared knowledge and performance outcomes.

Table 5.20 Cronbach's alpha, means, and standard deviations for Shared Knowledge and Performance Outcomes

	CT	IT	ST	TP	EC	PTO	PERF	PC	CS
alpha	**0.88**	**0.70**	**0.91**	**0.80**	**0.93**	**0.92**	**0.77**	**0.90**	**0.89**
mean	4.24	3.86	3.49	3.93	3.51	3.5	3.89	3.58	3.65
st dev	0.64	0.63	0.95	0.63	0.99	0.94	0.66	0.8	0.8

Table 5.21 Discriminant Validity for variables of Shared Knowledge and Performance Outcomes

	CT	IT	ST	TP	EC	PTO	PERF	PC	CS
CT									
IT	(correlation) 0.253 (AVE) .65 (chi-square difference) 85.55								
ST	0.06 0.75 210.38	0.53 0.7 44.86							
TP	0.37 0.66 180.35	0.66 0.59 8.85	0.41 0.68 182.28						
EC	0.15 0.78 391.97	0.42 0.68 63.25	0.39 0.79 342.44	0.44 0.69 174.87					
PTO	0.32 0.75 235.91	0.47 0.65 50.47	0.31 0.76 474.07	0.52 0.67 140.26	0.45 0.79 320.38				
PERF	0.28 0.68 122.9	0.51 0.59 32.87	0.45 0.7 98.96	0.58 0.62 41.61	0.61 0.72 56.07	0.45 0.69 95.39			
PC	0.11 0.69 258.76	0.49 0.62 49.05	0.36 0.7 403.58	0.39 0.64 172.13	0.44 0.71 320.17	0.53 0.69 339.1	0.52 0.64 70.04		
CS	0.28 0.7 239.14	0.35 0.63 76.67	0.33 0.7 402.76	0.34 0.65 200.69	0.25 0.73 380.19	0.55 0.71 286	0.3 0.66 122.76	0.33 0.67 395.31	

5.5 EXPLORATORY STRUCTURE ANALYSIS

To explore the relationship of the proposed variables, structural equation modeling (SEM) methodology was used. This not only allows the assessment of construct validity of the factors, but also gives an initial sensation of testing substantive hypotheses. In general, the SEM model can be decomposed into two sub models: a measurement model, and a structural model. The measurement model defines relations between the observed indicator variables and the underlying factors they are designed to measure (i.e. unobserved latent variables). The measurement model, then, represents the CFA model (Byrne, 2001). In contrast, the structural model defines the relations among the unobserved variables. Although a two-step process was followed, first the measurement model and then structural, results should be interpreted with caution since the same large-scale data was used for both the measurement model and the structural model.

However, since the nature of this study is exploratory, the remaining data analysis should still be considered exploratory even though SEM methodology has been employed.

To be congruent with the hypothesized model of work integration and knowledge integration in Chapter 3, heavyweight manager (HM), supplier involvement (SI), customer involvement (CI), mutual trust (MT), and mutual influence (MI) were treated as exogenous variables. Concurrent engineering (CW), team vision (TV), shared knowledge (SK), and new product performance outcomes (NPPO) were treated as endogenous variables. The term exogenous variables and endogenous variables within SEM terminology are synonymous with independent and dependent variables respectively. These terms are introduced here and will be used in the rest of the chapter where necessary.

5.5.1 Confirmatory Factor Analysis (CFA)

Within SEM methodology, CFA tests the validity of factors that are empirically and theoretically derived by the researchers. In order to assess CFA, factors need to be already empirically established through other methods (Byrne, 2001).

The factors proposed in the pilot and exploratory factor analysis of the large-scale data analysis were subjected to the CFA with AMOS 5.0 Graphics. During the earlier data analysis, these factors were obtained from the data analysis with SPSS. This outcome was considered exploratory factor analysis because SPSS by nature suggests the best possible factors within the criteria (fixed number of factors or factors with Eigen value of one or more) stipulated by the researcher. SEM procedure (for which AMOS 5 is used here) tests factors that are suggested by researchers, and gives output with indicators signifying their suitability as the factors.

For each measurement model (first order and second order) tested, statistical significance of parameter estimates (unstandardized regression weights and standardized regression weights) and the goodness-of-fit statistics were reported.

Within AMOS methodology, the test statistic is the critical ratio (C.R.), which represents the parameter estimate, divided by the standard error (S.E.); as such, it operates as a z-statistic in testing that the estimate is statistically different from zero. Based on a level of 0.05, the test statistic needs to be >+_ 1.96 before the hypothesis (that the estimate equals 0) can be rejected (Byrne, 2001).

There are many indices in the CFA that researchers may consider. CMIN (minimum discrepancy) represents the discrepancy between the unrestricted sample covariance matrix and the restricted covariance matrix and, in essence, represents the likelihood ratio test statistics, commonly expressed as chi-square. CMIN/df ratio takes degrees of freedom into account.

The CFI (comparative fit index) is one of the incremental fit measures in SEM. It is an adaptation and improvement of the NFI (normed fit index). NFI compares the researcher's model (default model) with the null model. The null model assumes that all the indicators considered in the default model fit perfectly to a single factor. CFI is an improvement over NFI because it takes into account the sample size. Therefore, it is useful even for the smaller sample size and also in model development. This is also considered a more robust indicator where the multivariate normality is in doubt. It is recommended that CFI be the index of choice (Byrne, 2001). Another incremental index, consistent with the NFI and CFI in reflecting of indication of good fit is the TLI (Tucker-Lewis index). The RMSEA (root mean square error of approximation) is the average of discrepancy between the estimated value and observed value of the covariance. It has been recognized as one of the most informative criteria in covariance structure modeling (Byrne, 2001). The recommended value of these fit indices is summarized in Table 5.22.

Table 5.22 Recommended Values for Model-fit

CMIN/DF	Chi-Square/df (Wheaton et al., 1977), good fit if CMIN/df < 2.00
TLI	Value range from 0 to 1, closer to 0.95 good fit (Hu and Bentler, 1992)
CFI	Value range from 0 to 1, >0.9 well-fitting model (Bentler, 1992)
RMSEA	<0.05 good fit (Browne and Cudeck, 1993), 0.05 to 0.08 reasonable (Browne and Cudeck, 1993), .08 to .1 mediocre (MacCallum et al., 1996), >.1 poor fit (MacCallum et al., 1996); 0.06 good fit (Hu and Bentler, 1999)

5.5.1.1 Heavyweight Manager (HM)

From the exploratory data analysis of the large scale study, it was concluded that HM3 be dropped from the HM factor. The output of the first order model for HM is presented in table 5.23. Each of the items loaded significantly on their respective factor. This table reports the results of estimates for both unstandardized regression weights and covariances. The first column of the table represents the relationships between the item and the respective factor. The second column represents the estimate values or the unstandardized regression weight. Next, the third and fourth columns represent the critical ratio (interpreted as z-scores), and standard error or S.E. The fifth column represents the standardized regression weight. Finally, the last column represents the significance at $p < 0.001$ level. All significant relations are represented by "***".

The result of parameter estimates of the first order measurement model for HM, is presented in table 5.23. The variable of heavyweight manager demonstrated a strong item loading. The standardized regression weights for HM1, HM2, HM4, HM5, and HM6 were .804, .779, .654, .680, and .702. The first order factor is shown below in figure 5.1.

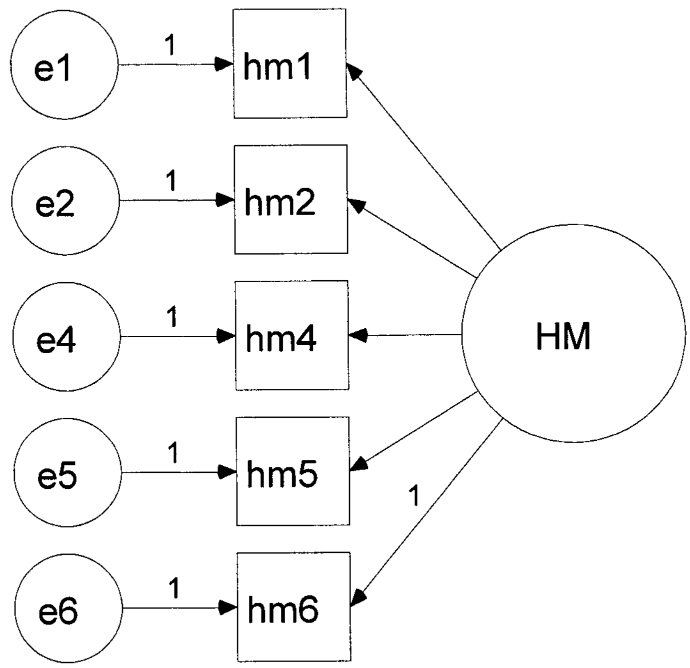


Figure 5.1 First order model of heavyweight manager

Table 5.23 Final AMOS output for first order heavyweight manager: Factor loading parameter estimates

	Estimates	S.E.	C.R.	Standardized regression weights	p
HM1 <-- HM	1			**0.804**	
HM2 <-- HM	0.735	0.073	10.1	**0.779**	***
HM4 <-- HM	0.738	0.088	8.375	**0.654**	***
HM5 <-- HM	0.779	0.089	8.752	**0.680**	***
HM6 <-- HM	0.708	0.079	9.06	**0.702**	***

As shown in Table 5.24 the goodness-for-fit values concluded the overall model-data fit for the HM.

Table 5.24 Goodness-for-Fit Model Summary for First Order Model of Heavyweight Manager

CMIN/DF	0.902
TLI	1.000
CFI	1.000
RMSEA	0.000

5.5.1.2 Supplier Involvement (SI)

From the exploratory data analysis of the large scale study, it was concluded that SI4 be dropped from the SI factor. The result of parameter estimates of the first order measurement model for HM, is presented in table 5.25. The first order measurement model demonstrated a strong item loading of the indictors on SI. The standardized regression weights for SI1, SI2, SI3, and SI6 were .767, .900, .734, .710.

Table 5.25 Final AMOS output for first order supplier involvement: Factor loading parameter estimates

	Estimates	S.E.	C.R.	Standardized regression weights	p
SI1 <-- SI	1.136	0.123	9.214	**0.767**	***
SI2 <-- SI	1.4	0.137	10.203	**0.9**	***
SI3 <-- SI	1.175	0.133	8.837	**0.734**	***
SI6 <-- SI	1	0.089	8.752	**0.71**	

As shown in Table 5.26, the goodness-for-fit values concluded the overall model-data fit for the SI.

Table 5.26 Goodness-for-Fit Model Summary for First Order Model of Supplier Involvement

CMIN/DF	1.441
TLI	.991
CFI	.997
RMSEA	0.051

5.5.1.3 Customer Involvement (CI)

Items CI1, CI2, and CI3 were recommended to be retained after the large scale study for the Customer Involvement factor. The result of parameter estimates of the first order measurement model for CI, is presented in table 5.27. The model demonstrated a strong item loading of the indictors on CI. The standardized regression weights for CI1, CI2, CI3 were .733, .743, and.733.

Table 5.27 Final AMOS output for first order customer involvement: Factor loading parameter estimates

	Estimates	S.E.	C.R.	Standardized regression weights	p
CI1 <-- CI	0.878	0.119	7.359	**0.733**	***
CI2 <-- CI	0.925	0.126	7.336	**0.743**	***
CI3 <-- CI	1		8.752	**0.733**	

As shown in Table 5.28, the goodness-for-fit values concluded the overall model-data fit for the CI. Only three items were studied in the CI factor, Cmin/DF is not available thus, TLI, CFI, and RMSEA is reported.

Table 5.28 Goodness-for-Fit Model Summary for First Order Model of Customer Involvement

TLI	1.00
CFI	1.00
RMSEA	0.00

5.5.1.4 Concurrent Engineering (CW)

Items CW5, CW6, CW9, and CW10 were recommended to be retained after the large scale study for the Concurrent Engineering factor. The result of parameter estimates of the first order measurement model for CW, is presented in table 5.29. The first order model demonstrated a moderate item loading of the indictors on CW. The standardized regression weights for CW5, CW6, CW9, and CW10 were .581, .788, .771, and .629.

Table 5.97 Final AMOS output for first order concurrent engineering: Factor loading parameter estimates

	Estimates	S.E.	C.R.	Standardized regression weights	p
CW5 <-- CW	0.597	0.089	6.741	**0.581**	***
CW6 <-- CW	1.044	0.124	8.386	**0.788**	***
CW9 <-- CW	1			**0.771**	
CW10 <-- CW	0.83	0.114	7.271	**0.629**	***

As shown in Table 5.30, the goodness-for-fit values concluded the overall model-data fit for concurrent engineering. The CFI index shows the first order model has good fit (.959); however, other indices such as RMSEA and CMIN/DF suggest the first order model for concurrent engineering has unsatisfactory model fit. This will be discussed in the measurement recommendations section in Chapter Six.

Table 5.30 Goodness-for-Fit Model Summary for First Order Model of Concurrent engineering

CMIN/DF	4.993
TLI	0.877
CFI	0.959
RMSEA	0.154

5.5.1.5 Team Vision (TV)

Team Vision was conceptualized to consist of mission (TM), strategic fit (SF) and project targets (PTT) factors and is the exogenous variable in the hypothesized knowledge integration model. After the pilot study, and the large-scale exploratory study, TM was recommended to have 5 indicators, whereas SF and PTT had three indicators each.

A first order CFA was conducted on the five indicators of TM. Standardized regression weights for all the five indicators for TM were reported be above.78, and were significant at 0.01. CFI for the model was reported to be .987. Overall, the CFA result for the first order model for TM with all the retained 5 indicators was either very good, or above satisfactory level and hence it was decided to retain all the five indicators.

Next, a first order measurement model was tested for all the items for TM, SF, and PTT with the CFA procedure suggested by Byrne (2001). The first-order model for TV is shown in Figure 5.2.

