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Knowledge Integration in Integrated Product Development

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An Abstract of

KNOWLEDGE INTEGRATION IN INTEGRATED PRODUCT DEVELOPMENT

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The first objective of this study is the development of a conceptual model of knowledge integration. A clear understanding of the components of knowledge integration and their outcomes in product development may provide an important missing link in integrated product development (IPD) research. The second objective is to develop valid and reliable instruments of three components of knowledge integration (role changes, team vision, and shared knowledge) and product development performance outcomes (process outcomes, manufacturing outcomes and customer outcomes). The third objective is to explore and test the relationships between knowledge integration and IPD outcomes based on the sound theory and standardized measures developed in this research.

The methodology used to derive the instruments (measures) includes an extensive review of literature, interviews with twelve practitioners and an evaluation with seven experts in the field. A pilot study was conducted with thirty firms. An exploratory data analysis with 205 firms followed. Reliabilities of fifteen variables were high (Cronbach's alpha > 0.80) and the instruments were found to be generalizable across the industries surveyed. The factor pattern matrix for each instrument exhibited a simple structure and was easily interpretable. Good discriminant and convergent validity was evident for all instruments.

Structural equations modeling (LISREL) methodology was used to test the relationships between constructs. Research findings support the notion that role changes of design and manufacturing engineers affect the extent of team vision and shared knowledge. It also supports the direct relationship between team vision and shared knowledge, between shared knowledge and product development outcomes (process and product outcomes), and between product development outcomes and market performance of projects.

Recommendations for future research include: (1) benchmark studies of firms by applying the instruments developed in this research to improve actual IPD performances; (2) a combination of work and knowledge integration measures to assess more comprehensive process and product outcomes of IPD; (3) confirmatory factor analysis, the use of multiple methods of obtaining data, and incorporation of contextual variables (e.g. knowledge environment).

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Chapter One

Introduction

The competitive battleground has shifted from improving manufacturing efficiencies to enhancing product development. Increasingly, the competitiveness of U.S. manufacturing firms is determined by their ability to rapidly develop, produce, and market new products successfully. An organization's ability to generate commercially successful products is central to its competitive advantage. Creating product concepts that have high value to customers and moving these concepts from R & D to design, from engineering to production, and into the marketplace with speed and efficiency are hallmarks of many of the world's most successful companies (Clark and Fujimoto, 1991; Clark and Wheelwright, 1993; Brown and Eisenhardt, 1995).

Clark and Fujimoto (1991) define product development as "a process by which an organization transforms data on market opportunities and technical possibilities into information assets for commercial production". Product development is knowledge intensive work. Firms' superior product development capabilities are derived from their ability to create, distribute and utilize knowledge throughout the product processes. According to Jassawalla and

Sashittal (1999), the most difficult yet important challenges facing product development teams are "integration of markets, products, and technologies". Developing highly successful new products is possible through the integration of the abilities of both upstream (e.g., design engineers) and downstream knowledge workers (e.g., manufacturing engineers). Such knowledge integration of cross-functional teams is a key aspect of integrated product development (IPD). In this study, integrated product development (IPD) is defined as "cross-functional product development that is to optimize the design, manufacturing and supporting processes to enhance multiple outcomes of product development" (Ettlie, 1995; Moffat, 1998; Magrab, 1997; DoD, 1998).

"Generic product development" includes five stages: concept development, system design, detail design, testing and refinement, and manufacturing production (Ulrich and Eppinger, 1995). However, the real causes of failures in most product development projects do not lie in their backend but frontend activities. Frontend activities include concept development and are 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 Rosental, 1998). Such strategic, conceptual, and planning activities typically precede the product development execution activities such as the detailed design, prototype test, volume manufacturing, and market launch. At this stage, project teams may not be quite sure of customers' needs, competitors' positions and their internal manufacturing capabilities. "Fuzzy frontend" refers to a lack of clear understanding of frontend activities in product development (Khurana and Rosenthal, 1997).

Knowledge integration affects the entire process of product development. Since critical failures occur at the frontend, effective knowledge integration should start in this early stage and its impact needs to be properly measured. Yet the frontend assessment measures are not yet developed. With an absence of good conceptual models and instruments that test and validate the models, understanding and evaluating the effectiveness of knowledge outcomes in product development teams is still a difficult task. Without good understanding of knowledge integration in the frontend, it is less clear about the knowledge outcomes in product development. Research in this area is still in an early stage of defining the contexts of knowledge integration. Empirical studies that validate sound conceptual models of knowledge integration in IPD are still rare (Pisano, 1994; Grant, 1996; Johannessen, et al., 1999; Hoopes and Postrel, 1999).

In view of such needed research in this area, the first objective is the development of a conceptual model of knowledge integration. An understanding of these relationships may provide an important missing link in IPD research. Thus far, the theoretical framework of IPD is 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: reducing time (Patterson, 1993; Gupta and Wilemon, 1990; Blackburn, 1991), cutting costs (Hartley, 1990; Carter and Baker, 1992;

Handfield, 1994), enhancing quality (Zairi, 1994), effective design of product and process (Rosenthal, 1992), and manufacturability (Ha and Porteus, 1995; Swink, 1999). As long as any management or engineering concepts or theories have any relevance to achieving the aforementioned objectives, they are regarded as a part of IPD. Literature has not yet defined what constitutes knowledge integration in IPD. Based on an extensive literature review, components of knowledge integration, which many authors discussed separately, will be clearly integrated in a model.

The second objective is to explore the relationships between (1) role changes of design and manufacturing engineers, (2) team vision (shared team purpose and mission), and (3) shared knowledge of teams through a large-scale survey. However, knowledge literature usually focuses on a particular aspect of knowledge integration but has not presented a model that captures the complex nature of knowledge integration in IPD. For example, general knowledge leadership is emphasized among cross-functional teams (Cordero, et al., 1998; Norrgren and Schaller, 1999; Maccoby, 1999). However, who should play such a role in cross-functional teams and what role changes need to be made among such leaders who come from highly functional backgrounds are not discussed (Willaert et al., 1998). Strategy literature has emphasized the importance of integrating strategic goals to project targets (Englund and Graham, 1999; Khurana and Rosenthal, 1998) but it is not clear how to assess the extent of strategic integration at project team level.

The appropriation of relevant shared knowledge is also stressed but exactly what constitutes this shared knowledge is not yet well-defined (Nonaka and Takeuchi, 1995; Singh, et al., 1997; Madhavan and Grover, 1998). Many success factors of IPD have been identified but their interrelationships in the context of knowledge integration have not been explored further (Cooper and Kleinschmidt, 1995; Cooper, 1998a; Cooper, 1999). The key assumption is that by bringing people, technology and processes together it is possible to simultaneously achieve the multiple performance requirements mentioned above. In this context, IPD researchers emphasized the importance of the integration of these factors but have not precisely examined the interrelationships of these key components of knowledge integration.

The third objective of this research is to develop valid and reliable instruments. Instrument development is a necessary foundation to test and validate a conceptual model. Standardized measures of knowledge integration measures (i.e., role changes, team vision and shared knowledge) also make it possible to examine their interrelationships. These standardized measures intend to be objective (e.g., testable with unambiguous procedures for documenting empirical evidences of learning practices of automotive industries in IPD), quantifiable (e.g., numerical indices in items make it possible to report results of knowledge integration practices of different firms in numbers), communicable (e.g., the process and product outcomes of learning practices are communicable to other researchers), economical (e.g., researchers and firms are able to save time and money in studying and comparing their integrated product development with others), and scientifically generalizable (e.g., the instruments may be useful beyond particular industries) (Nunnally, 1978). These benchmarking instruments are designed to capture the status of the best practices in knowledge integration early enough to make a difference in multiple performance outcomes of product development.

Finally, a fruitful 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 studies in knowledge integration 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. The research findings will be helpful to further promote understanding of this important research topic. Furthermore, it may shed better light on how to enhance IPD performances through knowledge integration.

Chapter Two

Theory Development

The three driving forces that put product development at the center stage of the competitive battlegrounds are: intense global competition, fragmented markets with sophisticated customers, and diversified technologies (Clark and Fujimoto, 1991). This changing competitive environment demands new products to display integrated sets of requirements--quality (i.e., total product quality including reliability, functionality, and customer satisfaction), efficiency/cost (i.e., product cost and the overall costs of development) and speed (i.e., time required to develop product from initial product concept to market introduction) (Clark and Wheelwright, 1995). In today's competitive environment, firms are expected to excel in multiple performance measures. Deficiency in even one area is regarded as a serious handicap.

It is widely accepted that integration across functional specialties drives superior product development performances in multiple areas. This conclusion is consistent across industries: automobiles (Clark and Fujimoto, 1991; Clark and Wheelwright, 1993), mainframe computers (Iansiti, 1997), and pharmaceuticals (Henderson, 1994; Pisano, 1994). Numerous other studies confirm this point as well (Clark and Fujimoto, 1991; Leonard Barton, et al., 1994; Adler, 1995; Cooper and Kleinschmidt, 1995; Cooper, 1998a, 1998b).

From a marketing and project management standpoint, the integration effort is directed in screening the most promising project proposals and securing the best possible portfolio of projects for overall business success (Cooper, 1996; Cooper, Edgett and Kleinschmidt, 1998b; Archer and Ghasemzadeh, 1999). The firm's mission and overall business strategies, not individual projects, should guide the effective portfolio of projects. This study, however, is not about project screening, selection or portfolio management. Neither does this research focus on specific work practices like concurrent engineering nor supply chain management; rather, the focus of this research is integrated product development (IPD) with special attention on project teams' abilities to create new knowledge, disseminate it, and embody it in products and services.

2.1. INTEGRATED PRODUCT DEVELOPMENT

In the early 1900's, as industrialization was intensified, organizations became more specialized in order to deal with the uncertainty associated with diverse environments (Daft, 1989). As specialization is intensified, functional departments with particular knowledge segments also develop differences in attitude and behavior. Marketing managers, for example, may have a unique knowledge of the external environment (e.g., competitors and customers), which is different from that of engineers. Engineers develop certain attitudes in regard to their design work and display behavioral patterns that may be quite distinct from research and development people. In this environment, traditional product development is characterized by work specialization. Different functions separately carry out narrowly confined areas of responsibility and they develop different attitudes and behavioral practices. Such increasing specialization and differentiation naturally hinders communication, coordination, and collaboration among functions and accordingly results in longer time and higher cost for product development. Specialization and differentiation may be inevitable and yet, the real challenge is how to integrate these different orientations and achieve the organization's overall purpose.

Figure 2.1. shows the evolution of product development—from sequential, functional specific product development to concurrent, cross-functional integrated product development (IPD). Researchers concluded that the key to simultaneously achieving these multiple objectives (i.e., successful product development) is the integration of critical processes and people. A shift toward IPD has occurred as firms increasingly recognize the problems associated with sequential product development activities in the rapidly changing and highly competitive environment.

As each function (R & D, marketing, engineering and manufacturing) operates in a fragmented and separated manner, barriers of communication exist, knowledge is not properly transferred and complex problems are not resolved in a timely manner. As a consequence, firms are less able to focus on multiple performance goals (e.g., time, quality, cost, and delivery) and to achieve strategic goals.

This integration takes increasingly complex forms to capture the synergy of intra-company and intercompany integration and relationships. Even integration in product development involves team integration (i.e., forming a team with members from all the appropriate functions), intra-process integration (i.e., managing the entire development project from its concept formulation through market introduction), resource integration (i.e., giving the team the authority and resources to carry out the project), and chain integration (i.e., involvement of customers and the supply chain for product development) (Lambert and Cooper, 2000). In this context, product development has evolved from a functional specific, step-by-step approach to a cross-fucntional, integrated product development (IPD).

2.1.1. Knowledge and Work Integration

Over the years, many firms have streamlined workflows and tried to improve the processes of product development. Such integration efforts have brought noticeable improvements to companies and resulted in good marketplace performances, but they have also created additional and unexpected problems. Cross-functional coordination has improved, but at the expense of depth of knowledge within functions (Sobek, Liker and Ward, 1998). The challenge is to develop team learning capabilities to provide the overall depth of knowledge required for sustainable innovation.

According to Kim (1993) the team learning process goes through Kofman's OADI cycle (observe, assess, design and implement). In his model, conceptual (i.e., assess and design) and operational (i.e., implement and observe) learning is distinguished. On a team level, the conceptual aspect of learning is knowledge integration (i.e., know-why or learning by planning or modeling) and the operational aspect of learning is work integration (i.e., know-how or learning by doing).

This study explores the nature of knowledge integration in IPD. Knowledge integration in IPD has the cycle of assess and design. The assessment cycle of a product development team is to exploit knowledge and the cycle of design is to explore knowledge. In this study, knowledge integration in IPD is defined as "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."

On the other hand, work integration in IPD also has the cycle of implement and observe. The implementation cycle of product development is devising optimum workflows. The observation cycle of product development is evaluating actual enhancement of multiple product development outcomes. In this study, work integration in IPD is defined as "operational optimization of cross-functional workflows for enhancement of multiple product development outcomes." In brief, the IPD cycle has both knowledge and work integration. IPD has two important aspects (i.e., work and knowledge integration). For the purpose of this study, work integration is briefly discussed in its relationship with knowledge integration. Then, knowledge integration is examined in depth.

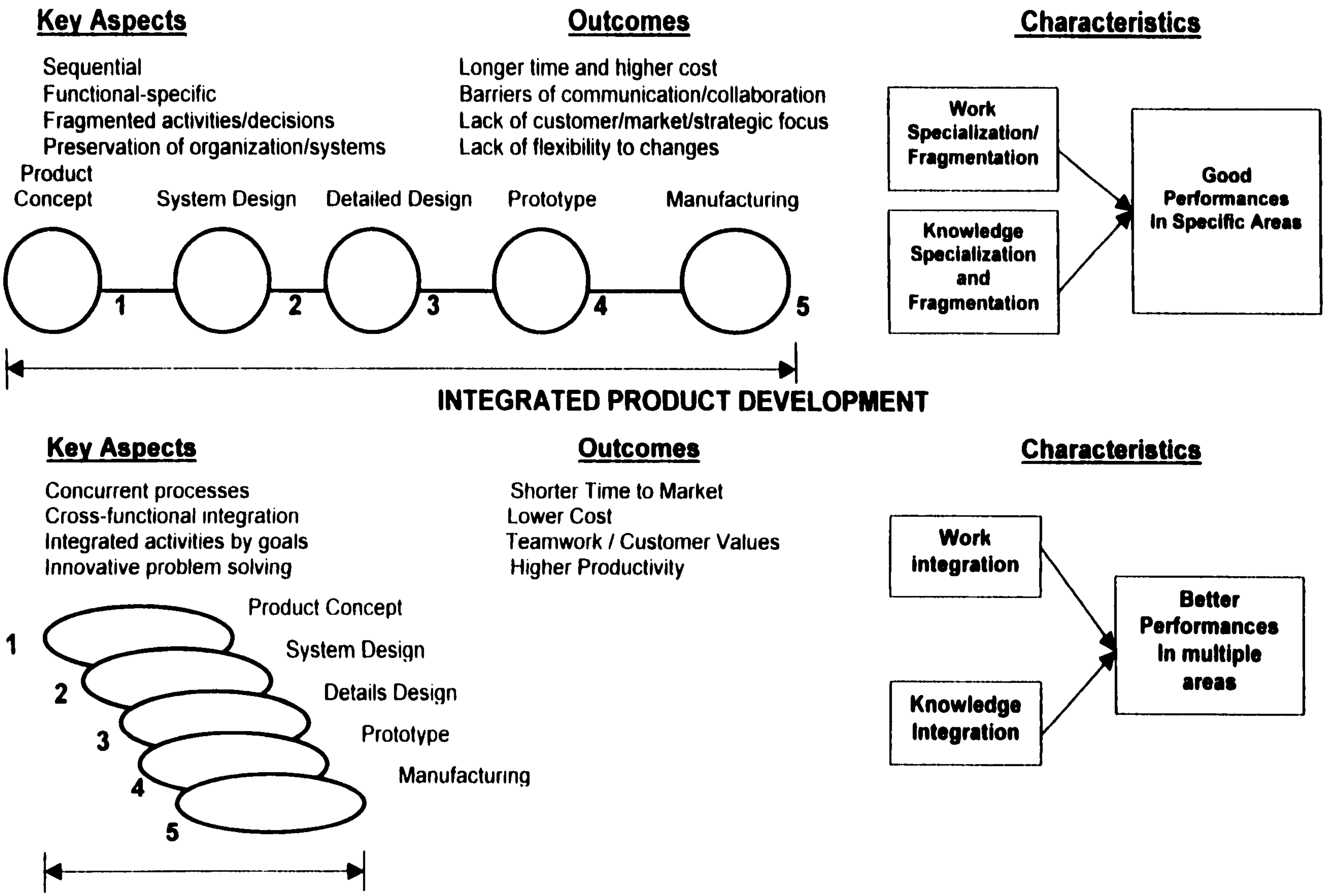
Unlike work integration, knowledge integration may not be easily formalized and integrated into the routine because knowledge is less observable and less easy to transfer. Workflows, however, may be more easily observed and their integrating mechanisms may be relatively simple to duplicate compared to knowledge integration. In that sense, knowledge integration is not as tangible and observable as workflow integration. It takes time and effort to develop a high degree of knowledge integration. It is essential to have collaboration and cooperation among team members to enhance their knowledge integration.

2.1.2. Knowledge Exploitation and Exploration

As IPD teams strive for performance enhancement, a lot of firms discover that their efforts to enhance IPD performance fail not necessarily because of lack of coordination or workflow disruptions (e.g., failures of meeting schedules and sequences), but because of a lack of cross-functional or inter-specialty knowledge about problem constraints (Hoopes and Postrel, 1999). An integration effort has to move beyond doing away with known and obvious inefficiencies within the system. It has to move to a much deeper level—finding a high level of innovative solutions for product development. For example, IPD teams share a great deal of preliminary information about their designs, which is subject to change as more definite decisions are made down the road. An efficient streamlining of the work process alone is not what makes IPD successful. Rather, what matters is the collaboration and coordination of design and manufacturing engineers to effectively deal with manufacturing issues in the early stages.

In a broad sense, successful IPD requires the creation and utilization of new knowledge, because ultimately the new products and services are the outcome of creation, utilization and the embodiment of the knowledge. Integration has to occur on a conceptual level--beyond operational work--because knowledge is embedded in people and products. This knowledge needs to be continuously explored and used. Sustaining knowledge exploitation and exploration are essential elements of successful product development (McNamara and Baden-Fuller, 1999).

Figure 2.1. IPD: Evolution of Product Development



Under rapidly changing market needs and a wide variety of available technologies, design and manufacturing engineers continue to define and modify product concepts, design specifications and manufacturing processes. Knowledge integration requires the coordination and collaboration of team members. For this, knowledge leadership is important. Engineers can assume knowledge leadership with proper changes in the aspects of their traditional roles. Therefore, role changes of engineers are an essential component of knowledge integration. Successful product development depends on how quickly project teams capture, share and utilize relevant knowledge components (i.e., shared knowledge) and integrate them to derive innovative solutions for new products (Iansiti and MacCormack, 1997).

To further explore the key components of knowledge integration, it is helpful to examine the nature of knowledge integration. Knowledge integration involves both exploitation and exploration of new knowledge for innovative problem solving. Knowledge exploitation has to do with utilizing existing knowledge to identify problems. Knowledge exploration occurs when existing knowledge is not sufficient to solve the problems identified.