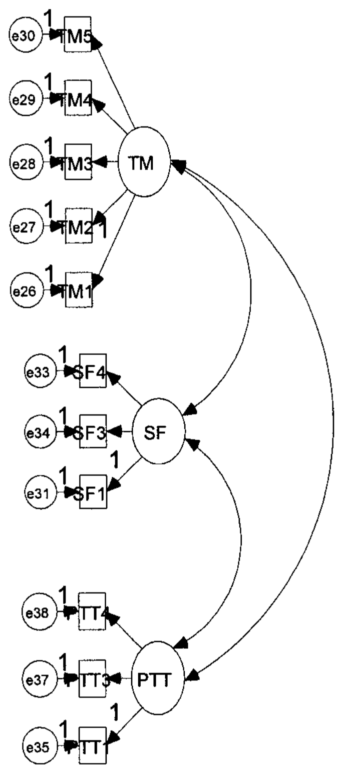


Figure 5.2: First order measurement model of TV

Table 5.31 Final AMOS Output for First Order Model Team Vision (TV): Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weights	p
TM1 <-- TM	1			**0.864**	
TM2 <-- TM	1.085	0.084	12.841	**0.791**	***
TM3 <-- TM	1.142	0.07	16.274	**0.903**	***
TM4 <-- TM	1.131	0.075	15.043	**0.866**	***
TM5 <-- TM	1.009	0.069	14.543	**0.85**	***
SF1 <-- SF	1			**0.891**	
SF3 <-- SF	0.327	0.07	4.657	**0.381**	***
SF4 <-- SF	0.868	0.099	80774	**0.814**	***
PTT1 <--PTT	1			**0.833**	
PTT3 <--PTT	1.012	0.089	11.321	**0.831**	***
PTT4 <--PTT	0.916	0.084	10.493	**0.797**	***
Covariances					
TM <--> SF	0.247	0.054	4.546		***
TM <--> PTT	0.214	0.051	4.191		***
SF <--> PTT	0.365	0.079	4.624		***

The goodness-for-fit value for the first order model, as presented in Table 5.32, demonstrated the overall fit for the model as acceptable.

Table 5.32 Goodness-for-Fit Model Summary for First Order Model of Team Vision

CMIN/DF	1.742
TLI	0.964
CFI	0.973
RMSEA	0.066

TV was conceptualized to consist of TM, SF and PTT. Figure 5.3 represents the second order measurement model for TV.

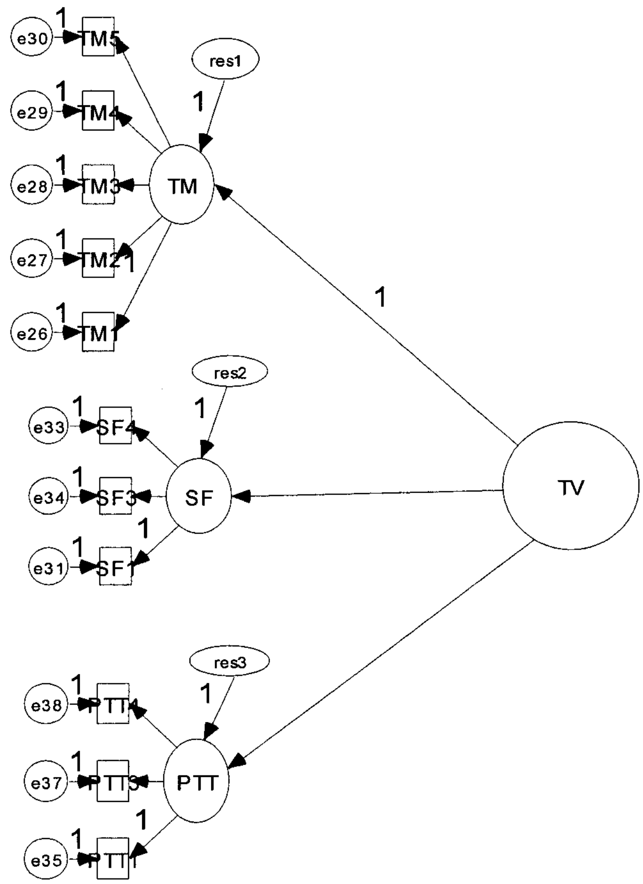


Figure 5.3 Second order measurement model for TV

The fit estimates, as reported in Table 5.33, show all items strongly loaded in their respective factors.

Table 5.33 AMOS Output for the Second Order Model Team Vision (TV): Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
TM <-- TV	1			**0.607**	
SF <-- TV	1.707	0.399	4.275	**0.715**	***
PTT <-- TV	1.475	0.34	4.336	**0.652**	***

The standardized regression weight for TM and TV was .607, SF and TV was .715, and PTT and TV was .652. The goodness-for-fit values for the second order model for TV, as presented in Table 5.34, showed the overall fit for model to be acceptable.

Table 5.34 Goodness-for-Fit Model Summary for Second Order Model of Team Vision

CMIN/DF	1.742
TLI	0.964
CFI	0.973
RMSEA	0.066

5.5.1.6 Mutual Trust (MT)

MT was conceptualized to contain a single factor and accordingly, CFA was conducted with all the ten indicators of MT, as shown in Figure 5.4.

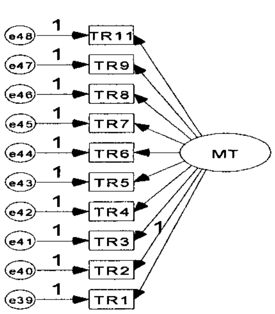


Figure 5.4 First order measurement model of MT

The modification index suggested some correlation error associated with TR3, TR5, and TR 11. With all the ten items of MT, the RMSEA value for the default model was reported to be 0.118. Elimination of TR3, and TR5, and TR 11 led to the improvement of the RMSEA value to 0.086, 0.054, and 0.024 respectively. Since there was a significant improvement in the RMSEA value for MT, it was thus decided to drop TR3, TR5, and TR11 from the subsequent analysis.

The output of the revised first order measurement model for MT is presented in Table 5.35, which shows high loading of the indicators on the factor.

Table 5.35 Final AMOS Output for First Order Mutual Trust (MT): Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weights	p
TR1 <-- TR	1			**.84**	
TR2 <-- TR	1.039	0.073	14.315	**.857**	***
TR4 <-- TR	1.244	0.074	16.811	**.937**	***
TR6 <-- TR	1.088	0.077	14.197	**.853**	***
TR7 <-- TR	1.141	0.075	15.275	**.89**	***
TR8 <-- TR	0.661	0.062	10.624	**.706**	***
TR9 <-- TR	0.921	0.071	13.055	**.811**	***

The standardized regression weighs of TR1, TR2, TR4, TR6, TR7, TR8, and TR9 were .84, .857, .937, .853, .89, .706, and .811. From Table 5.36, the goodness-for-fit value for the model indicated that the fit for the model was acceptable.

Table 5.36 Goodness-for-Fit Model Summary for First Order Model of Mutual Trust

CMIN/DF	1.097
TLI	0.998
CFI	0.999
RMSEA	0.024

5.5.1.7 Mutual Influence (MI)

From the exploratory data analysis of the large-scale study, it was concluded that MI1 should be dropped from the MI factor. The result of parameter estimates of the first order measurement model for MI, as presented in Table 5.37, demonstrated a strong items loading on MI. During the CFA, MI2 and MI7 were dropped because of correlation in the respective error terms and improvement in the RMSEA values. The standardized regression weights for MI3, MI4, MI5, MI6, MI8, and MI9 were .743, .815, .816, .844, .835, and .848.

Table 5.37 Final AMOS Output for First Order Mutual Influence (MI): Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
MI3 <-- MI	1			**.743**	
MI4 <-- MI	0.96	0.089	10.784	**.815**	***
MI5 <-- MI	0.969	0.09	10.798	**.816**	***
MI6 <-- MI	0.959	0.086	11.204	**.844**	***
MI8 <-- MI	0.901	0.081	11.067	**.835**	***
MI9 <-- MI	1.038	0.092	11.254	**.848**	***

As shown in Table 5.38, the goodness-for-fit values for MI are acceptable for overall model fit.

Table 5.38 Goodness-for-Fit Model Summary for First Order Model of Mutual Influence

CMIN/DF	1.797
TLI	0.983
CFI	0.99
RMSEA	0.069

5.5.1.8 Shared Knowledge (SK)

Shared Knowledge had four factors: shared knowledge of customer (CT), internal capabilities (IT), suppliers (ST), and process (TP). From the large-scale exploratory data analysis, CT3, IT4, ST2, TP5, TP6, and TP7 were dropped from the CFA. Since TP had more than 3 items, CFA was conducted for the TP. The result from the parameter estimate is presented in Table 5.39.

Table 5.39 Final AMOS Output for First Order Shared Knowledge of Process: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
TP1 <-- TP	1			**0.593**	
TP2 <-- TP	1.165	0.154	7.567	**0.791**	***
TP3 <-- TP	1.044	0.147	7.093	**0.712**	***
TP5 <-- TP	1.169	0.159	7.346	**0.752**	***
TP8 <-- TP	1.302	0.169	7.717	**0.821**	***

The standardized regression weights for TP1, TP2, TP3, TP5, and TP8 were .593, .791, .712, .752, and .821 respectively. The goodness-of-fit values in table 5.40 for TP were considered good.

Table 5.40 Goodness-for-Fit Model Summary for First Order Model of Shared Knowledge of Process

CMIN/DF	1.005
TLI	1
CFI	1
RMSEA	0.006

Similarly, a first order CFA was conducted for Shared Knowledge of Suppliers (ST) had more than 3 indicators. The standardized regression weight for ST1, ST3, ST5, and ST6 were reported to be .868, .729, .907, and .893. The goodness-for-fit values for ST were also acceptable. The result of parameter estimates and goodness-for-fit value is presented in Table 5.41 and Table 5.42

respectively. Next, as shown in Figure 5.5, all the factors of SK were analyzed in the first order CFA.

Table 5.41 Final AMOS Output for First Order Shared Knowledge of Suppliers: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
ST1 <-- ST	1			**0.868**	
ST3 <-- ST	0.836	0.075	11.224	**0.729**	***
ST5 <-- ST	1.106	0.069	16.111	**0.907**	***
ST6 <-- ST	1.057	0.067	15.718	**0.893**	***

Table 5.42 Goodness-for-Fit Model Summary for First Order Model of Shared Knowledge of Suppliers

CMIN/DF	1.361
TLI	0.995
CFI	0.998
RMSEA	0.046

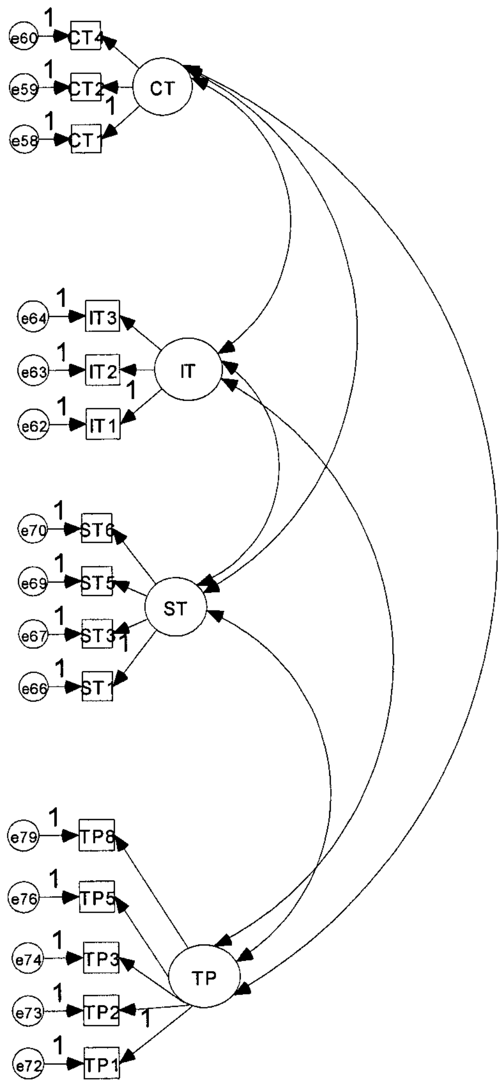


Figure 5.5 First order measurement model of SK

Parameter estimates for the first order model for SK, as presented in Table 5.43, indicated a strong loading of the indicators on their respective factors.

Table 5.43 Final AMOS Output for First Order Model Shared Knowledge: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
TP1 <-- TP	1			**0.606**	
TP2 <-- TP	1.106	0.143	7.737	**0.767**	***
TP3 <-- TP	1.043	0.14	7.465	**0.728**	***
TP5 <-- TP	1.13	0.149	7.572	**0.743**	***
TP8 <-- TP	1.287	0.159	8.118	**0.83**	***
ST1 <-- ST	1			**0.866**	
ST3 <-- ST	0.84	0.075	11.281	**0.731**	***
ST5 <-- ST	1.105	0.069	16.1	**0.905**	***
ST6 <-- ST	1.062	0.067	15.826	**0.895**	
IT1 <-- IT	1			**0.743**	***
IT2 <-- IT	0.705	0.098	7.194	**0.62**	***
IT3 <-- IT	0.667	0.099	6.715	**0.577**	***
CT1 <-- CT	1			**0.807**	
CT2 <-- CT	1.15	0.098	11.721	**0.845**	***
CT4 <-- CT	1.142	0.096	11.876	**0.862**	***
Covariances					
IT <--> CT	0.117	0.037	3.149		0.002
ST <--> CT	0.039	0.042	0.927		0.354
TP <--> CT	0.14	0.033	4.27		***
ST <--> IT	0.391	0.07	5.632		***
TP <--> IT	0.283	0.053	5.338		***
TP <--> ST	0.219	0.052	4.233		***

The standardized regression weight for this first order model is presented in Table 5.43, which are all high. The goodness-for-fit values for the first order measurement model are presented in Table 5.44 demonstrating an overall acceptable model.