The knowledge exploitation stream primarily focuses on goal-integration and innovative problem definition based on existing knowledge. Innovative problem definition includes the firm's capacity to assimilate and exploit knowledge (Cohen and Levinthal, 1990), the value of information (Von Hippel, 1994), interfunctional information transfers (Soulder and Moerhart, 1992), factors affecting the success of product development (Brown and Eisenhart, 1995), product innovation determinant (Romano 1990), interpretative barriers to successful product development (Doughty 1992), factors of organizational and technical innovation for product development (Dougherty and Heller, 1994), and factors of developing products quickly (Schoonhoven, Eisenhardt and Lyman, 1990; Ettlie, 1995; Eisenhardt and Tabrizi, 1995; Adler, Mandelbaum, Nguyen and Schwerer, 1995; Liberatore and Stylianou, 1995; Brown and Karagozoglu, 1993; Banbury and Mitchell, 1995).

On the other hand, the knowledge exploration research focuses on finding innovative solutions for problems through cooperation and collaboration among firms (Shan, Walker and Kogut, 1994; Zander and Kogut, 1995), identifying processes and methods of knowledge diffusion (Abrahamson, 1991; Abrahamson and Fombrun, 1994), roles of information systems for knowledge creation (Swanson, 1994), knowledge creation for new products (Dougherty 1990), methods creation for capturing the value from process innovation (Ettlie and Reza, 1992), utilizing product knowledge embedded in culture and information processing systems (MacCrimmon and Wagner, 1994), and computer-based idea generation (Henderson and Clark, 1990). Knowledge exploration is directed to create new knowledge while utilizing existing knowledge as a base for expansion.

Fiol (1996) urged the researchers to integrate both streams of knowledge exploitation and exploration. The knowledge exploitation research stream focuses on problem definition (i.e., *what is the problem and solution based on the existing mental models and perspectives).* Knowledge exploration research streams deal with problem solution (i.e., *what to do about the problem*) with expanded perspectives and shared mental models. In that sense, knowledge integration includes both knowledge exploitatin and exploration to achieve multiple IPD performance outcomes. Team vision is, in a sense, a focus on innovative problem definition. Team vision directs team members to set broad and specific goals that lead to desirable IPD performance outcomes. On the other hand, shared knowledge is about finding innovative problem solving through sharing relevant knowledge among cross-functional teams. Shared knowledge of customers, suppliers, competitors, products, and internal capabilities not only utilizes existing knowledge but also enhances a greater level of knowledge exploration because shared understanding of key knowledge components facilitates tackling problems with innovative solutions which were not available in the past. Both team vision and shared knowledge may effect performance enhancement in IPD. In order to understand the impact of a particular element of team vision or shared knowledge, multiple measures of product development performance need to be properly identified.

2.2. A RESEARCH MODEL OF KNOWLEDGE INTEGRATION

Table 2.1. is a brief description of key constructs of knowledge integration. This is not a comprehensive list of literature. The purpose of Table 2.1. is to show that different authors have focused on some of the aspects of knowledge integration. But each of these components was not properly linked together in a

coherent model. Yet, each of these representative authors emphasized some of the important aspects of integration.

The first important research stream focuses on the importance of integration of product design and manufacturing processes. Successful product development involves integration of product design and manufacturing process design (Ettlie and Reza, 1992; Ettlie, 1995). Based on an extensive case study of the Toyota Company, Sobek (1997) emphasized the knowledge leadership of engineers, especially that of chief engineers, for effective integrated product development effort. Broad integration of product design and manufacturing process design is a key aspect of knowledge integration and this requires active involvement of design and manufacturing engineers in IPD.

The second aspect of knowledge integration is the importance of strategic focus in IPD. Successful product development is possible when the IPD teams of companies maintain a strategic focus (Ettlie, 1995). Because of resource constraints, firms expand their product lines within reasonable boundaries, stay in touch with changing customer needs and utilize their internal capabilities (Madique and Hayes, 1984, Crawford, 1991). Such focus has to occur in the very early part of the product development processes. Khurana and Rosenthal (1997, 1998) stressed the importance of frontend activities in product development. Frontend activities involve clear definitions of product concepts, careful planning of projects and clear assessments of customers' needs. All these frontend activities require a high level of focused work by cross-functional teams.

Table 2.1. Key Constructs of Knowledge Integration in IPD

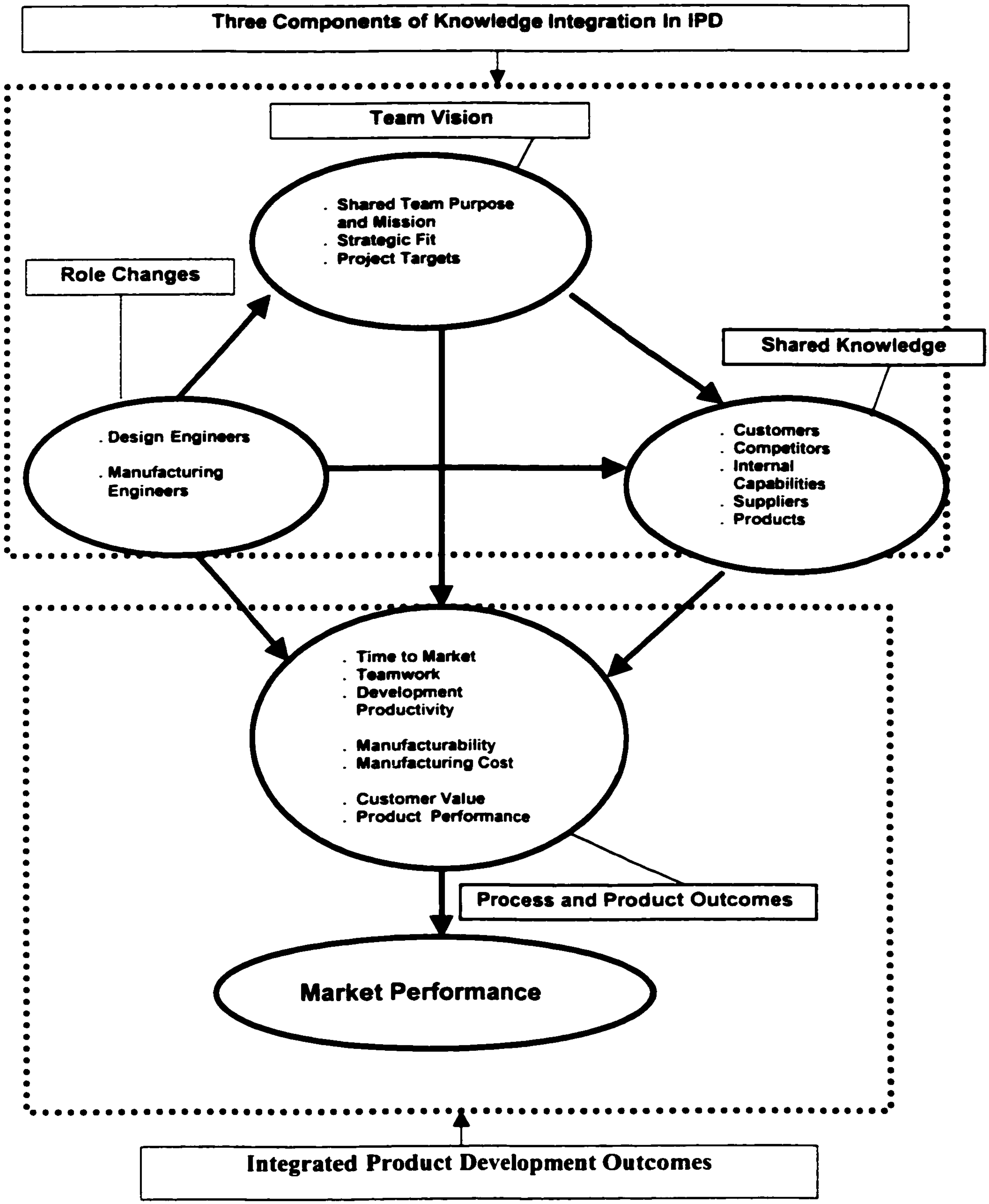
Constructs	Authors	Research Themes
Engineers' Role Changes in Cross-functional Teams	Page, 1993; Turtle, 1994; Paashuis, 1998 Sobek, 1997; Sobek et al.,1998, 1999 Ettlie and Reza, 1992; Ettlie, 1995	(1) Cross-functional teams are the structural solutions for managing product development task (2) Importance of engineers' knowledge leadership in cross-functional teams (3) Importance of integration of product design and manufacturing processes
Team Vision	Madique and Hayes, 1984; Crawford, 1991, 1992; Ettlie, 1995 Khurana and Rosen-thal,1997, 1998 Paashuis, 1998	(1) Importance of strategic focus (2) Identifying integration mechanisms in IPD, focused on front end activities (3) Identifying five integration mecha-nisms in IPD, esp., strategy and goals
Shared Knowledge	Ettlie and Stoll, 1994; Clark, 1989; Ettlie, 1995 Zander & Kogut 1995; Henderson & Clark, 1990; Pisano, 1994; Simonin, 1997	(1) Importance of disciplined problem solving (2) The importance of collaborative know-how (i.e., shared knowledge) for innovation in general and product development in particular
Performance Outcomes	Calantone, Vickery, Droge, 1995; Cooper and Kleinschmidt, 1995; Cooper, 1998a	Value of IPD performance measures–process, product outcomes, and market performance of projects

The third aspect of knowledge integration is disciplined problem solving. Successful firms concentrate effort on a few, high priority issues (Ettlie and Stoll, 1990; Ettlie, 1995; Clark, 1989). Problems that IPD teams face are complex and their implications are multiple. New knowledge is constantly created in the course of the product development processes. The amount of available knowledge is in many cases more than enough for team members to handle. In this context, effective sharing of relevant knowledge is what matters (Zander and Kogut, 1995; Henderson and Clark, 1990; Pisano, 1994; Simonin, 1997). This requires a high level of discipline among the project team members so that team members may have shared mental models and adequate understanding of key issues and problems but not be overloaded with unnecessary information (Nelson and Cooprider, 1996; Hoopes and Postrel, 1999).

The value of product development performance measures has been emphasized (Calantone, et al., 1995; Cooper and Kleinschmidt, 1995; Cooper, 1998a). In the subsequent section, the detailed aspects of these constructs will be examined further.

Figure 2.2. is the research model, which shows the components of knowledge integration and their interrelationships. This model indicates the critical importance of knowledge leadership of design and manufacturing engineers, a team's shared vision and mission, and the shared knowledge of cross-functional teams. The dotted upper rectangular area identifies three components of knowledge integration (i.e., role changes, team vision, and shared knowledge). The dotted lower rectangular area denotes two outcome components (i.e., product development performances and market performance) of knowledge integration in IPD.

Figure 2.2. RESEARCH FRAMEWORK



2.2.1. Role Changes of Engineers

The topics of work roles and role adjustment have been investigated in various contexts. Work role transitions (or changes) have been explored in the case of job changes (Nicholson, 1984; West, Nicholson and Rees, 1987), organizational changes (Rizzo, House and Lirtman, 1970; Sarbin and Allen, 1968), and changes in work assignments overseas (Black, 1988). Very little has been done in studying the role changes of engineers in the context of IPD, with special focus on knowledge integration. With limited research on the role changes of engineers in IPD, items are drawn from a wide variety of literature from areas of organizational behavior, leadership, teamwork, empowerment and job design.

2.2.1.1. Engineering Leadership in IPD

Authors on IPD believe team organization to be the most appropriate product development organization (Ulrich and Eppinger, 1995; Turtle, 1994; Smith and Reinersten, 1991). According to a study by the Product Development and Management Association (PDMA), technical professionals spend approximately 56% of their time in product development and over 76% of firms in the study used cross-functional teams to develop new products (Page, 1993). IPD, as an example of cross-functional and knowledge intensive work, requires high involvement and collaboration of its team members (Spreitzer, 1996; Jassawalla and Sashittal, 1999).

An IPD team can integrate its knowledge intensive work effectively if it is assigned all the tasks (i.e., from product concept to market introduction) and is given the authority and resources to carry out the project. On a program level, empowered leadership (i.e., heavyweight managers) is critical for integration. Their primary contribution is to secure resources for specific projects that might otherwise be neglected and to oversee the different projects to achieve overall program objectives (Ancona and Caldwell, 1990; Clark and Fujimoto, 1991; Sicotte and Langley, 2000). On a project level, the critical aspect of knowledge leadership is how to "integrate" (i.e., create, share and use) knowledge of diverse specialists (Griffin and Hauser, 1996; Song and Parry, 1993; Davenport, De Long, and Beers, 1998) to effectively implement the projects and successfully develop new products according to specified goals that fit the overall organizational purposes.

Turtle (1994) reports that up to 70% of project delays are due to poor planning at the outset. For manufacturing industries, team structures are often associated with high levels of engineering and manufacturing influence in the early stages of IPD product development (Izuchukwu, 1996; Sobek, et al., 1998). They involve planning the process and managing concurrent engineering for the project's overall effectiveness. Wheelwright and Clark (1992) assert that effective concurrent engineering requires knowledge of manufacturing constrains and capabilities. Design and manufacturing engineers supply their expertise on design reviews and manufacturing process planning in the early planning stage (Ulrich and Eppinger, 1995; Leonard-Barton, et al., 1994). In that sense, the more IPD is implemented, the more engineers are expected to work on the front-end strategic, conceptual work that precedes the detailed design and manufacturing of a new product.

2.2.1.2. Nature of Role Changes of Design and Manufacturing Engineers

Table 2.2. defines the scales of role changes of design and manufacturing engineers and their literature base is cited. In IPD, team members interact with other members from different disciplines. Each member represents his/her particular functional area and therefore, he/she is expected to act as an expert in that area. Therefore, as the team is engaged in a higher level of knowledge integration, each team member's qualification requirements in terms of education, training and technical skills would not be diminished but rather enhanced. Each functional representative needs to have a solid grasp of his/her area. Design or manufacturing engineers, for example, would be expected to handle more complicated design requirements with his/her increasing design or manufacturing capabilities. Both design and manufacturing engineers' technical skills become more complicated and their education/training requirements might become more rigorous than before (Nicholson, 1984; Redmond, Mumford and Teach, 1993).

As IPD team members interact with one another, the behavioral aspect of their work is as important as the technical aspect. Their work includes relating to their team members effectively. Therefore, the behavioral components of their work (e.g., the ability to communicate, work together and resolve conflicts) are essential in successful work outputs (Vliert, Nauta, Giebels and Janssen, 1999).

Table 2.2. Role Changes in Integrated Product Development

Variables	Definition	Literature-Base
Role Changes of Design and Manufacturing Engineers	The extent of alternation of design and manufacturing engineers'	Etllie and Reza, 1992; Ettlie and Stoll, 1994; Ettlie, 1995; Tatikonda, 1994
	• personal qualities (i.e., professional qualifications, training, technical and behavioral skills),	Nicholson,1984; Redmond, Mumford, and Teach, 1993
	• member relationships (i.e., power or influence),	Blau and Alba, 1982; Lawrence and Lorsch, 1986; Spreitrzer, 1996
	• perceptions of their work (i.e., job complexity,	Locke, 1976; Hagedoorn, Yperen, Vliert and Buunk, 1999
	• job enrichment, • job enlargement,	Hackman and Oldham, 1980; Hackman, 1986
	• job satisfaction)	Cranny and Stone, 1992; Spector, 1997; Robie, et al., 1998
	in the course of implementing cross-functional teamwork in product development.	Thomas, and Tymon, 1994; Cordero, Farris, DiTomaso, 1998

In IPD teams, individuals who have a high degree of access to information or knowledge tend to have a higher level of power and influence (Blau and Alba, 1982; Spreitrzer, 1996). Naturally, with the implementation of IPD, the power and influence of engineers may increase among the team members because of their deeper understanding of design and manufacturing capabilities.

Lawrence and Lorsch (1986) found that the characteristics of effective knowledge integration are balance (i.e., a team does not depend too much on one particular functional orientation), influence (i.e., influence derived from knowledge and expertise valued by all team members, not just positional authority), and rich exchange (i.e., formal and informal sharing of information and knowledge to solve problems). The core of engineers' knowledge leadership is the combination of their particular functional knowledge and their ability to utilize or assimilate the knowledge of other team members in order to attain common objectives. Therefore, with the implementation of IPD, design and manufacturing engineers need to tackle broader issues beyond their narrowly defined technical engineering areas. For example, both design and manufacturing engineers' roles are critical when a cross-functional team reviews project status with respect to not only design for manufacturability but also other key performance targets such as cost, time and quality. Therefore, traditional engineers' roles need to be enlarged so as to effectively resolve complex product development issues in IPD (Hackman and Oldham, 1980; Hackman, 1986).

As members of a cross-functional team, engineers' work may be more demanding and rewarding than working as members of a functional group

(Cordero, Farris and DiTomaso, 1998). With a greater perceived importance of their work, engineers may experience enrichment of their work. They may have a better sense of their work with increasing intelligence/knowledge requirements and appreciation of their work among the team members (Hackman and Oldham, 1980; Brief and Nord, 1990).

With the implementation of IPD, perceived favorable causal factors (e.g., more autonomy, power and influence) may positively affect the level of job satisfaction (Robie, et al, 1998; Uhl-Bien and Graen, 1998; Spector, 1997). In spite of the potential negative impact of increasing job complexity and added responsibilities, the overall job satisfaction may be positively affected (Cranny and Stone, 1992; Ganzach, 1998).

2.2.2. Team Vision

Growth in organizations typically results from successful projects that generate new products, services, or procedures. Project managers are increasingly concerned about getting better results from the projects that are under way in their organizations and in getting better cross-functional cooperation. Developing cooperation across projects requires that upper managers take a strategic and systematic approach to projects. This means that they need to look at projects as a system of interrelated activities and carefully examine each project's contribution for the overall strategic objectives (Graham and Englund, 1997; Englund and Graham, 1999).

In IPD, team vision is a shared purpose and plan of action that clarifies mission, strategic fit, and sets of project targets and priorities that are consistent with the firm's internal capabilities and the market place realities (Rosenthal and Tatikonda, 1990; Rosenthal and March, 1986; Clark and Wheelwright, 1993; Marquart and Reynolds, 1996). Team vision is a critical linkage between role changes and shared knowledge to bring about positive product development outcomes.

Table 2.3. shows the four variables of team vision (i.e., shared purpose and mission, strategic fit of project targets, clarity of project targets and tradeoff of project targets), their definitions and each corresponding literature base. Shared purpose and mission describes the future state associated with project success. Strategic fit of project targets is for use in identifying important factors that assess and compare a projects' ability to achieve overall strategic goals. On the other hand, clarity of project targets is for use in evaluating alternatives among existing and potential projects and deciding exactly what the project is to accomplish among the set of targets. Tradeoff of project targets is for use in analyzing cost and benefits of project target specification. the first two variables (i.e., shared purpose and strategic fit) relate project characteristics to broad organizational or program goals, while the last two variables (i.e, clarity and tradeoff of project targets) examine project specific characteristics.

2.2.2.1. Shared Team Purpose and Mission

"In innovation, as in any other endeavor, 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." (Peter Drucker, 1998)

Team vision 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. 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. Product concept is an elaborated version of the idea expressed in meaningful consumer terms (Khurana and Rosenthal, 1997; Kotler, 1999).

A lack of shared vision is a major reason for disappointing performance (Lynn, 1998). Having a clear vision and having that vision shared and agreed to by others on the team (i.e., coherent vision) were recurring themes for successful innovation (Leonard-Barton, et al., 1994). 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).