Table 5.44 Goodness-for-Fit Model Summary for First Order Model of Shared Knowledge

CMIN/DF	1.653
TLI	0.95
CFI	0.96
RMSEA	0.062

Since, SK was compromised of shared knowledge of customers, suppliers, process, and internal capabilities, a second order CFA was tested for Figure 5.6 next.

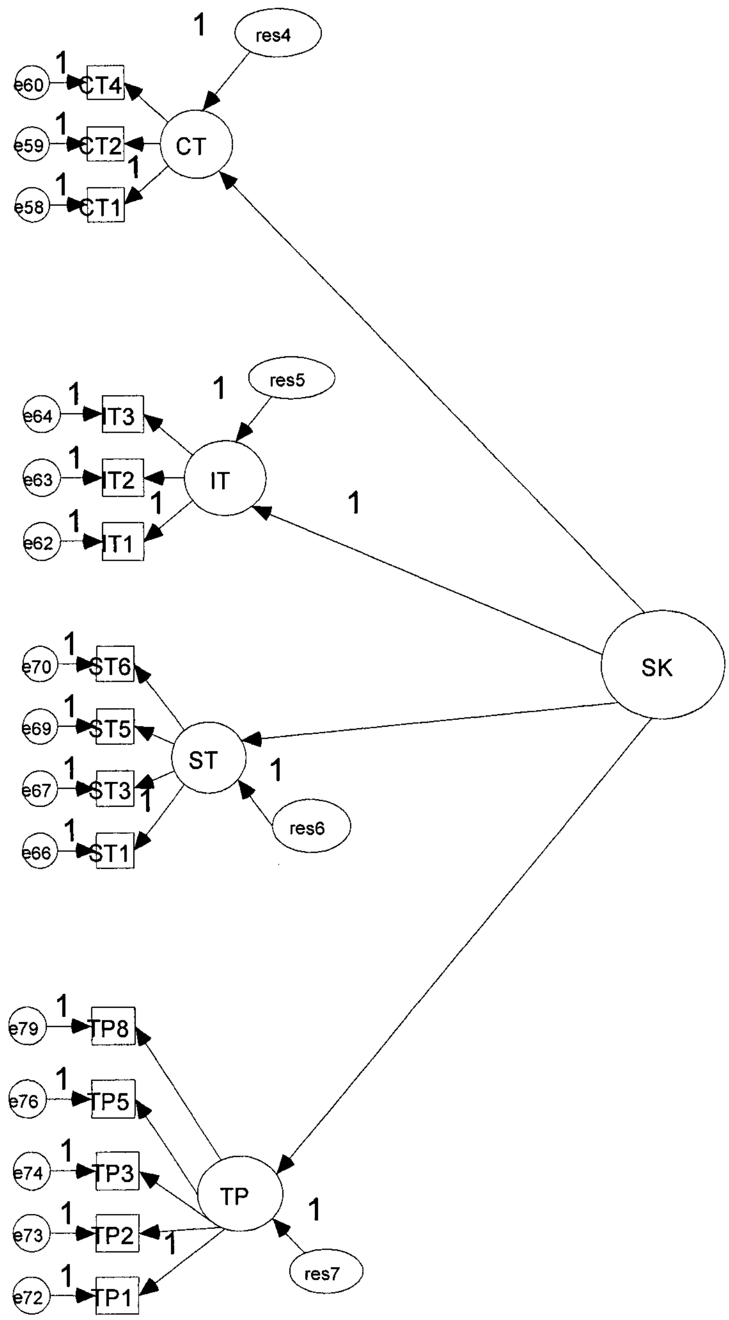


Figure: 5.6: Second order Measurement Model of Shared Knolwedge

Table 5.45 summarizes the result of the parameter estimates for the second order model of SK.

Table 5.45 AMOS Output for Second Order Model Shared Knowledge: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
CT <--SK	0.31	0.08	3.891	**.374**	***
IT <-- SK	1			**1.108**	
ST <-- SK	0.83	0.139	5.986	**.697**	***
TP <-- SK	0.66	0.117	5.641	**.704**	***

The standardized regression weight for CT and SK was .374, IT and SK was 1.108, ST and SK was .697, and TP and SK was .704.

Prior research has shown that understanding user needs and incorporating them into new product design is a key determinant of product development success. Kahn and Pinegar (1999) classified the customer's role in application development and technology development into four categories; coaching (technology forecasting, identification of problems and opportunities, concept generation and definition), partnering (co-development, resource sharing, exploring), advising (product councils, focus group, beta testing), and reporting (testing, customer research, market sensing).

The data in this research points out that shared knowledge of customer has a low standardized regression estimate of 0.374. There could be two possible explanations for this.

First, this research did not differentiate between the radical or truly innovative product and the incremental or not –so innovative product. In their analysis, Song and Montoya-Weiss (1998) revealed that business and market opportunity analyses were not helpful to firms developing really new products, given how user needs are often ill defined. Veryzer (1998) noted that in the early phase of development, radical innovation tends to use a qualitative research technique that allows an organization to explore and gain a deeper understanding of the users whereas formal, quantitative techniques, such as focus groups and market studies, used incremental product developments. His case analyses revealed that new product ideas did not come from customers. Lynn et al. (1996) found that, not only was the information generated from conventional market research techniques not useful in a radical innovation project, it was often misleading. Therefore, the shared knowledge of customer in NPD is dependent upon the nature of product innovation types, which may determine to what extent customers should be involved in the development process.

Another possible explanation could be found in the timing of customers in the product development. Von Hippel (1986) defines 'lead users" as those who have needs well in advance of the general marketplace. Lead user analysis, although a complex process, involves accurate information on market trends, identification of the users, and generation of product concept, testing etc. (Urban and von Hippel, 1988). The implication is that in such a scenario, shared knowledge of customer begins from the beginning of the product development process, i.e. customer involvement is high in the process. Whereas in other cases, customers may be involved in beta testing or the product testing phase only. In such cases where customers are involved occasionally, customer knowledge is not a continuous process but a one point input as feedback in the development process. This could have been the reason why the respondents of this survey did not find shared knowledge of customer as valuable as shared knowledge suppliers, internal capabilities, and process. Table 5.46 concluded that the model fit indices for the second order model was acceptable.

Table 5.46 Goodness-for-Fit Model Summary for Second Order Model of Shared Knowledge

CMIN/DF	1.816
TLI	0.938
CFI	0.949
RMSEA	0.069

5.5.1.9 IPD Performance Outcomes (NPPO)

NPPO was conceptualized to consist of five factors: engineering change time (EC), team performance (PERF), product cost (PC), product development time (PTO), and customer satisfaction (CS). As recommended in the large-scale exploratory data analysis, it was decided to drop MC4, TPO3, TW4, and TW5 from the CFA.

A first order CFA for PC resulted in the standardized regression weight for PC1, PC3, PC4, MC1, MC3, and MC5 to be .707, .668, .749, .854, .81, and .846. The parameter estimates and the goodness-for-fit for PC are presented in Table 5.47 and Table 5.48. The result for CMIN/df is greater than 2, but it is still in the range of 5 and thus considered to be an average fit. Similarly, the RMSEA value reported was also above 0.05 and can be considered as a mediocre fit (MacCallum et al., 1996).

Table 5.47 Final AMOS Output for First Order Product Cost: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
PC1 <-- PC	1			**0.707**	
PC3 <-- PC	0.945	0.115	8.208	**0.668**	***
PC4 <-- PC	1.073	0.117	9.177	**0.749**	***
MC1 <-- PC	1.3	0.125	10.387	**0.854**	***
MC3 <-- PC	1.227	0.124	9.893	**0.81**	***
MC5 <-- PC	1.239	0.12	10.295	**0.846**	***

Table 5.48 Goodness-for-Fit Model Summary for First Order Model of Product Cost

CMIN/DF	2.597
TLI	0.958
CFI	0.975
RMSEA	0.097

The standardized regression weight for CS2, CS3, CS4, CS5, and CS6 were reported at .708, .81, .697, .902, and .814. The computed parameter estimates and goodness-of-fit for CS are presented in Table 5.49 and Table 5.50. The goodness-of-fit indices suggest a good model fit for customer satisfaction for TLI (.969) and CFI (.984); however, based upon the suggestion of MacCallum et al. (1996), the RMSEA value of 0.093 for CS was considered to be mediocre. Thus, a recommendation has been made to further explore this issue in the measurement issues in Chapter Six of this study.

Table 5.49 Final AMOS Output for First Order Customer Satisfaction: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
CS2 <-- CS	1			**0.708**	
CS3 <-- CS	1.387	0.14	9.895	**0.81**	***
CS4 <-- CS	1.187	0.139	8.564	**0.697**	***
CS5 <-- CS	1.404	0.13	10.836	**0.902**	***
CS6 <-- CS	1.353	0.136	9.948	**0.814**	***

Table 5.50 Goodness-for-Fit Model Summary for First Order Model of Customer Satisfaction

CMIN/DF	2.464
TLI	0.969
CFI	0.984
RMSEA	0.093

The standardized regression weight for PTO1, PTO3, PTO4, and PTO5 were reported to be .832, .765, .95, and .983. The parameter estimates and the goodness-of-fit values from the CFA of PTO are presented in Table 5.51 and Table 5.52.

Table 5.51 Final AMOS Output for First Order Product Development Time: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
PTO1 <-- PTO	1			**0.832**	
PTO3 <-- PTO	0.872	0.075	11.676	**0.765**	***
PTO4 <-- PTO	1.094	0.068	16.196	**0.95**	***
PTO5 <-- PTO	1.053	0.071	14.893	**0.983**	***

Table 5.52 Goodness-for-Fit Model Summary for First Order Model of Product Development Time

CMIN/DF	0.362
TLI	1.007
CFI	1
RMSEA	0

Next, CFA for first order model for NPPO was conducted. The parameter estimates for the first order model are presented in Table 5.53.

Table 5.53 Final AMOS Output for First Order Model New Product Performance Outcomes: Factor Loading Parameter Estimates

	Estimates	S.E.	C.R.	Standardized Regression Weight	p
EC2 <-- EC	1			**0.882**	
EC3 <-- EC	1.064	0.062	17.169	**0.913**	***
EC4 <-- EC	1.035	0.061	16.911	**0.905**	***
PTO1 <-- PTO	1			**0.832**	
PTO3 <-- PTO	0.884	0.075	11.726	**0.775**	***
PTO4 <-- PTO	1.087	0.074	14.716	**0.944**	***
TW2 <-- PERF	1			**0.781**	
TPO1 <-- PERF	0.757	0.085	8.947	**0.736**	***
TPO3 <-- PERF	0.68	0.082	8.335	**0.683**	***
PC1 <--PC	1			**0.714**	
PC3 <-- PC	0.929	0.113	8.245	**0.662**	***
PC4 <-- PC	1.059	0.114	9.287	**0.746**	***
MC1 <-- PC	1.3	0.122	10.684	**0.862**	***
MC3 <-- PC	1.214	0.121	10.052	**0.809**	***
MC5 <-- PC	1.217	0.117	10.416	**0.839**	***
CS2 <- CS	1			**0.715**	
CS3 <-- CS	1.362	0.137	9.956	**0.803**	***
CS4 <-- CS	1.185	0.136	8.728	**0.703**	***
CS5 <-- CS	1.382	0.126	10.999	**0.896**	***
CS6 <-- CS	1.349	0.133	10.164	**0.82**	***
Covariances					
EC <--> PTO	0.372	0.078	4.78		***
CE <--> PERF	0.474	0.077	6.176		***
EC <--> PC	0.397	0.077	5.123		***
EC <--> CS	0.142	0.049	2.908		0.004
PTO <--> PERF	0.32	0.068	4.73		***
PTO <--> PC	0.438	0.08	5.494		***
PTO <--> CS	0.313	0.059	5.33		***
PC <--> CS	0.171	0.049	0.3497		***
PERF <-->CS	0.146	0.043	3.39		***
PERF <--> PC	0.399	0.071	5.626		***

All the items loaded high on their respective factors. Goodnessofr-fit from Table 5.54 indicated an overall acceptable model fit for the first order model of NPPO.

Table 5.54 Goodness-for-Fit Model Summary for First Order Model of New Product Performance Outcomes

CMIN/DF	1.606
TLI	0.948
CFI	0.956
RMSEA	0.06

Next, CFA for the second order measurement model of NPPO was conducted as shown in Figure 5.7. The parameter fit statistics in table 5.55 and goodnessofr-fit values in table 5.56 for the second order model led to conclude the overall model for NPPO to be acceptable.

Table: 5.55 AMOS Output for Second Order Model New Product Performance Outcomes: Factor Loading Parameter Estimates

	Estimate	S.E.	C.R.	**Standardized Regression Weight**	**p**
PTO <-- NPPO	0.933	0.143	6.515	0.695	***
PERF <-- NPPO	0.91	0.132	6.874	0.844	***
PC <-- NPPO	0.745	0.118	6.31	0.731	***
CS <-- NPPO	0.442	0.092	4.811	0.721	***
EC <-- NPPO	1			0.883	

The standardized regression weight of PTO and NPPO was .695, PERF and NPPO was .844, PC and NPPO was .731, CS and NPPO was .721, and EC and NPPO was .883.