Table 2.3. Team Vision in Integrated Product Development

Variables	Definition	Literature-Base
Shared Team Purpose and Mission	The extent of a shared purpose and plan of action for product development.	Tjosvold, 1989; Rosenthal 1992; Rosenthal and Tatikonda, 1992 , 1993; McComb, Green, and Compton, 1999.
Strategic Fit of Project Targets	The extent of alignment between team's mission and overall business, technology and product strategy.	Cooper, 1983, 1985; Cooper and Kleinschmidt, 1987; Lilien, 1989; Rosenthal and Tatikonda, 1992; Rosenthal and Tatikonda, 1993.; Englund and Graham, 1999.
Clarity of Project Targets	The extent of communication and understanding of a set of project goals that guided develop-ment efforts.	Rosenau, 1989; Clark and Wheelwright, 1993; Marquardt and Reynolds, 1996; Schein, 1996.
Tradeoff of Project Targets	The extent of project targets specification in terms of performance, cost, quality and time.	Kloppenborg and Mantel, 1990; Gupta and Klaus, 1992; Prabuddha, Dunne, Ghosh, and Wells, 1995; Babu and Suresh, 1996.

2.2.2.2. Strategic Fit of Project Targets

Strategic fit is the extent of alignment between the team's mission and overall business, technology and product strategy. Strategic fit is the extent to which a firm's overall business, product, and technology guide the product development contents and processes (Cooper, 1983, 1985; Cooper and Kleinschmidt, 1987; Wheelwright and Clark, 1992b). The team members need to 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, 1993).

If a particular product concept fits the overall strategic direction, it has a better chance of being selected (i.e., the project moves faster), accepted (i.e., better team coordination) and executed (i.e., less cost) among team members (Crawford, 1991, 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, Muth, and Schmenner, 1992), and manufacturing cost (Cusumano and Nobeoka, 1992).

2.2.2.3. Clarity of Project Targets

Clarity of project targets relates to the extent of communication and understanding of a set of project goals that guide development efforts. Clarity of project targets requires unambiguous definition, rich communication, and common understanding of project targets among team members (Gupta and Klaus, 1992; Schein, 1996; Marquardt and Reynolds, 1996). Effective project targets are based on realistic customer requirements (Rosenau, 1989), and good understanding of competitive situations and technical risks (Clark and Wheelwright, 1993). Sound team members strive to set project objectives that are consistent with manufacturing capabilities, suppliers' capabilities, and resources (Clark and Wheelwright, 1993; Schein, 1996).

Having clear project targets may be critical in improving cycle time (i.e., time to market), teamwork and overall process productivity because knowing clear project targets enable team members to focus their resources faster and more effectively (Murmann, 1994).

2.2.2.4. Tradeoffs of Project Targets

Contingent theories have long held that performance is contingent on the fit between the organization's strategy and its product development practices (Gupta, et al., 1986; Dougherty, 1990, 1992). For firms that compete by being able to develop products faster than competitors, this supports the organization's strategy by enabling quicker response to changing technologies and customer demands. In contrast, firms competing on the basis of low cost or mature products or with products that have long life cycles or high switching costs and barriers to entry may see little gain from quicker product development (Crawford, 1992; Ittner and Larcker, 1997).

Tradeoffs of project targets refers to the extent of project targets specifications in terms of performance, cost, quality and time. Time-cost tradeoff analyses were well developed in the project management literature (Robinson, 1975; Moder, et al., 1995). Larger and more complex projects take more time. Accelrated product development incurs higher hidden costs (Crawford, 1992). In IPD, time-cost tradeoff is about the overall product development time and its associated costs. Technologically more advanced products take longer to develop than less advanced products (Karlsson and Ahlstrom, 1999). Cost-quality tradeoff is about comparing the cost in terms of resources for producing particular products and the quality of the products received by customers (Bolot, 1996).

As more firms engage 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 teamwork and enhance development productivity.

2.2.3. Shared Knowledge

Dougherty and Heller (1994) argued that the activities that constitute product innovation may be grouped into three sets of linkages. The first set of linkages is the one that innovators make between market and technological possibilities. The second set of linkages is made between the expertise of different functions or departments within the organization. The third set of linkages is made between the product and the firm's strategy and resources (i.e., strategy and goals). The first linkage is about external knowledge components, which are, in an IPD context, knowledge of customers, competitors and suppliers. The second linkage is about internal knowledge components, which are knowledge of internal capabilities and products. The third linkage is about linking a particular project with overall strategic goals and objectives (i.e., team vision). Therefore, the two knowledge integration components (i.e., team vision and shared knowledge) are a part of vital knowledge integration linkages. Recently, some researchers have explored the importance of shared knowledge for the success of a firm's product development efforts (Nonaka and Takeuchi, 1995). However, studies of shared knowledge are limited in a particular industry: information systems (Nelson and Cooprider, 1996), and the software industry (Li and Calanton, 1998; Hoopes and Postrel, 1999). At present, little is known about the impact of shared knowledge in IPD for manufacturing firms. Also, little is known about whether, or under what conditions, a particular aspect of shared knowledge enhances a firm's product development outcomes.

Shared knowledge is one of the unique, valuable and critical resources that is central to having a competitive advantage (Nonaka and Takeuchi, 1994, 1995; Prahalad and Hamel, 1990). Firms increasingly rely on building and creating a shared knowledge base as an important resource capability (Huber, 1991, 1996; Nonaka, 1994; Matusik and Hill, 1998). On a project level, teams share knowledge of individuals in order to solve problems and find innovative solutions (Davenport, Jarvenpaa and Beers, 1996; Drucker, 1991; Kogut and Zander; 1992; Winter, 1987). Shared knowledge is viewed as an understanding and appreciation among different functions and effective shared knowledge is viewed as a synergy between team members (Bostrom, 1989; Hoopes and Postrel, 1999).

Table 2.4. Shared Knowledge in Integrated Product Development

Variables	Definition	Literature–Base
1. Knowledge of Customers	The extent of a shared understanding of current customer needs and future value to customer creation opportunities among product development team members.	Day, 1990, 1994a; Clark and Wheelwright, 1993; Dolan, 1993; Slater and Narver, 1995; Cordell, 1997.
2. Knowledge of Competitors	The extent of a shared understanding of product development team members concerning competitive realities (e.g., advantages and disadvantages of competitors, threats and opportunites).	Porter, 1985, 1990, 1998; Day and Prakash, 1994; Day and Wensley, 1994; Sanchez, 1996; Andrew, 1996; Baldwin, 1997; Hendricks and Singhal, 1997; Whitehill, 1997.
3. Knowledge of Internal Capabilities	The extent of a shared understanding of the firm's internal design, process and manufacturing capabilities among product development team members.	Clark and Wheelwright, 1993; Garvin, 1993; Adler, et al., 1996; Numata, 1996; Kim and Mauborgne, 1997; Moorman, 1997.
4. Knowledge of Suppliers	The extent of a shared understanding of suppliers' design, process, manufacturing capabilities among product development team members.	Hahn, Watts and Kim, 1990; Slade, 1993; Ragatz, Handfield and Scannell, 1997; Evans and Lindsay, 1996; Hartley, 1997.
5. Knowledge of Products	The extent of a shared understandanding of products (e.g., components, financial performance, history and costs) among product development team members.	Day, 1990; Boon and Kurtz, 1995; Garrison and Noreen, 1994, 1997; Liberatore, 1995; Kim and Mauborgne, 1997; Kalyana-ram, 1997.

In this study, shared knowledge is defined as "shared understanding of customers, competitors, internal capabilities, suppliers and products in cross-functional product development teams." 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), and Hoopes and Postrel (1999) in regard to the importance of shared learning and knowledge. Table 2.4. identifies five variables of shared knowledge, their definition and the relevant literature base of each variable. Shared knowledge affects product development performance outcomes (Zack, 1999).

2.2.3.1. Shared Knowledge of Customers

Shared Knowledge of Customers (SKCUST) refers to the extent of a shared understanding of current customers' needs and future value to customer creation opportunities among product development members (Narver and Slater, 1990; Griffin and Hauser, 1991; Calantone, Vickery and Droge, 1995; Calantone, Schmidt and Song, 1996). The extent of shared knowledge is an indication of a continuous, proactive disposition toward creating high customer values across the functions of an organization and; therefore, it is regarded as the most fundamental aspect of product development (Deshpande, Farley and Webster, 1993).

Those who have a high level of contact with customers (e.g., a marketing manager or a chief engineer) may have high degrees of understanding the changing needs of customers (Slater and Narver, 1994a, 1995), the value to customer attributes (Slater and Narver, 1994b), and levels of satisfaction with customers to the products (Gatignon and Robertson, 1991; Day, 1993; Gale, 1994). A key of product development success is how much other product development team members (e.g., product and process design engineers and manufacturing team members) understand the customer needs, requirements, use, and value attributes in the early stage of the product development process (Clark and Wheelwright, 1993). Instead of relying on the experience or insight of particular functional team members, when cross-functional team members meet with customers directly in focus groups, common experience may improve the information quality and knowledge content of customers (Dougherty, 1992; Brown and Eiserhardt, 1995; Jaworski and Kohli, 1993). Shared understanding of customer knowledge also enhances the chances of meeting changing needs of customers, coping with internal dynamics on how customers make their purchase decisions (Holak and Lehmann, 1990), and assessing characteristics of target customers, in broader viewpoints (Cooper, 1983, 1984, 1992; Wheelwright and Clark, 1992).

The more knowledge about the needs of current customers and potential customers is shared among product development members, the better chance there is to understand more realistic customer requirements. Such shared knowledge of customers also provides the basis of creating greater value for customers because the product might better satisfy customer needs and expectations. Accordingly, the product might have a better chance for success in the market place.

2.2.3.2. Shared Knowledge of Competitors

A balanced mix of customer and competitor orientation is a requisite for maintaining a competitive advantage in the market place (Day and Wensley, 1988; Deshpande, Farley, and Webster, 1993; Narver and Slater, 1990).

Shared knowledge of competitors asks fundamental questions about competitors: (1) Who are our competitors? (2) What technologies do they offer/use? (3) Do they represent threats to our customers? (Han, Kim, and Srivastava, 1998).