Table 5.56 Goodness-for-Fit Model Summary for Second Order Model of New Product Performance Outcomes

CMIN/DF	1.782
TLI	0.932
CFI	0.941
RMSEA	0.068

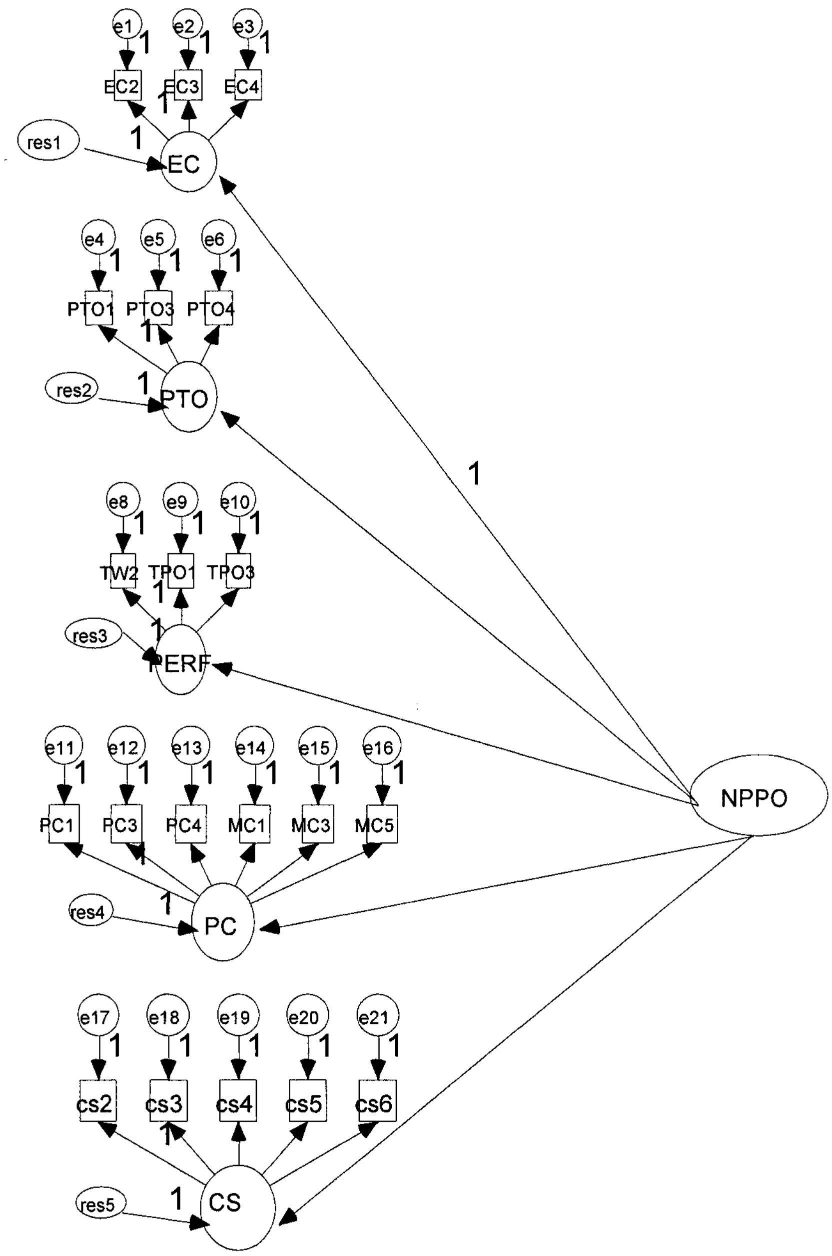


Figure 5.7: Second Order Model for NPPO

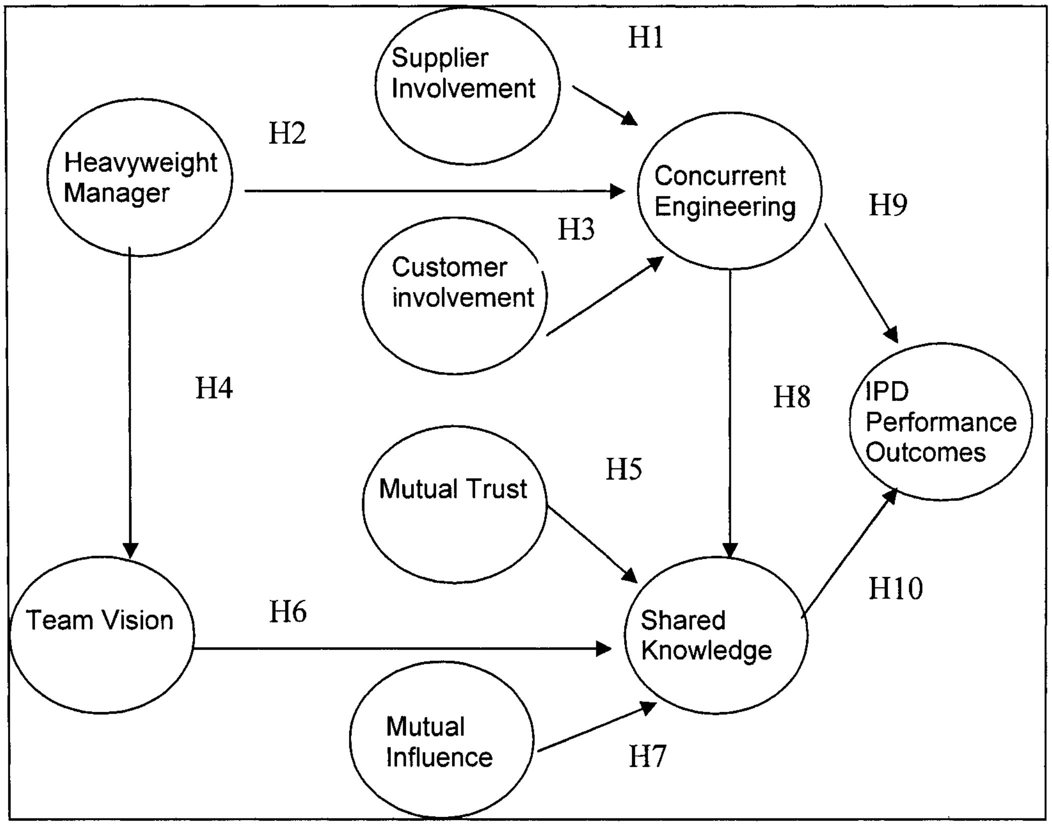
Based upon the parameter estimates and goodness-of-fit values, the second order measurement model for NPPO was acceptable.

5.6 The Complete Model

The purpose of exploratory factor analysis (along with analysis of reliability and item purification) and CFA (first order, and second order) was to statistically make sure that each variable of the hypothesized complete model was a valid. In contrast to the factor-analytic model, the full latent variable model allows for the specification of regression structure among the latent variables of work and knowledge integration. Next, the hypotheses for the proposed model in integrated product development were tested using the complete structural model.

According to the conceptualized model, heavyweight manager (HM), supplier involvement (SI), and customer involvement (CI) have a direct and positive relationship on concurrent engineering (CW). Also, team vision (TV), mutual trust (MT), and mutual influence (MI) have a direct and positive impact on shared knowledge (SK). Heavyweight manager was proposed to have a direct positive effect on team vision (TV) and concurrent engineering (CW) was also hypothesized to have a direct impact on shared knowledge (SK). Finally, CW and SK had a direct positive impact on the new product performance outcome (NPPO).

Figure 5.8 Proposed research model



The complete path diagram model in the AMOS 5.0 is presented in Figure 5.9. Each of the second order models were tested separately as discussed earlier. The AMOS analysis tested the viability of these measurement models and the relationships (the hypotheses) between the factors simultaneously.

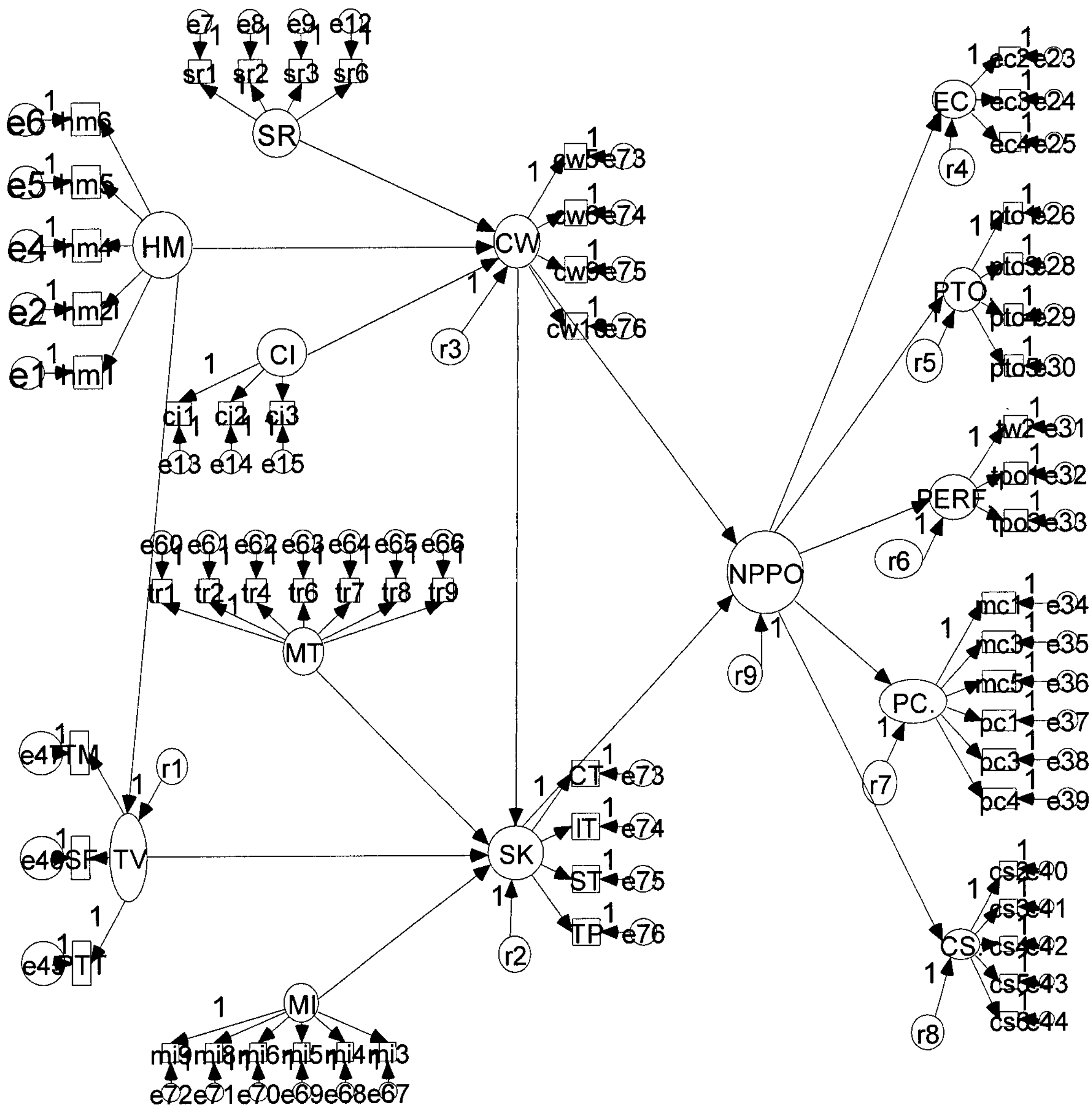


Figure 5.9: The complete path diagram model

The result from the structural analysis is presented in Table 5.57. The standardized regression weight for HW and CW was reported to be .347, for SI and CW is .250, for CI and CW is .210, for HW and TV is .547, for TV and SK is .343, for MT and SK is .323, for MI and SK is .204, for CW and SK is .590, for CW and NPPO -.139 and for SK and NPPO is .985.

Table 5.57 AMOS result of the Complete Structural Model

Relationship (Hypothesis)			Estimate	S.E.	C.R.	Standardized regression weights	P
CW	<---	HM	0.174	0.04	3.572	**0.347**	***
CW	<---	SI	0.121	0.044	2.77	**0.250**	0.006
CW	<---	CI	0.128	0.057	2.23	**0.210**	0.026
TV	<---	HM	0.32	0.066	4.866	**0.547**	***
SK	<---	TV	0.113	0.042	2.708	**0.343**	0.007
SK	<---	MT	0.088	0.03	2.96	**0.323**	0.003
SK	<---	MI	0.053	0.022	2.382	**0.204**	0.017
SK	<---	CW	0.227	0.073	3.109	**0.590**	0.002
NPPO	<---	CW	-0.15	0.142	-1.06	**-0.139**	0.289
NPPO	<---	SK	2.754	0.874	3.15	**0.985**	0.002

From table 5.57, the relationship between CW and NPPO is found to be not significant, i.e. there is no direct and positive impact of CW on NPPO when all other relationships are specified. All other nine propositions were found to be significant including CW on SK and HW on TV.

The goodness of fit for this model is presented in table 5.58. According to RMSEA and CMIN/ DF the model has reasonable fit. TLI and CFI are >.80, which with a large number of measures / factors, it is not uncommon for fit to be degraded. Cote 2001, suggests, "Complex models with fit indexes in the .80

range would still meet the acceptability requirements suggested by Carmines and McIver, 1981". Thus the model overfit is satisfactory.

Table 5.58: Goodness-for-Fit Model Summary for Complete Model

CMIN/DF	1.778
TLI	0.815
CFI	0.824
RMSEA	0.068

5.7 Alternative Model Generation

Next it was decided to follow the MG approach and test the model again. In the original model, when a relationship was hypothesized between CW and SK, the link from concurrent engineering (CW) to performance outcomes (NPPO) was non-significant. Although the relationship between CW and NPPO has been a subject of at least one study in the past (Koufterous, 1995), there has been no empirical study of testing this relationship when also specifying a relationship with shared knowledge. Thus, it was decided to drop the relationship from the proposed model of CW to SK and test if CE and SK had a direct and positive impact on the NPPO.

The new generated model is presented in Figure 5.10.