Knowledge of competitors refers to the extent of a shared knowledge base and understanding (i.e., know-why) of product development team members concerning competitors (Porter, 1980, 1990, 1992, 1994; Sanchez, 1996; Andrew, 1996; Baldwin, 1997; Hendricks and Singhal, 1997). Shared knowledge of competitors includes competitive threats (Day and Wensley, 1983; Day, 1991, 1994), advantages and disadvantages of competitors (Dickson, 1992; Hamel and Prahalad, 1994; Porter, 1985), strengths and weaknesses of competitors (Hunt and Morgan, 1995; Porter, 1990), and competitors' product technologies (Wheelwright and Clark, 1992). Strengths/weaknesses of competitors usually refers to the technical and marketing attributes of the product and/or services offered, while advantages/disadvantages of competitors focuses more on a broad level of competitors' capabilities and market positions (Han, Kim and Srivastava, 1998; Porter, 1990).

Shared knowledge of competitors would be helpful in developing products that meet "time to market requirements (e.g., getting products to market ahead of competitors and develop products on schedule), have high values to customers (e.g., work on product's success in the marketplace), and improve product performance (e.g., better overall performance of the product than competitors).

2.2.3.3. Shared Knowledge Of Internal Capabilities

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 (Clark and Wheelwright, 1993; Garvin, 1993; Adler, et al., 1996).

Knowledge of internal capabilities resides usually among design and manufacturing team members. The key is how many different functional specialists (e.g., product design engineers, marketing managers) are aware of the strengths and weaknesses of various aspects of design capabilities, manufacturing processes, facilities and other manufacturing capabilities. Standard work processes (e.g., standard forms and procedures that are simple, devised by the people who use them, and updated as needed) are an important element of process technologies (Sobek II, Liker and Ward, 1998).

The more knowledge of internal capabilities is shared among product development members, the faster they start working on their project targets and increase development productivity (e.g., reducing engineering hours). IPD decisions made by a particular function (e.g., that of a design engineer) may affect other functions (e.g., that of a manufacturing engineer). Knowing what other team members can do would enable team members to make better quality decisions that effect the different performance 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. Effective decision making in all aspects of IPD requires a good understanding of what other functions can do as much as what a particular function can do because knowledge and work is highly interdependent.

2.2.3.4. Shared Knowledge of Suppliers

Shared knowledge of suppliers refers to the extent of the shared understanding (i.e., know-why) of suppliers' design, process, and manufacturing capabilities among product development team members (Maas, 1988; Hahn, Watts and Kim, 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, 1996).

Shared knowledge of suppliers allows product development members to improve product performance (e.g., its technical and overall performance) and reduce manufacturing costs (e.g., cost of raw materials of the product supplied by the suppliers) because a substantial portion or part of their final product depends on suppliers' work.

2.2.3.5. Shared Knowledge of Products

Products can be viewed as a collection of ideas and solutions to design concepts. A great amount of knowledge (e.g., assumptions about its intended use, the product concept, and the design specifications) generated during the development of a new product is ingrained in the product itself. The final product is the outcome of the development team's decisions and all innovative ideas plus application of the available technologies (Nonaka and Takeuchi, 1995; Olivera and Argote, 1999). A failure to define the product—its target market, the concept, benefits and positioning, and its requirements, features and specs—before development begins is a major cause of new product failures and serious delays in time to market (Cooper and Kleinschmidt, 1993; Montoya-Weiss and Calantone, 1994; Cooper, 1999). Early and stable product definition is consistently cited as a key to success of product development (Cooper and Kleinschmidt, 1995).

Knowledge of products refers to the extent of a Shared Knowledge base and understanding (i.e., know-why) of products (e.g., components, financial performance, history and costs) among product development team members. Since product characteristics (e.g., product advantages, product disadvantages, product strengths, product history, and product technologies) are regarded as the most important determinants of product success, the knowledge of products is critical for product development success.

Product advantage/disadvantage refers to the abundance or lack of contextual value (e.g., product location, company image, product after-services)(Cooper, 1983, 1984, 1992, 1999; Clark and Fujimoto, 1991) and tangible value (cost, uniqueness, and differentiated and unique benefits) (Edgett, Shipley and Forbes, 1990; Jones, 1991). Product strengths/weaknesses refers to the technical and marketing attributes of the product and/or services offerings, including functionality, compatibility, product integrity, high quality, and innovative features (Cooper, 1979; Cooper and Kleinschmidt, 1987; Brown & Eisenhardt, 1995). Customers may use these terms interchangeably.

Sutton and Hargadon (1996) described how existing products are used as sources of ideas in brainstorming sessions at a product development firm. These products not only provide ideas that can be creatively recombined in a new product but also support the organization's memory by storing the ideas of previously designed products. In that sense, product history is specific knowledge of a product platform of mature products (Kuczmanski, 1988; Meyer and Seliger, 1998), financial performance of the products (Liberatore, 1995; Kim, 1997; Kalyanaram, 1997), costs (Garrison and Noreen, 1994, 1997) and development history (Cusumano and Nobeoka, 1992; Dougherty and Hardy, 1996) embedded in particular members of the product development team.

Increasingly, a product becomes more complex so that it requires product technologies in designing and producing it. Depending on what type of product technologies a firm uses, it may affect the cost, quality, time-span of product processes and its outcomes as well.

Shared knowledge of products (i.e., product advantage, product disadvantage, product strengths, product history and product technologies), may be important to improve development productivity (e.g., reducing its development costs) and manufacturing costs (e.g., reducing overall manufacturing costs).

2.2.4. Product Development Performance Ooutcomes

IPD performance measures are multiple. Since the effectiveness of IPD processes can be measured only in relation to the performance measures, proper identification of these measures is important. Multiple performance measures are necessary for two reasons: (1) to understand the relationships between knowledge integration components (i.e., role changes, team vision, and shared knowledge) and the multiple performance outcomes in order to find specific ways to improve the IPD processes, and (2) to outperform competitors in multiple criteria.

In this study, these IPD performance measures are classified into three components: (1) process outcomes looks at the effectiveness of the IPD process in terms of teamwork, productivity, and time; (2) product outcomes concern the characteristics associated with products. These product outcomes are further classified into two areas. Manufacturing performance measures are expressed in terms of manufacturability and manufacturing cost. Customer performance measures denote value to customer and product performance; (3) market performance of projects is about how a particular project actually contributes to the bottom line of the business.

Process outcomes measure the effectiveness of the product development process itself. The effectiveness of the IPD process is measured in terms of teamwork, development productivity and finally time to market. In this study, time to market (i.e., product development cycle time) is regarded as one of the process outcomes because it measures the critical aspect of the product development process–the time aspect from a product concept to the market introduction. Table 2.5. shows three variables of process outcomes, their definition and relevant literature base for each variable.

2.2.4.1. Teamwork

Teamwork refers to the degree of collaborative behavior of product development teams. The indicators of a high level of teamwork are: timely conflict resolution (Zirger and Maidique, 1990; Clark and Fujimoto, 1991), effective decision implementation (Mabert, et al., 1992), creative problem solving (Guftafson, 1994), effective communication (Brown and Eisenhardt, 1995; Fisher, et al, 1997), and good coordination of activities (Heany, 1989; Griffin, 1993). Defining later stage problems (e.g., manufacturing and design problems) is an indication of a high level of teamwork (Clark and Fujimoto, 1991).

What are the antecedents of teamwork? As a representative of a particular function, it is easy for team members to look out for their narrowly perceived interests. When cooperation lags, what brings team members together is a sense of shared purpose and mission (Graham and Englund, 1997). Knowing about common enemies can unite team members for their common interest. In that sense, shared knowledge of competitors may be critical. Ultimately, team members work to create business, which is about satisfying existing customers or creating new customers. In that sense, the shared knowledge of customers may be critical in promoting teamwork as well.

2.2.4.2. Development Productivity

Development productivity refers to effectiveness of developing new products from product concept to manufacturing. Product development members with a high level of development productivity would get work done quickly, reduce cost and engineering hours and have a general sense of their productivity (Crawford, 1992; Ali, Krapfel and LaBahan, 1995; Tersine and Hummingbird, 1995; Adler, 1995). Although development productivity is affected by the time element, it is quite different from time to market. Time to market is about the total cycle time required from product concept to ramp-up and manufacturing. Development productivity is about the total costs incurred in all activities of the product development. For example, the time to market of a project may be shorter than that of a competitor (e.g., 1 year vs. 1 .5 year), and yet because of the high concentration of work in each step, the total costs of all activities may be higher (e.g., 10,000 engineering hours vs. 7,000 engineering hours). Development productivity is measured by overall technical and team performance in terms of efficiency, budget, schedule, and innovation (Cooper and Kleinschmidt, 1987, 1995; Ancona and Caldwell, 1990, 1992; Cooper, 1999). Time to market, teamwork and development productivity are regarded as process outcomes in that they reflect product development process characteristics rather than the product itself.

Table 2.5. Process Outcomes of Integrated Product Development

Variables	Definition	Literature-Base
Team Work	The degree of effective action (e.g., conflicts resolutions, decision implementation, creative problem solving, and problem definitions, and team communication) of product development teams.	Zirger and Maidique, 1990; Mabert, et al., 1992; Gustafson, 1994; Griffin and Hauser, 1992; Griffin, 1993.
Development Productivity	Process efficiency of developing new products (e.g., allocation of resources, usage of engineering man hours) from product concept to manufacturing.	Crawford, 1992; Ali, Krapfel and LaBahn, 1995; Tersine and Hummingbird, 1995; Adler, 1995; Adler, Mandelbaum, Ngyyen and Schwerer, 1996.
Time to Market	Product development time (e.g., product introduction on schedule or ahead of competitors) required from concept generation to market introduction.	Youssef, 1995; Cohen, 1996; Haddad, 1996; Zirger, 1996; Datar, et al., 1997; Dyer, Gupta and Wilemon, 1999.

2.2.4.3. Time to Market

Time to market refers to how fast a firm completes its product development projects from concept generation to market introduction (Takeuchi and Nonaka, 1986; Clark and Fujimoto, 1991; Gupta and Wilemon, 1990; Dyer, Gupta and Wilemon, 1999). A product development team that values time to market would strive to get products to market ahead of competitors (Lieberman, M. B. and Montgomery, D. B., 1988; Stalk and Hout, 1990; Blackburn, 1991; Youssef, 1995), develop products on schedule (Cohen, 1996; Zirger, 1996) and keep improving on the previous time to market (Mabert, Muth and Schmenner, 1992; Haddad, 1996).