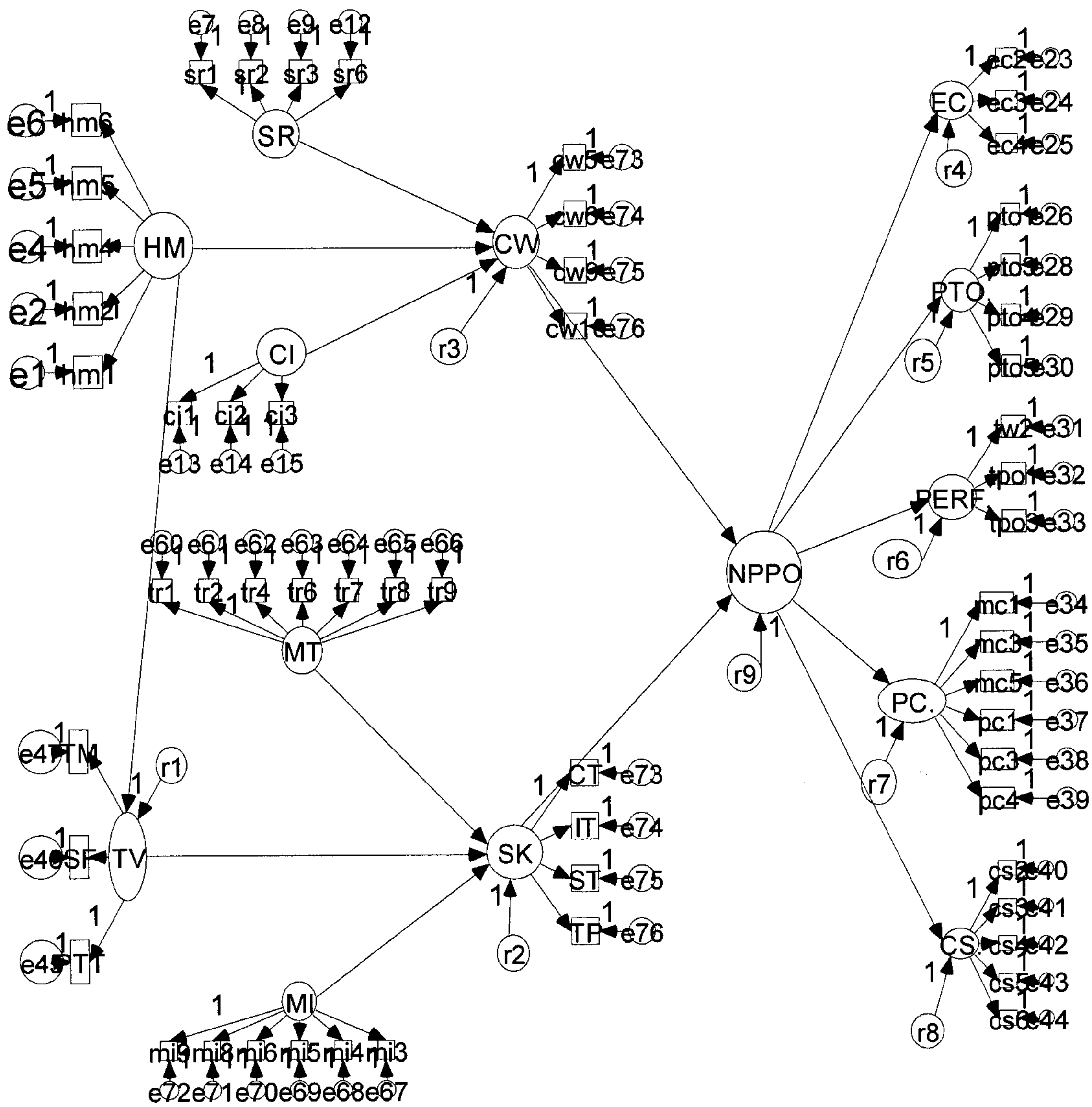


Figure 5.10 Alternative model one in IPD

The result of the parameter estimates for the above structural model is presented in Table 5.59.

Table 5.59 AMOS result for Alternative Model One of the Complete Structural Model

Relationship (Hypothesis)			Estimate	S.E.	C.R.	Standardized regression weights	P
CW	<---	HM	0.208	0.052	3.991	**.398**	***
CW	<---	SI	0.096	0.045	2.157	**.189**	0.031
CW	<---	CI	0.136	0.06	2.273	**.215**	0.023
TV	<---	HM	0.341	0.06	5.136	**.563**	***
SK	<---	TV	0.206	0.062	3.322	**.587**	***
SK	<---	MT	0.121	0.037	3.299	**.404**	***
SK	<---	MI	0.063	0.026	2.454	**.222**	0.014
NPPO	<---	CW	0.229	0.086	2.671	**.221**	0.008
NPPO	<---	SK	2.09	0.595	3.514	**.819**	***

The above results for the newly generated model show all hypotheses to be significant. In the new model, the link between concurrent engineering and performance outcomes is significant at alpha <.01 level. Thus, when taking out the linkage between CW and SK, both CW to NPPO and SK to NPPO are significant, which is consistent with past theories for both work and knowledge integration variables.

Table 5.60 presents the goodness-of-fit indices value for the new model. Judging for CMIN/df, RMSEA values indicated an adequate overall fit for the model. TLI and CFI display .81 and .82 respectively for the model, which still meets the >.80 requirement suggested by Cote, 2001.

Table 5.60: Goodness-for-Fit Model Summary for Alternative model one

CMIN/DF	1.795
TLI	0.811
CFI	0.820
RMSEA	0.069

The theoretical literature assumes that if team members are working concurrently the performance of that particular project should be enhanced. Additionally, if there are high levels of shared knowledge on the project development team the literature states this will also be a direct relationship. The alternative model has displayed and confirmed this theory. However, the aim of this dissertation was to explore the relationship between work integration variables and knowledge integration variable and at the same time study the effects of CW and SK on product outcomes. A plausible argument, based on the rejection of CW and PTTO in the first model is that just because people are working together on a product development team, it does not mean these interactions will be productive and fruitful. Team members may be meeting, but nothing may be being accomplished. When studying these relationships in the context of IPD, team members must be working together but also sharing knowledge throughout this process. In the original model, concurrent engineering was found to be significant to shared knowledge and lead to a strong significant relationship with performance outcomes. Thus much of the literature today has focused on enhancing concurrent engineering in product development, but the results of the original model clearly show that what companies and managers should be focusing on is enhancing the shared knowledge on the development team.

The data has shown that both concurrent engineering and shared knowledge effect product development outcomes. However, concurrent engineering is significant only through shared knowledge; shared knowledge wins in impacting performance outcomes. Based on these results, the final alternative model places back the relationship of concurrent engineering on shared knowledge and removes the linkage between concurrent engineering and performance outcomes. This final model can be seen below in table figure 5.11.

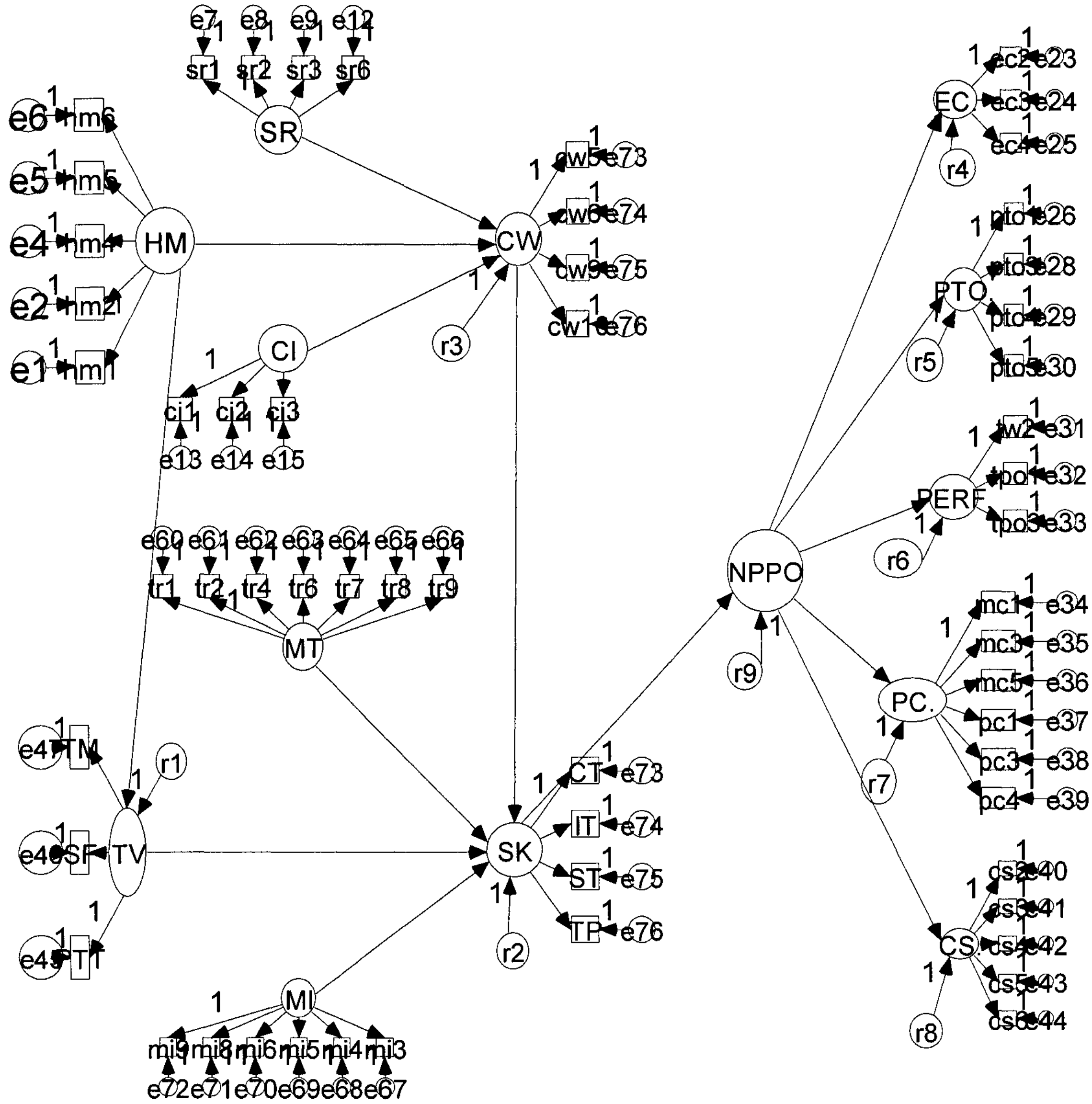


Figure 5.11 Final Alternative Model in IPD

The result of the parameter estimates for the final structural model is presented in Table 5.61.

Table 5.61 Final Alternative Model AMOS result for the Complete Structural Model

Relationship (Hypothesis)			Estimate	S.E.	C.R.	Standardized regression weights	P
CW	<---	HM	0.178	0.04	3.631	**0.354**	***
CW	<---	SI	0.12	0.044	2.737	**0.246**	0.006
CW	<---	CI	0.129	0.057	2.245	**0.211**	0.025
TV	<---	HM	0.32	0.066	4.853	**0.545**	***
SK	<---	TV	0.117	0.043	2.717	**0.352**	0.007
SK	<---	MT	0.091	0.031	2.969	**0.328**	0.003
SK	<---	MI	0.056	0.023	2.407	**0.214**	0.016
SK	<---	CW	0.211	0.068	3.109	**0.546**	0.002
NPPO	<---	SK	2.47	0.742	3.327	**0.885**	***

The above results for the newly generated model show all hypotheses to be significant. Again concurrent engineering is significant upon shared knowledge and thus works through shared knowledge to affect the outcome of the developing project.

Table 5.62 presents the goodness-for-fit indices value for the new model. Judging for CMIN/df, RMSEA values indicated an adequate overall fit for the model. TLI and CFI display .81 and .82 respectively for the model, which still meets the >.80 requirement suggested by Cote, 2001.

Table 5.62: Goodness-for-Fit Model Summary for Final Alternative Model

CMIN/DF	1.777
TLI	0.816
CFI	0.824
RMSEA	0.068

5.8 Test for mediating effect of shared knowledge

This research work attempts to explore the relationship of work integration variables and knowledge integration variables in the context of new product development outcomes. One plausible relationship is the mediating effect of shared knowledge between concurrent engineering and performance outcomes. The mediating effect of shared knowledge on performance outcomes seems to be supported in the literature. Several researchers have described product development as a knowledge intensive activity (Eder, 1997; Iansiti and MacCormack, 1997; Hong, 2000). NPD requires integration of knowledge of the cross functional team members in order to solve complex problems during the design and development phases. Integrative practices help the team members acquire environmental information, exchange views, interpret the task environment, resolve cross functional conflicts, and reach a mutual understanding of the development task (Koufteros, 2002).

Therefore, it was further proposed and suggested that concurrent engineering may have an indirect and positive effect on performance outcomes. To test the mediating effect, nested-model comparison in SEM from the study of Niechoff and Moorman (1993) was followed in general.

The test of a mediating effect of shared knowledge in the proposed research was conducted for the general model illustrated in Figure 5.12.

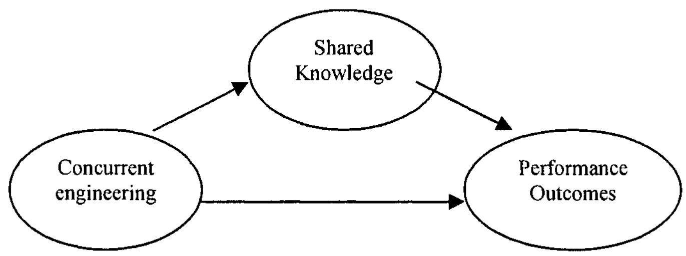


Figure 5.12 : Mediating Relationship of CE on SK and NPPO

The general strategy is to follow the guideline used in the empirical study of Niechoff and Moorman (1993) to use a chi-square test to test for mediating effect. Four separate models were tested using CFA in AMOS 5.0. The results of these models are presented in Table 5.63.

Table 5.63: Nested-model Analysis for Mediating Effect

Models		Chi-Square	df	p*	RMSEA
Model 1:	CE-->NPPO	500.85	269	***	0.071
Model 2:	CE-->SK	463.79	269	***	0.065
Model 3:	SK-->NPPO	40.885	19	0.002	0.083
Model 4:	CE-->SK-->NPPO	647.24	370	***	0.067

***p<0.001

Model 1, model 2, and model 3 were tested to evaluate the direct relationship between concurrent engineering and performance outcomes, concurrent engineering and shared knowledge, and shared knowledge and performance outcomes. Model 4 is the complete model which has all the three variables. Chi-square, degree of freedom (df), p-value at 0.001 and RMSEA values are presented in the above table for each of the four models evaluated.

Model 1, which tests the direct relationship between CE and NPPO, was found to be significant. Additionally, in model 4, when shared knowledge was introduced, the overall model was found to be significant and the RMSEA value also was lowered to .067, suggesting the support of the mediating effect of shared knowledge between concurrent engineering and performance outcomes. In addition the relationship between concurrent engineering and shared knowledge, model 2, was found to be significant. Similarly, the relationship between shared knowledge and performance outcomes, model 3, was also found to be significant. The p values for these tests were also reported below $p<.01$.

From the above analysis, it was thus established that shared knowledge mediated the relationship between concurrent engineering and performance outcomes in the proposed research study. Thus, just because people are working together does not mean the NPD project will be successful. Team members must be not only work together, but sharing valuable knowledge to ensure NPD success.

5.9 CONCLUSION

The research work proposed ten hypotheses in the field of integrated product development. Overall, the research indicates many interesting insights in product development integration. These insights are discussed below in terms of the research's hypotheses.

Hypothesis 1 (significant): The greater the extent of supplier involvement, the greater the extent of concurrent engineering.

Supplier involvement was found to have a significant effect upon concurrent engineering. For supplier involvement, the rationale is that suppliers drive the need for cross functional involvement because they expecte integrated answers to questions involving engineering design, manufacturing, and the development process. Suppliers that fulfill requests contribute valuable information and expertise and force an integrated team response to issues and opportunities they raise.

Hypothesis 2 (significant): The greater the influence (both formal and informal) of the heavyweight manager, the greater the extent of concurrent engineering.

The data has shown that heavyweight managers have a significant positive influence on concurrent engineering. The argument is that heavyweights possess power and authority to demand that key functional areas are represented on the product development team. Additionally, they see that schedules are met among cross functional team members, and that the necessary resources for the development team are provided.

Hypothesis 3 (significant): The greater the extent of customer involvement, the greater the extent of concurrent engineering

Customer involvement was found to significantly impact concurrent engineering. The reasoning is that customers expect integrated answers to their demands and force the development team to work together across functions. Customers need a central place to get a reaction.

Hypothesis 4 (significant): The greater the extent of use of a heavyweight manager the greater the level of team vision for the project.

Heavyweights also serve as a bridge between work integration and knowledge integration. The model found a significant relationship between the heavyweight manager and the team vision on the product development team. Often times this period is in the fuzzy front end of development where the heavyweight will communicate the mission, strategic fit, and clarify goals of the particular project.

Hypothesis 5 (significant): The greater the extent of use of a mutual trust the greater the level of shared knowledge

Mutual trust leads to effective knowledge sharing. In product development, there is a high need for interdependence between disciplines which means that team members must rely upon the functional expertise of each other for timely and accurate information, view points, and decisions. Lack of mutual trust will withhold information sharing that needs to take place for effective problem solving.

Hypothesis 6 (significant): The greater the extent of team vision the greater the level of shared knowledge.

By having a shared vision of the project, team members know what information they want to share and find more valuable information to contribute to the project. A shared team vision contributes to a common purpose to share information and acts as a lens that is focused on the necessary kinds of information to share on the development team.

Hypothesis 7 (significant): The greater the extent of mutual influence the greater the level of shared knowledge.

Mutual influence is the third variable which enhances shared knowledge. The argument is that if knowledge is to be exchanged to solve complex product development questions, mutual influence will ensure that the exchanging parties appreciate and understand the knowledge offered by others. If there exists equal power among IPD members, each team member will have an equal opportunity to change others' view on a product development problem. With mutual influence present in the development team, information is exchanged and accepted in an open mutual environment and provides a basis for sharing information and joint decision making.

Hypothesis 8 (significant): The greater the extent of concurrent engineering, the greater the extent of shared knowledge.

Product development is an integrated problem solving activity. By involving cross functional team members early in the new product development process, it leads to better trade off decisions among alternatives, enhanced design, production, and allows the development team to achieve optimum solutions.

Hypothesis 9 (non-significant): The greater the extent of concurrent engineering the greater the extent of new product development performance.

Through this exploratory analysis, it was found that with all integration variables interacting, the link between concurrent engineering and product outcomes was no longer significant, A plausible argument is that even though team members are meeting, it does not mean it will be productive. The model indicates that concurrent engineering works through shared knowledge to enhance product development outcomes. Or in other words, team members must be integrated and sharing knowledge in order to be successful in the IPD effort. This was demonstrated through a mediating test in section 5.6.1.

Hypothesis 10 (significant): The greater the extent of shared knowledge the greater the extent of new product development performance.

The link between shared knowledge and product outcomes in terms of quality (customer satisfaction), time (engineering change time and product development time), team productivity, and cost (product cost and manufacturing cost) were shown to be significant. Having a lack of shared knowledge on a development team causes inappropriate trade off decisions where team members have different agendas and objectives for the project. This causes glitches in the development process.

Chapter Six

Summary, Recommendations, and Discussions

6.1 Summary

Due to the relative newness of integration variables between work integration and knowledge integration in the context of new product development, much speculation about its influence on performance (and in the product development strategy on a more organizational context) has become a popular subject of interest among the research communities and industry. However, much of the research evidence concerning this integration is theoretical and anecdotal; based primarily on personal experiences, case studies, and a very few empirical studies. Although these cases have made important contributions, the literature on the relationship between work integration and knowledge integration variables and product development performance is still in its infancy. More importantly, the specific interrelationship between work integration and knowledge integration variables in the product development environment has not been empirically studied.

The purpose of this research was to complement the previous studies in integration in product development and to bring some uniformity to the literature.

By hypothesizing a conceptual model for work integration and knowledge integration in new product development and conducting an analysis across a relatively large number of organizations with reliable instruments, this study contributes to our understanding of integration in product development in a number of ways.

First, a theoretical framework of work and knowledge integration for new product development is provided that identifies the role of heavyweight manager, supplier involvement, and customer involvement on concurrent engineering and from the knowledge integration aspect, team vision, mutual trust, and mutual influence on shared knowledge. Also, two bridges between these two literature streams have been studied from heavyweight manager to team vision and from concurrent engineering to shared knowledge. Additionally, concurrent engineering and shared knowledge's impact on new product development performance outcomes was explored in the comprehensive model.

Second, the study provides a set of validated instruments of work integration and knowledge integration variables. Some of the varaibles were used from previous studies, while new measurements were added or modified for shared knowledge of process, team productivity, and customer satisfaction. Such measurement instruments have been lacking in the context of a more comprehensive framework of integration in product development. It is hoped that this research has provided the groundwork for future research in the field of work integration and knowledge integration in product development.

Third, this research provides a methodological guide for researchers in manufacturing management who may not be familiar with rudimentary and advanced procedures for assessing reliability, validity, and SEM methods for CFA for basic instruments. Because empirical research is relatively new to the field of manufacturing management (Koufteros, 1995), this study provides a guide to those who are to undertake empirical research in the area.

Fourth, this study also provides a valuable tool for the product development professionals to assess their product development practices. For example, heavyweight product managers can evaluate the extent of knowledge sharing during the project and study their relative impact on performance. Also performance outcome measures may also be useful to managers for evaluation procedures in their NPD process. In fact, a large number of respondents have indicated that they would like to receive the results from this study.

Fifth, the study provides supporting evidence of previously untested statements regarding variables of concurrent engineering to shared knowledge (SK ← CE) and heavyweight to team vision (TV ← HW) in the context of IPD. As presented in the model generation section of large-scale structural analysis, greater extent of use for a heavyweight manager and concurrent engineering can improve the level of team vision and shared knowledge respectively among the cross-functional team members in the product development.

Several measurements as well as structural issues recommendations are provided in the following section.

By addressing these issues, possible directions for future research are provided.

6.2 Recommendations and Discussions for Measurement Issues

This section presents recommendations for the measurement results from the study.

Recommendation 1: Future research should cross validate the scale using firms from the same referent population and other industries.

The generic nature of the integrated product development variables used in this study allows for their broad usage. While using these scales, a researcher may have to be careful about using the proposed scales. The scales were developed with the objective of being used confidently in an automotive environment.

For example, certain work integration and knowledge sharing practices may not be applicable. In certain cases a heavyweight manager may not be involved during the product development process, especially when the new project is a minor modification (derivative project) as opposed to the radical innovation. If the project is only an incremental improvement, assigning the limited resource of a heavyweight to the team would not be necessary.

Similarly, different projects may not have equal priority to the cost, time, and quality objectives and accordingly certain performance measures of this study may be more relevant than others.

The generalizability of the scales is currently supported by acceptable reliabilities (above 0.80; except customer involvement 0.78, concurrent engineering 0.79, shared knowledge of internal capabilities at 0.71 and team productivity at 0.75) across the automotive industry and its supply chain. Due to exploratory nature of this study, these scales should be cross-validated in the same industries and also in other industries.

Recommendation 2: Future research should conduct a confirmatory study for the hypothesized model.

This study has presented the development of the instruments for shared knowledge of process. Additionally, work integration variables were studied for the first time along with knowledge integration variables. Furthermore, measurements of performance outcomes were consolidated from multiple studies. Due to all this, the entire study was exploratory in nature. The research cycle for developing standardized measurement instruments has two steps: 1) exploratory studies that develop the hypothesized measurement model (s) via the analysis of empirical data from a referent population, and 2) confirmatory studies that test the hypothesized measurement models against new data gathered from the same referent population.

Although, SEM methodology for measurement model and structural model was used in the large-scale study, the same data sample was used for both exploratory and confirmatory study. Based upon the results of this study, a new set of large-scale data should be collected and subjected to a confirmatory study in order to provide a more rigorous and systematic test for the IPD model.

Recommendation 3: Factorial invariance tests should be used in future research.

The generalizibility of measurement instruments may be further supported by factorial invariance tests. Using the instruments developed in this research, one may test for factorial invariance across the supply chain (first tier, second tier, third tier, OEM, customer involvement) and across different firm size (small versus medium versus large). The instruments developed were to be widely applicable and the factor structure is expected to be similar across different groups. Factorial invariance tests are very rare in the manufacturing research as a part of instrument development for research.

Marsch and Hocevar (1985) provide directives to perform factorial invariance tests using SEM methodology. Such tests are relevant to the researchers who use factor analysis in theory development. The value of one factor is greatly enhanced if the same factor can be replicated in random samples from the same population and identified in responses from different populations (Bejar, 1980). Although it is rarely tested, an implicit assumption in the comparison of different groups is that the underlying construct being measured is the same for the two groups, and this is the issue of factorial invariance (Marsch and Hocevar, 1985). However, to conduct factorial invariance tests, it is necessary to collect sufficient data for each of the groups for comparison.

Recommendation 4: Future research should use multiple methods of obtaining data.

The use of a single respondent to represent project team wide variables may have generated some inaccuracy. More than the usual amount of random error is likely because informants were making individual inferences about macro-level phenomena over team and project. Over-reporting or under-reporting of certain phenomena may occur as a function of the informant's position, length of time in the project, project outcomes, job satisfaction, or role characteristics (Bagozzi et al., 1991). It is also sometimes recognized that biases arising from a common method used to derive measures across independent and dependent variables can artificially increase the association observed therein (Fiske, 1982). It is thus suggested that multiple methods (e.g. subjective and objective methods) should be used to derive the estimates, which can then be analyzed, using multitrait-multimethod approach (Campbell and Fiske, 1959).

Recommendation 5: Future research should focus on new product complexity to analyze the importance of knowledge integration of customer and supplier.

The present research provided a generic model of IPD in the context of work integration and knowledge integration without taking into account the level of product (and process) complexity faced by the company or the industry. In a more product complex environment, the level of customer and supplier involvement in the product development may vary. Moreover, customers and supplier involvement may be limited during the initial and the final stages of the product development process; as opposed to their continuous involvement throughout the product development stages. As such, measures for the level of product (and process) complexity and the level of customer and supplier participation in the product development should be developed and studied.

Recommendation 6: Future research should explore potential problematic scales of concurrent engineering, shared knowledge of internal capabilities, and customer satisfaction.

The research tested a number of variables however, three such variables need to be revisited to improve the measurement model. The first order model for concurrent engineering held a Cronbach's alpha of .787 with and an RMSEA value of .154 and a CMIN/DF value of 4.993. Even though other model fit indices such as CFI was above >.90 (.959), it would be recommended to generate additional items in a future study or even use a second order variable to measure concurrent engineering as was utilized by Koufteros (2000).

Secondly, only four items were used in the study to describe shared knowledge of internal capabilities. This variable had a Cronbach's alpha of. 71, and item IT1 cross loaded with the shared knowledge of process factor. However, because IT had only three items left at the point of the large scale study, it was decided to be included in the research. Thus additional items are recommended which are generated through literature support.

Finally the first order model for customer satisfaction, had a sufficient Cronbach's alpha at .90, and TLI (.97) and CFI (.98) displayed good fit, however, RMSEA (.09) indicated the model need improvement. This issue needs to be further explored in further research.

6.3 Recommendations and Discussion for Structural Issues

In this section recommendation and discussion surrounding the structural issues for future study is presented.

Recommendation 7: Future research should test the proposed model with a different referent population.

The Society of Automotive Engineers (SAE), which focuses on engineering development work in the automotive industry, provided the mailing address that was used for this study to collect large scale data.

As such, one of the recommendations (and also a limitation of this study from generalizing the result) is to test the structural relationship with a different population that represents multiple industries. Traditionally, researchers use Analysis of Variance (ANOVA) and Multivariate Analysis of Variance (MANOVA) to establish that there is no difference in means across industries. Assuming an adequate sample in each industry, one may study the covariance or correlation matrices by industry and check for significant differences. Where significant differences are apparent and a sufficient sample is available for each industry, structural analyses may be done by industry.