Reducing product development time and hence the time to the introduction of a new product can create relative advantages in market share, profit, and long-term competitive advantage (McDonough and Spital, 1984; Lieberman and Montgomery, 1988; Brown and Karagozoglu, 1993; Sanchez, 1995; Ward, Liker, Cristiano and Sobek, 1995; Ali, Krapfel and LaBahn, 1995).

Technologically more advanced products take longer to develop than less advanced products. When shortening product development cycle time, the challenge is not to cut corners, but to carry out the development task faster without sacrificing quality or eliminating steps (Gupta and Wilemon, 1990; Karlsson and Ahlstrom, 1999). In the case of Toyota's product development system, Toyota considers a broader range of possible design options and delays key decisions longer than many other automotive companies, yet has what may be the fastest and most efficient vehicle development cycle in the industry (Ward, Liker, Cristiano and Sobek, 1995; Sobek, Ward, Liker, 1999). Toyota maps the design and establishes feasibility before commitment (Sobek, Ward and Liker, 1999). In brief, Toyota teams generate a great deal of shared knowledge in considering a broader range of possible designs and manufacturing options, not only in light of internal and suppliers' capabilities but also in light of strategic fits before they make a commitment of their resources. This has to do with developing internal capabilities, especially design and manufacturing engineers. Another important principle is a suppliers' high engineering capability and a close but demanding relationship between the parent company and the suppliers (Kamath and Liker, 1994).

Although the success of an individual project may not be indicative of a systematic relationship between time to market and overall organizational performance (Clark and Fujimoto, 1991; Cusamano and Nobeoka, 1992; Smith and Reinertsen, 1991), the extent of shared knowledge is related to the project's time to market. Thus, the sample responses provide insights on how each team's shared knowledge is related to the time to market of projects in general. Stalk and Webber (1993) argue that 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. The extent of shared knowledge of customers, therefore, is critical to ensure that the resulting products satisfy customer needs (Ciccantelli and Magidson, 1993).

Reducing the time to market requires adequate knowledge of customers earlier in the process (Mabert, Muth and Schmenner, 1992). Substantial work in accelerating time to market (e.g., understanding the earlier availability of prototypes, increased standardization of parts, consistency between designs and suppliers' process capabilities, and reduced engineering changes) is based on the proper understanding of suppliers and internal capabilities (Bonaccorsi and Lapparini, 1994). Understanding internal capabilities is significant in reducing time to market. Deere and Company focused on process identification and simplification to reduce cycle time (Hunt, 1993).

Having a shared understanding of vision, purpose of the project and strategic intent substantially affects the time to market (Mabert, Muth, and

Schmenner, 1992). Clear project targets are also another critical factor in reducing Time to Market (Murmann, 1994).

Product outcomes have four variables: manufacturability, manufacturing cost, value to customer and product performance. These are all classified as product outcomes in that these variables all represent the elements of a final product as it passes through its manufacturing stage and customer assessment. Table 2.6. shows four variables of product outcomes, their definition and relevant literature base. Manufacturability and manufacturing cost are regarded as manufacturing performance measures.

2.2.4.4. Manufacturability

Manufacturability measures how easy new products are to design, manufacture and assemble (Clark and Fujimoto, 1991; Susman, 1992; Walleigh, 1989; Tatikonda, 1994). Somewhere near the end of the project, a key member of the manufacturing team may discover that not all elements of the design are readily manufacturable. This kind of problem is not uncommon and it adds a great deal of cost to the process of a product development. This is primarily because the manufacturability issue has not been addressed in the early stages of product development.

Table 2.6. Product Outcomes of IPD

Variables	Definition	Literature-Base
	Manufacturing Outcomes	
(1) Manufacturability	The degree of easiness of the new products to design, manufacture and assemble.	Clark and Fujimoto, 1991; Walleigh,1989; Susman, 1992; Tatikonda, 1994; Ha and Porteus, 1995; Youssef, 1995.
(2) Manufacturing Cost	Cost of materials, labor and overhead for producing new products.	Myers and Marquis, 1969; Cooper, 1979; Cooper and Kleinschmidt, 1987; Maidique and Zirger, 1984, 1985, 1990; Ittner and Macduffie, 1995; Cooper and Slagmulder, 1999.
	Customer Outcomes	
(1) Value to Customer	Value of new products in terms of meeting customer needs, requirements, and expectations.	Clark and Fujimoto, 1991; Clark and Wheelwright, 1993; Day, 1993; Slater and Narver, 1995; Lengenick-Hall, 1996; Cordell, 1997; Koen and Kohli, 1998; Slater and Narver, 2000.
(2) Product Performance	New product performance in terms of technical, system and product integrity).	Hayes, Wheelwright and Clark, 1988; Clark and Fujimoto, 1991; Iansiti, 1997a, 1997b; Clark and Wheelwright, 1993.

Research aimed at finding ways to improve manufacturability has led to a greater understanding of this power of the design and development process in affecting manufacturing performance. Experience in a variety of industries suggests that a significant fraction (as much as 80 percent in some cases) of total product cost is established during the product engineer stage of development (Jaikumar 1986; Soderberg 1989; Clark and Fujimoto, 1991). The effective way to improve manufacturability is to have a shared understanding of knowledge of customers, suppliers, internal capabilities and products.

2.2.4.5. Manufacturing Cost

Manufacturing cost is defined as the cost of materials, labor and overhead for the product (Garrison and Noreen, 1997). Manufacturing cost is, therefore, interchangeable for total product cost, except for service and distribution costs. The cost strength of a particular company is relative to industry performance, so each item is compared to the industry average. Usually, changes in the later stages of design are quite costly. Such changes may occur because of lack of understanding of customer knowledge, project targets, and the degree of the suppliers' capabilities in advance. In that sense, the cost impact of IPD is most significant during the product design phase. It is estimated that 80 percent of product development cost is determined in the early design and process planning (Hunt, 1993).

Low manufacturing cost is highly related to the early involvement of manufacturing people in the product development process (Walleigh, 1989). To reduce manufacturing cost, knowledge of suppliers' capabilities is also critical. To increase suppliers' capabilities, firms are willing to empower suppliers with expert knowledge as long as such an arrangement does not create long-term dependence (MacDuffle and Helper, 1998). Low manufacturing cost may also be related to the shared knowledge of suppliers because typical industrial firms spend more than one half of every sales dollar on purchased products (Dyer, Cho and Chu, 1998). Therefore, more than half of the manufacturing cost is purchase costs from suppliers .

Value to customer and product performance are the other two product outcomes. Customers ultimately assess and appreciate the extent of these outcomes. Therefore, value to customer and product performance are regarded as customer outcomes.

2.2.4.6. Value to Customer

Value to customer is the customer-perceived worth adjusted for the relative price of the product (Gale, 1994). It 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 commonalties in what customers value (Kim and Mauborgne, 1997). Value to customers is enhanced through shared knowledge of customers (Koen and Kohli, 1998).

2.2.4.7. Product Performance

Product performance is the extent of the product's technical function and system integrity. It is measured by the overall performance rating, the level of technical and system performance and perceived improvement of the performance (Hayes, Wheelwright and Clark, 1989; Clark and Fujimoto, 1991; Iansiti, 1992, 1993; Clark and Wheelwright, 1993; Cohen, 1996). Product performance would be enhanced if team members have a shared understanding of internal capabilities, products, and customers. This also has to do with the clarity of project targets that identifies key outcomes of the project.

2.3. HYPOTHESES

The nature of relationships among components of knowledge integration and their outcomes is described in terms of a hypothesis. This study does not examine the detailed relationship of each variable (e.g., shared knowledge of customer and teamwork). These hypotheses examine the relationships among partially aggregated models. Figure 2.3. shows how three components of knowledge integration (i.e., role changes, team vision and shared knowledge) are related. It also depicts how these components affect product development performances.