Recommendation 8: Future research should incorporate contextual variables in the structural model.

The proposed structural relationships may also be affected by contextual variables. For example, Handfield (1994) measures the complexity of the products, recognizing that some variance can be explained by contextual variables. This research focused on shared knowledge in product development and had no prior hypotheses concerning the relationships between contextual variables and model variables. Contextual variables that could be added in a future study could included: degree of technology change, competitive environment of the industry, team financial and non-financial incentives, individual financial and non-financial incentives, and fair process. Through extensive literature review, a total of 19 instruments for multiple contextual variables have been developed. Future study may incorporate such contextual variables as antecedents in the model.

Recommendation 9: Future research should also test structural relationships at the specific shared knowledge level.

This research only hypothesized relationships at the aggregate level of shared knowledge and the drivers of shared knowledge. The use of the aggregate variables for testing purposes was supported by high target values for all instruments (high target coefficients for second order factor structure accounted for high proportion of the covariation of the first order factors). Alleged relationships were then tested at the aggregate level. Practitioners, however, would be interested to know how each driver affects particular shared knowledge factors. It has not been documented in the research how team vision, mutual trust, and mutual influence effect specific levels of shared knowledge of customer, suppliers, internal capabilities and process. Specific practices may also be involved with shared knowledge of customer with performance (time, customer satisfaction, etc.) and shared knowledge of suppliers and performance (cost reduction, development time, etc.)

Chapter 7

Conclusion

This dissertation has successfully obtained the objectives mentioned in chapter one. From a methodological standpoint, this dissertation has contributed to the development of an overall IPD model including work integration and knowledge integration which was tested using structural equation modeling through AMOS. This is the first time these variables have been looked at simultaneously in the context of IPD.

For practitioners, this dissertation finds that both work integration and knowledge integration are important aspects of new product development success. Two bridges were found to be significant linking a path between work integration and knowledge integration. This first bridge is created earlier in the fuzzy front end of product development where the extent of use of a heavyweight manager would enhance the overall team vision for that particular project. The second bridge which was found significant was the that level of concurrent engineering increases the shared knowledge level on that particular team. Of interest for both practitioners and researchers was the link of concurrent engineering and shared knowledge to IPD performance outcomes. Concurrent engineering was found to have a non-significant relationship with IPD performance outcomes while shared knowledge displayed a highly significant relationship. The results suggest that although there exists emphasis on concurrent engineering as a major driver of NPD success, what companies and researchers should be focusing on is how to improve levels of shared knowledge either through concurrent engineering or through the drivers of shared knowledge in the IPD team. By the use of concurrent engineering, shared knowledge levels are enhanced which then impacts IPD success.

Finally this dissertation also suggests some recommendations for further research which have been mentioned in Chapter Six. These recommendations involve both measurement and structural issues for future research in IPD. Through these results and future recommendations, this dissertation serves as a starting point for research combining work integration and knowledge practices in IPD.

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Appendix I : Pilot Study Questionnaire

I. For each item, please choose the response that best describes the extent of these practices in the focal project you named.

The 5 point scale is as follows:

1	2	3	4	5
None or to A little extent	To some extent	To a moderate extent	to a great extent	to a very great extent

1. Various disciplines were involved in product development from the early	1	2	3	4	5
stages.	1	2	3	4	5
2. We involved customers in the early stages of product development.	1	2	3	4	5
3. Product development team members represented a variety of disciplines.	1	2	3	4	5
4. Our suppliers were involved in the early stages of product development.	1	2	3	4	5
5. Our suppliers did the product engineering of component parts for us.	1	2	3	4	5
6. Product development managers have a broad influence across the	1	2	3	4	5
organization.	1	2	3	4	5
7. Our product development team met with customers.	1	2	3	4	5
8. Product requirements are solicited, consolidated, and fed back to potential	1	2	3	4	5
customers.	1	2	3	4	5
9. During the requirements definition, potential customers are involved	1	2	3	4	5
continuously and interactively.	1	2	3	4	5
10. Product development managers were given "real" authority over personnel.	1	2	3	4	5
11. Product and process designs were developed concurrently by a team of	1	2	3	4	5
employees from various departments.	1	2	3	4	5
12. Product performance is verified by testing of prototypes by customers.	1	2	3	4	5
13. Product improvements / redesigns occur because improvement ideas from	1	2	3	4	5
customers are solicited.	1	2	3	4	5
14. The team consisted of cross-functional members of the organization.	1	2	3	4	5
15. Our suppliers developed whole subassemblies for us.	1	2	3	4	5
16. Product development mangers had enough influence to make things happen.					
17. The entire project team was involved since the early stages of the project.	1	2	3	4	5
18. All necessary functions of the organization were represented in the project	1	2	3	4	5
team.					
19. Product development managers had a final say in product design decisions.	1	2	3	4	5
20. We visited our customers to discuss product development issues.	1	2	3	4	5
21. Process engineers were involved from the early stage of product development.	1	2	3	4	5
22. Our suppliers developed component parts for us.	1	2	3	4	5
23. We made use of suppliers' expertise in the development of our products.	1	2	3	4	5
24. Manufacturing engineers were involved from the early stages of product	1	2	3	4	5
development.	1	2	3	4	5
25. The team simultaneously planned the product, process, and manufacturing	1	2	3	4	5
activities of the project.	1	2	3	4	5
26. Product development managers had a final say in budget decisions.	1	2	3	4	5

II. The following questions enable you to describe factors that encourage team members to share their knowledge/expertise with other members of their cross-functional team. For each item, please choose the response that best describes the focal project you named above.

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. There was mutual trust among team members.	1	2	3	4	5
2. Everyone on the team had some power to influence others.	1	2	3	4	5
3. The project mission was well communicated to all team members.	1	2	3	4	5
4. The team members shared a belief that all members were acting in good faith.	1	2	3	4	5
5. The team shared a belief that all members were honest.	1	2	3	4	5
7. Our firm's overall technology strategy guided a setting of the project targets.	1	2	3	4	5
8. Each team member had some ability to affect the decisions of others.	1	2	3	4	5
9. Our firms overall product strategy guided a setting of project targets.	1	2	3	4	5
10. Team members trusted each other enough to share sensitive information.	1	2	3	4	5
11. Mutual influence was broadly spread among the team.	1	2	3	4	5
12. The project mission was well understood by the entire team.	1	2	3	4	5
13. Team members trusted each other.	1	2	3	4	5
14. Power was broadly shared among the members.	1	2	3	4	5
15. Each team member had at least some control over the decisions of the team.	1	2	3	4	5
16. The project targets clearly specified tradeoffs between performance and cost.	1	2	3	4	5
17. The team members were confident they could trust each other.	1	2	3	4	5
18. The project purpose was well understood by the entire team.	1	2	3	4	5
19. Each team member had some power to affect team decisions.	1	2	3	4	5
20. The team members trusted each other to share accurate information.	1	2	3	4	5
21. The relative priority of each project target was clear.	1	2	3	4	5
22. The team members relied on each other for the truthfulness of the information shared.	1	2	3	4	5
25. Project targets clearly specified tradeoffs between quality and cost.	1	2	3	4	5
26. The team members trusted each other enough to share all relevant information.	1	2	3	4	5
27. Influence was shared among the team members.	1	2	3	4	5
29. The project mission was well defined for all team members.	1	2	3	4	5
30. The team members were willing to share sensitive information.	1	2	3	4	5
31. All the team members had some authority to influence team decisions.	1	2	3	4	5
32. Project targets reflected the competitive situation.	1	2	3	4	5
33. The project targets clearly specified tradeoffs between time and cost.	1	2	3	4	5
34. All the team members had at least some ability to persuade each other.	1	2	3	4	5
35. The product development team had a well-defined mission.	1	2	3	4	5
36. The project targets were consistent with our overall business strategy.	1	2	3	4	5
37. The Relative priority of each project target was clear	1	2	3	4	5

III. **The following questions enable you to describe the level of shared or common knowledge among the members of your product development team. For each item, please choose the response that best describes the focal project named above.**

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. This product development team shared knowledge of:	
a. Our suppliers design capabilities.	1 2 3 4 5
b. Which features were most valued by target customers.	1 2 3 4 5
c. The capabilities of our engineering staff.	1 2 3 4 5
d. Our suppliers' manufacturing facilities.	1 2 3 4 5
b. Key decision points in the product development process.	1 2 3 4 5
e. What our customers wanted.	1 2 3 4 5
f. The strengths of our manufacturing facilities.	1 2 3 4 5
g. Our suppliers' capabilities to meet quality requirements.	1 2 3 4 5
h. Customer requirements.	1 2 3 4 5
i. Our suppliers' capabilities to meet time requirements.	1 2 3 4 5
j. How our firm should develop products.	1 2 3 4 5
k. The strengths of our engineering development capabilities.	1 2 3 4 5
l. Our suppliers' capabilities to meet cost requirements.	1 2 3 4 5
m. The process of product development.	1 2 3 4 5
n. Our suppliers' process capabilities.	1 2 3 4 5
o. Each other's roles in the product development process.	1 2 3 4 5
p. Current customer needs.	1 2 3 4 5
q. The activities in the product development process that were on the critical path	1 2 3 4 5
r. The capabilities of the process technologies we used.	1 2 3 4 5

IV. **The following statements describe process outcomes. Please choose the appropriate number to indicate the extent to which you agree or disagree with each statement.**

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. This product development team:	
a. Finished engineering change orders on time.	1 2 3 4 5
b. Coordinated design activities effectively.	1 2 3 4 5
c. Was productive.	1 2 3 4 5
d. Delivered engineering change notices on time.	1 2 3 4 5
e. Worked on product improvements successfully.	1 2 3 4 5
2. This product development team:	
a. Resolved design conflicts on time.	1 2 3 4 5
b. Met engineering change deadline regularly.	1 2 3 4 5
c. Completed work quickly.	1 2 3 4 5
d. Communicated effectively.	1 2 3 4 5

V.	The following statements describe product outcomes. Please choose the appropriate number to indicate the extent to which you agree or disagree with each statement.

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1. This product development team:	
a. Reduced the number of parts successfully.	1 2 3 4 5
b. Reduced manufacturing cost successfully.	1 2 3 4 5
c. Reduced the number of manufacturing steps effectively.	1 2 3 4 5
d. Reduced product costs successfully.	1 2 3 4 5
e. Successfully reduced assembly cost.	1 2 3 4 5
2. This product development team:	
a. Reduced material costs successfully.	1 2 3 4 5
b. Reduced equipment costs successfully.	1 2 3 4 5
c. Simplified the design successfully.	1 2 3 4 5
d. Reduced production tooling costs successfully.	1 2 3 4 5
3. Compared to the average industry our product development team:	
a. Launched product to the market faster.	1 2 3 4 5
b. Enabled our company to start volume production faster.	1 2 3 4 5
c. Brought product to the market before our competitors.	1 2 3 4 5
d. Developed product from concept to commercial production faster.	1 2 3 4 5
e. Made better progress in reducing total product development time.	1 2 3 4 5
4. Compared to the average in the industry, our product:	
a. Satisfied customers better.	1 2 3 4 5
b. Fit target customers better	1 2 3 4 5
c. Has more loyal customers.	1 2 3 4 5
d. Was more successful in the marketplace.	1 2 3 4 5
e. Was more highly valued by customers.	1 2 3 4 5
f. generated more new customers	1 2 3 4 5

VI. Shared knowledge "glitches" in NPD. (Glitch is a problem that occurs in design, development, ramp-up, and marketing introduction of new product development): Please rate to what extent "glitches" occurred? **The 5 point scale is as follows:** **1** — **Strongly Disagree**; **2** — **Disagree**; **3** — **Neutral**; **4** — **Agree**; **5** — **Strongly Agree**	
1. To what extent in each of the following did "glitches" occur:	
a. Product design did not meet customer requirements.	1 2 3 4 5
b. Product design did not meet supplier requirements.	1 2 3 4 5
c. Product design did not meet internal manufacturing requirements.	1 2 3 4 5
d. The product was not designed well for assembly.	1 2 3 4 5
e. The design went out for development without considering problem constraints.	1 2 3 4 5
2. General Information:	
a. Knowledge intensity of your product development process is	1 2 3 4 5
b. Your firm's product complexity is	1 2 3 4 5
c. Your firm's process complexity is	1 2 3 4 5
d. The rate of technology change that your firm currently experiences is	
e. The intensity of competition that your firm currently experiences is	1 2 3 4 5
	1 2 3 4 5

VII. General Information: Please provide the following information for statistical purpose.

1. Number of employees

a. _____ up – 499
b. _____ 500 – 999
c. _____ 1,000 – 4,999
d. _____ 5,000 – 9,999
e. _____ Over 10,000

2. In which vehicle system is your company's focal product mentioned (page 1) primarily used?

a. _____ Body Exterior
b. _____ Body Interior
c. _____ Powertrain
d. _____ Body Component
e. _____ Chassis
f. _____ Electrical/Electronic Equipment
g. _____ Other (please describe)

3. The primary status of your company is:

a. _____ Auto Manufacturer / Original Equipment Manufacturer (OEM)
b. _____ Auto supplier
c. _____ Other (please describe)

4. If you are an auto supplier, your company is:

a. _____ An auto supplier owned fully or partially by an OEM
b. _____ An independent auto supplier not owned by an OEM

5. If you are an auto supplier, you company is:

a. _____ First-tier supplier
b. _____ Third-tier supplier
c. _____ Second-tier supplier
d. _____ Other (please describe)

6. If you are an auto supplier, how are you primarily involved by your customer in the design of your products?

a. _____ Customers provide concept, we do the rest
b. _____ We provide initial feedback to the customer on their design
c. _____ Customers provides critical specifications, we do the rest
d. _____ Customer provides complete design, we are not involved
e. _____ We work with the customer to co-develop the design
f. _____ Other (please describe)

7. In what form do you primarily involve your suppliers in product development?

a. _____ We provide concept. Suppliers do the rest
b. _____ Suppliers provide initial feedback to our design
c. _____ We provide critical specifications, suppliers to the rest
d. _____ We provide complete specifications to suppliers
e. _____ We work with suppliers to co-develop the design

f. _____ Other (please describe)

Thank you again for your assistance!

If you have any comments, please write in the following area

Greg Rawski
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Appendix II : Large Scale Study Questionnaire

A Survey of Work Integration and Knowledge Integration In Integrated Product Development

Dear Product Development Professional,

As a doctoral student in manufacturing management and engineering at the University of Toledo, I am conducting my doctoral dissertation research to develop theories on important drivers of work integration and knowledge integration during new product development (NPD) process.

Such research has not been conducted in the past, and it is our belief that the findings of this research will serve a valuable contribution to uncover important practices for product development practitioners that can help in better managing product development processes.

As our survey has been targeted to limited practitioners, I would be personally grateful to you if you can take 20 minutes of your valuable time to fill and mail this questionnaire to me. The data collected in this research is strictly meant for my doctoral dissertation and will not be used for any other purpose. Also, you are not required to disclose any personal information in this survey..

This questionnaire should be answered by those (e.g., product development manager, vice-president, CEO) who have recently managed a cross-functional product development team. Your response to this questionnaire should be based on a particular project in which you were involved, regardless of its success or disappointing result in the market.

Please supply us with information on a particular product development project that you have been involved with:

Name of the Project: ______________________

Market Introduction Date: ___________________

Greg Rawski
Doctoral Student in Manufacturing Management
The University of Toledo
College of Business Administration
Toledo, Ohio 43606

I. For each item, please choose the response that best describes the extent of these practices in the focal project you named above.

The 5 point scale is as follows:

1	2	3	4	5
None or to a Little extent	**To Some Extent**	**To a Moderate Extent**	**To a Great Extent**	**To a very Great Extent**

1. Various disciplines were involved in product development from the early stage.	1	2	3	4	5
2. We involved customers in the early stages of product development.	1	2	3	4	5
3. Product development team members represented a variety of disciplines.	1	2	3	4	5
4. Our suppliers were involved in the early stages of product development.	1	2	3	4	5
5. Our suppliers did the product engineering of component parts for us.	1	2	3	4	5
6. Product development managers have broad influence across the organization.	1	2	3	4	5
7. Our product development team met with customers.	1	2	3	4	5
8. Product requirements are solicited, consolidated, and fed back to potential customers.	1	2	3	4	5
9. During the requirements definition, potential customers are involved continuously and interactively.	1	2	3	4	5
10. Product development managers were given "real" authority over personnel.	1	2	3	4	5
11. Product and process designs were developed concurrently by a team of employees from various departments.	1	2	3	4	5
12. Product performance is verified by testing of prototypes by customers.	1	2	3	4	5
13. Product improvements/redesigns occur because improvement ideas from customers are solicited.	1	2	3	4	5
14. The team consisted of cross-functional members of the organization.	1	2	3	4	5
15. Our suppliers developed whole subassemblies for us.	1	2	3	4	5
16. Product development managers had enough influence to make things happen.	1	2	3	4	5
17. The entire project team was involved since the early stages of the project.	1	2	3	4	5
18. All necessary functions of the organization were represented in the project team.	1	2	3	4	5
19. Product development managers had a final say in product design decisions.	1	2	3	4	5
20. We visited our customers to discuss product development issues.	1	2	3	4	5
21. Process engineers were involved from the early stage of product development.	1	2	3	4	5
22. Our suppliers developed component parts for us.	1	2	3	4	5
23. We made use of suppliers' expertise in the development of our products.	1	2	3	4	5
24. Manufacturing engineers were involved from the early stages of product development.	1	2	3	4	5
25. The team simultaneously planned the product, process, and manufacturing activities of the project.	1	2	3	4	5
26. Product development managers had a final say in budget decisions.	1	2	3	4	5

II. For each item, please choose the response that best describes the focal project you named above.

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. There was mutual trust among team members.	1	2	3	4	5
2. Everyone on the team had some power to influence others.	1	2	3	4	5
3. The project mission was well communicated to all team members.	1	2	3	4	5
4. The team members shared a belief that all members were acting in good faith.	1	2	3	4	5
5. The team shared a belief that all members were honest.	1	2	3	4	5
6. Our firm's overall technology strategy guided a setting of the project targets.	1	2	3	4	5
7. Each team member had some ability to affect the decisions of others.	1	2	3	4	5
8. Our firms overall product strategy guided the setting of project targets.	1	2	3	4	5
9. Team members trusted each other enough to share sensitive information.	1	2	3	4	5
10. Mutual influence was broadly spread among the team.	1	2	3	4	5
11. The project mission was well understood by the entire team.	1	2	3	4	5
12. Team members trusted each other.	1	2	3	4	5
13. Power was broadly shared among the members.	1	2	3	4	5
14. Each team member had at least some control over the decisions of the team.	1	2	3	4	5
15. The project targets clearly specified tradeoffs between performance and cost.	1	2	3	4	5
16. The team members were confident they could trust each other.	1	2	3	4	5
17. The project purpose was well understood by the entire team.	1	2	3	4	5
18. Each team member had some power to affect team decisions.	1	2	3	4	5
19. The team members trusted each other to share accurate information.	1	2	3	4	5
20. The relative priority of each project target was clear.	1	2	3	4	5
21. The team members relied on each other for the truthfulness of the information shared.	1	2	3	4	5
22. Project targets clearly specified tradeoffs between quality and cost.	1	2	3	4	5
23. The team members trusted each other enough to share all relevant information.	1	2	3	4	5
24. Influence was shared among the team members.	1	2	3	4	5
25. The project mission was well defined for all team members.	1	2	3	4	5
26. The team members were willing to share sensitive information.	1	2	3	4	5
27. All the team members had some authority to influence team decisions.	1	2	3	4	5
28. Project targets reflected the competitive situation.	1	2	3	4	5
29. The project targets clearly specified tradeoffs between time and cost.	1	2	3	4	5
30. All the team members had at least some ability to persuade each other.	1	2	3	4	5
31. The product development team had a well-defined mission.	1	2	3	4	5

32. The project targets were consistent with our overall business strategy.	1 2 3 4 5

III. For each item, please choose the response that best describes the focal project named above.

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. This product development team shared knowledge of:	
a. Our suppliers design capabilities.	1 2 3 4 5
b. Which features were most valued by target customers.	1 2 3 4 5
c. The strength of our engineering staff.	1 2 3 4 5
d. Our suppliers' manufacturing facilities.	1 2 3 4 5
e. The steps in the product development process.	1 2 3 4 5
g. The activities in the product development process that were on the critical path.	1 2 3 4 5
h. The points in the product development process where information needed to be exchanged.	1 2 3 4 5
i. Key decision points in the product development process.	1 2 3 4 5
j. What our customers wanted.	1 2 3 4 5
k. The strengths of our manufacturing facilities.	1 2 3 4 5
2. This product development team shared knowledge of:	
a. Our suppliers' capabilities to meet quality requirements.	1 2 3 4 5
b. Customer requirements.	1 2 3 4 5
c. Our suppliers' capabilities to meet time requirements.	1 2 3 4 5
d. How our firm should develop products.	1 2 3 4 5
e. The strengths of our engineering design capabilities.	1 2 3 4 5
f. Our suppliers' capabilities to meet cost requirements.	1 2 3 4 5
g. The process of product development.	1 2 3 4 5
h. Our suppliers' process capabilities.	1 2 3 4 5
i. Each other's roles in the product development process.	1 2 3 4 5
j. Current customer needs.	1 2 3 4 5
3. This product development team shared knowledge of:	
a. Where key deliverables in the product development process were essential to subsequent activities.	1 2 3 4 5
b. The capabilities of the process technologies we used.	1 2 3 4 5
c. Key decision points in the product development process.	1 2 3 4 5
d. What percentage of this team's member had worked with each other in prior development project? _______________ % .	
e. NPD team members had frequent work interactions.	1 2 3 4 5

IV. Please choose the appropriate number to indicate the extent to which you agree or disagree with each statement.

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. This product development team:	
a. Finished engineering change orders on time.	1 2 3 4 5
b. Coordinated design activities effectively.	1 2 3 4 5
c. Was productive.	1 2 3 4 5
d. Delivered engineering change notices on time.	1 2 3 4 5
e. Worked on product improvements successfully.	1 2 3 4 5
f. Resolved design conflicts on time.	1 2 3 4 5
g. Met engineering change deadline regularly.	1 2 3 4 5
h. Completed work quickly.	1 2 3 4 5
i. Communicated effectively.	1 2 3 4 5
2. This product development team:	
a. Reduced the number of parts successfully.	1 2 3 4 5
b. Reduced manufacturing cost successfully.	1 2 3 4 5
c. Reduced the number of manufacturing steps effectively.	1 2 3 4 5
d. Reduced product costs successfully.	1 2 3 4 5
e. Successfully reduced assembly cost.	1 2 3 4 5
f. Simplified the design successfully.	1 2 3 4 5
g. Reduced material costs successfully.	1 2 3 4 5
h. Reduced equipment costs successfully.	1 2 3 4 5
i. Simplified the design successfully.	1 2 3 4 5
j. Reduced production tooling costs successfully.	1 2 3 4 5
3. Compared to the average industry our product development team:	
a. Launched product to the market faster.	1 2 3 4 5
b. Enabled our company to start volume production faster.	1 2 3 4 5
c. Brought product to the market before our competitors.	1 2 3 4 5
d. Developed product from concept to commercial production faster.	1 2 3 4 5
e. Made better progress in reducing total product development time.	1 2 3 4 5
4. Compared to the average in the industry, our product:	
a. Satisfied customers better.	1 2 3 4 5
b. Fit target customers better.	1 2 3 4 5
c. Has more loyal customers.	1 2 3 4 5
d. Was more successful in the marketplace.	1 2 3 4 5
e. Was more highly valued by customers.	1 2 3 4 5
f. Generated more new customers	1 2 3 4 5
	1 2 3 4 5

V. Please rate to what extent did following occur?

The 5 point scale is as follows:

1	2	3	4	5
Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

1. To what extent do you agree that following occurred:					
a. Product design did not meet customer requirements.	1	2	3	4	5
b. Product design did not meet supplier requirements.	1	2	3	4	5
c. Product design did not meet internal manufacturing requirements.	1	2	3	4	5
d. The product was not designed well for assembly.	1	2	3	4	5
e. The design went out for development without considering problem constraints.	1	2	3	4	5
2. To what extent do you agree on following:					
a. Individual NPD team members received regular feedback on their performance.	1	2	3	4	5
b. NPD team received regular feedback on how well the project was progressing.	1	2	3	4	5
c. NPD team membership is considered to be a matter of pride.	1	2	3	4	5
d. Team members receive bonus for successful NPD projects.	1	2	3	4	5
e. Financial incentives are provided for individual performance.	1	2	3	4	5
f. Non-financial incentives (recognition, certificate, etc.) are provided for individual performance.	1	2	3	4	5
g. Financial incentives are provided for team performance.	1	2	3	4	5
h. Non-financial incentives (recognition, certificate, etc.) are provided for team performance.	1	2	3	4	5
i. Team members had a fair chance to participate in decision makings.	1	2	3	4	5
j. Team leaders provided rationale regarding the final decisions.	1	2	3	4	5
k. When trade-offs had to be considered, the decision making process was fair to all.	1	2	3	4	5
l. Team leaders encouraged participation during the meetings.	1	2	3	4	5
m. All meetings and events were announced in advance in time and through proper channels.	1	2	3	4	5
n. Decision making was free from personal or political motives.	1	2	3	4	5
o. Decisions were implemented as per earlier agreement.	1	2	3	4	5
3. Please use the following scale to answer these questions.					

1	2	3	4	5
very low	**low**	**moderate**	**high**	**very high**

a. Your firm's product complexity is	1	2	3	4	5
b. Your firm's process complexity is	1	2	3	4	5
c. The rate of technology change that your firm currently experiences is	1	2	3	4	5
d. The intensity of competition that your firm currently experiences is	1	2	3	4	5

VI. General Information: Please provide the following information for statistical purpose.

1. Number of employees in your company

a. _____ up – 499　　b. _____ 500 – 999
c. _____ 1,000 – 4,999　　d. _____ 5,000 – 9,999
e. _____ Over 10,000

3. If in auto industry, in which vehicle system is your company's focal product mentioned (page 1) primarily used?

a. _____ Body Exterior　　b. _____ Body Interior
c. _____ Powertrain　　d. _____ Body Component
e. _____ Chassis　　f. _____ Electrical/Electronic Equipment
g. ____ Other (please describe) ________________________________

4. The primary status of your company is

a. _____ Manufacturer / Original Equipment Manufacturer (OEM) go to #7
b. _____Supplier
c. _____ Other (please describe)______________________

5. If you are a supplier, your company is:

a. _____ A supplier owned fully or partially by an OEM
b. _____ An independent supplier not owned by an OEM

6. If you are a supplier, you company is:

a. _____ First-tier supplier　　b. _____ Third-tier supplier
c. _____ Second-tier supplier　　d. _____ Other (please describe)

8. If you are a supplier, how are you primarily involved by your customer in the design of your products?

a. _____ Customers provide concept, we do the rest
b. _____ We provide initial feedback to the customer on their design
c. _____ Customers provides critical specifications, we do the rest
d. _____ Customer provides complete design, we are not involved
e. _____ We work with the customer to co-develop the design
f. _____ Other (please describe)_________________________

9. In what form do you primarily involve your suppliers in product development?

a. _____ We provide concept. Suppliers do the rest
b. _____ Suppliers provide initial feedback to our design
c. _____ We provide critical specifications, suppliers to the rest
d. _____ We provide complete specifications to suppliers
e. _____ We work with suppliers to co-develop the design
f. _____ Other (please describe)___________________________