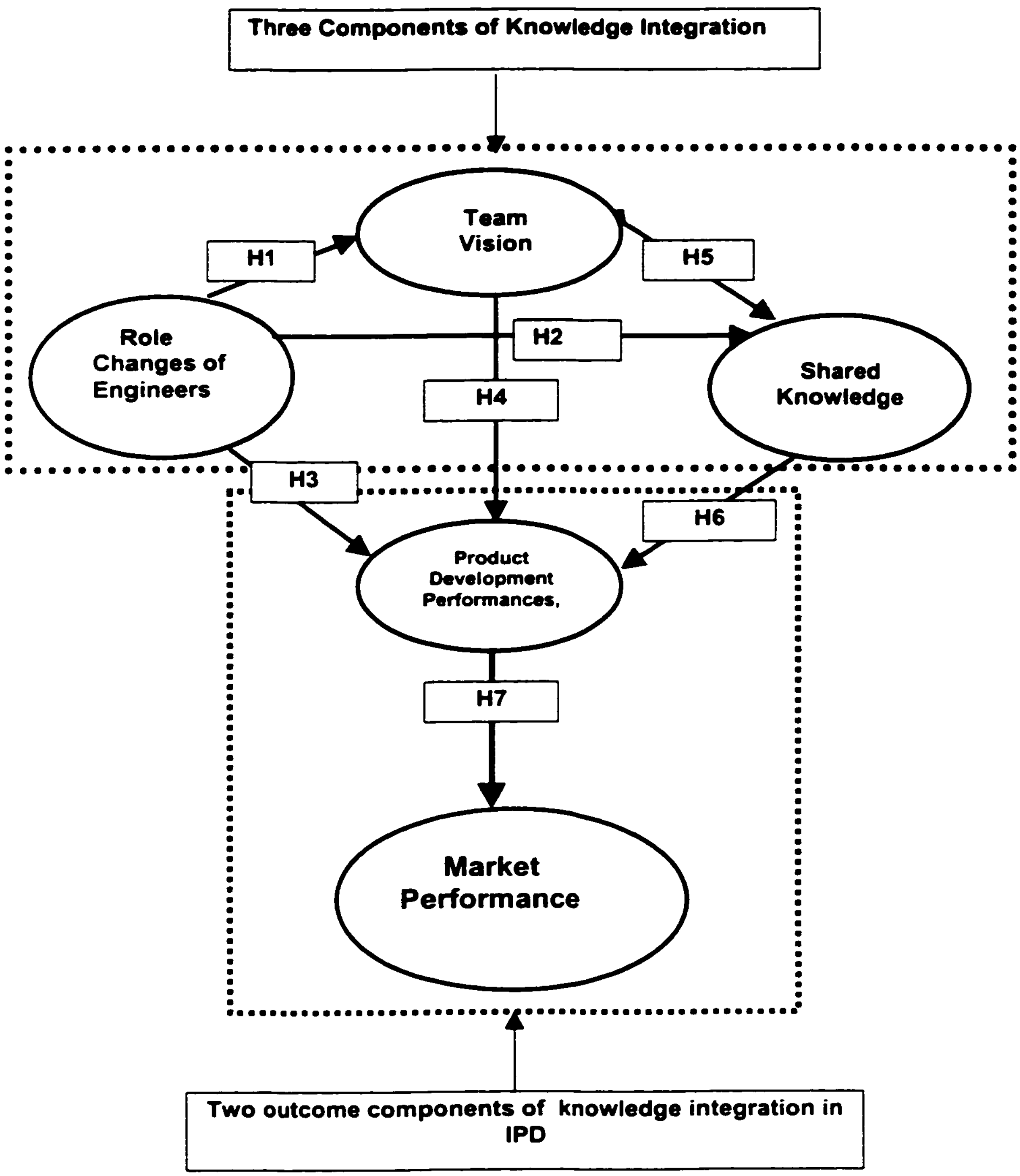
2.3.1. Development of Hypothesis 1

Role changes are related to the organizational culture, structure and leadership arrangement. Depending on the culture of an organization, role definition or changes are relatively stable. In the Toyota Company, the Chief Engineer's role is quite consistent throughout projects and this leadership is critical in IPD performance. As Toyota defines itself as primarily a manufacturing firm, the manufacturing engineers' roles are noticeably more prominent than that of design engineers. On the other hand, in Chrysler's case, the role of design engineers is much greater and even more prestigious than that of manufacturing engineers (Sobek, 1997).

At the organizational level, it is people that provide vision. It is not an impersonal vision and mission that brings new leaders. Rather, new leaders personify the direction for the future and bring their vision into an organization. At a project level, this is much more obvious. It is not vision that brings new leaders; rather those who assume leadership introduce new vision for a project's success. In typical firms, numerous teams work on different product development projects. Role definition or changes across teams tend to be fairly stable. It is people that determine project targets. Therefore, it is assumed that role changes of engineers occur prior to determining team vision and goals. In that sense, role changes are regarded as antecedents to team vision.

Hypothesis 1: The greater the extent of the role changes of engineers, the greater the extent of the team vision.

Figure 2.3: Hypotheses of Key Relationships



2.3.2. Development of Hypothesis 2

According to Davenport, De Long and Beers (1998), " Knowledge is fuzzy and closely linked to the people who hold it. Building an organizational infrastructure for knowledge management means establishing a set of roles and organizational groups whose members have the skills to see resources for individual projects." Shared knowledge (i.e., the extent of sharing knowledge among a cross-functional team) requires collaboration and cooperation among its team members. The positive role of collaborator and coordinator would enhance the extent of shared knowledge among team members.

The role changes of engineers among IPD teams represent the enhanced collaborative and coordinative influence of engineers among team members. The increased role changes of engineers show their respectful position in IPD teams with increased power and influence and better training and qualification. In addition, the increased role changes of engineers suggest their usage of behavioral skills to better collaborate and coordinate knowledge sharing among team members. Therefore, it is assumed that the more the role changes of engineers occurs, the more likely it is that the extent of shared knowledge will increase among IPD members.

Hypothesis 2: The greater the extent of the role changes, the greater the extent of the shared knowledge.

2.3.3. Development of Hypothesis 3

Role changes of design and manufacturing engineers signify the nature of knowledge leadership in IPD teams. The more the engineers' qualifications (both technical and behavioral), power and influence, job characteristics and level of satisfaction change, the better the outcome of product development performance. Knowledge leadership by engineers would not only move them beyond the traditional role of technical specialists but also improve overall performances that are affected so much by the quality of knowledge utilized by the team members.

Hypothesis 3: The greater the extent of role changes, the greater the extent of product development performances

2.3.4. Development of Hypothesis 4

Lynn (1998) studied a progression of new product projects, which included Apple II, IIe, III, Lisa, Mac, and Mac+, the Hewlett-Packard 85, 125, 150, Vectra, and the IBM DataMaster, PC, and PCjr. This is his conclusion about these teams: "Having a clear vision and having that vision shared and agreed to by others on the team were reoccurring themes for successful innovation. Successful teams were totally committed to the vision of the project and had a crystal-clear understanding of the goals and objectives of the project. This commitment and understanding helped motivate teams members to work extremely long hours to accomplish the goal." A clear, shared team purpose and mission facilitate teamwork. The degree of strategic fit may also enhance team work and development productivity because perception about the stragegic fit of a project provides the necessary motivation and will for team members to work hard. In many firms, projects that are strategically in line have good chances to get quick approval. The development effort of such projects may be more productive and less time consuming.

The degree of clarity of project targets indicates the extent of defining, understanding and communicating project goals among team members. Such clear understanding of project goals may enable manufacturing and process engineers to get involved in the early design stages to better determine manufacturability. Therefore, teams with high levels of team vision may achieve higher levels of process or product outcomes.

Hypothesis 4: The greater the extent of team vision, the greater the extent of product development performance outcomes.

2.3.5. Development of Hypothesis 5

It is critical to integrate shared knowledge and team vision. Khurana and Rosenthal (1997) concluded after studying 11 different projects in three different countries as follows: " The failure to integrate a product strategy, a well-planned portfolio, and a facilitating organizational structure with clearly identified customer needs, a well-defined product concept, and a project plan can severely hamper product development. Improving the entire product development process depends on improving the effectiveness of the front-end process." They primarily pointed out the needs of integration of the knowledge of customer and team vision and goals (e.g., a product strategy, a well-planned portfolio, a facilitating organizational structure, a well-defined product concept, and a project plan). Such has to be done in the frontend of the product development.

Two extreme cases would make shared knowledge ineffective and the degree of shared team vision low, although the absolute amount of information shared may be great. One example is knowledge sharing without any focus or direction. People may just come and share about their experiences. In the corporate context, such practices may not go on too long. At some point, team members need to clarify why they meet and why they share. If the underlying purpose is not clarified, then the extent of shared knowledge would be quite negatively affected. Another extreme is when a particular individual with specific functional orientation primarily determines the team vision. For example, team members may have shared understanding of customers' current needs and their changing future needs because a marketing manager is a quite dominant member of the team. However, if other engineers are passive members, then the extent of shared knowledge as a whole would not be great. Therefore, in determining the effective level of shared knowledge, goal integration among team members is quite critical.

A shared vision embodies the common goals and aspirations of the team members. With a shared purpose and vision among team members, they can avoid possible misunderstandings in their communications and have more opportunities to exchange their ideas and/or resources freely. Furthermore, the common goals they share help them to see the potential value of their resource exchanges and benefits of cooperation. As a result, team members who share a vision will be more likely to share or exchange their critical knowledge resources (Orton & Weick, 1990; Tsai and Ghoshal, 1998). Therefore, teams with a greater level of team vision will achieve higher levels of shared knowledge. In that sense, there is a positive relationship between team vision practices and shared knowledge.

Hypothesis 5: the greater the extent of the team vision, the greater the extent of the shared knowledge.

2.3.6. Development of Hypothesis 6

Zaltman, Duncan and Holbeck (1973) offer an explanation of how openness in communication across functions facilitates responsiveness in creating customer value. In a meta-analysis with a sample of 782 studies, Damanpour (1991) reports a positive association between cross-functional communication coordination and organizational innovativeness. Coordinated effort of cross-functional teams not only increases the level of market intelligence but also increases the firm's responsiveness to customers' needs (Kohli and Jaworski, 1990; Kohli, and Jumar, 1993; Jaworski and Kohli, 1993).

Shared knowledge among cross-functional team members is indicative of a coordinated effort among various functions. The level of shared knowledge in a team indicates its ability to translate critical knowledge about customers, products, suppliers, competitors and their own process capabilities into successful products (Prahalad and Hamel, 1990; Rumelt, Schendel and Teece, 1991). The hypothesis, taken at the project level, is also consistent with the findings of Moorman and Miner (1997) at the organizational level--the greater the dispersion of organizational memory for a new product domain, the greater the new product short-term performance. Therefore, teams with higher levels of shared knowledge will achieve higher levels of process (e.g., teamwork and development productivity) and product outcomes (e.g., value to customer and manufacturing cost).

Hypothesis 6: The greater the shared knowledge, the greater the product dvelopment outcomes.

2.3.7. Development of Hypothesis 7

The final objective of any project is success in market performance. Market performance is not based on any single performance criteria. For example, faster cycle time (i.e., product development time) alone is not associated with overall market success (Ittner and Larcker, 1997). Rather, market performance is based on multiple outcomes (Clark and Fujimoto, 1991; Clark and Wheelwright, 1993). Market performance may improve if a final product displays increased product development outcome measures in terms of time, cost, quality, value to customer and product performance.

The product development outcomes in this research model are multidimensional (e.g., process outcome, manufacturing outcomes and customer performance outcomes). If a new product demonstrates higher process effectiveness evidenced by early introduction to the market, greater teamwork and development productivity, there may be a greater chance for market success of the product. If a new product displays higher value to customer and product performance, it is more likely that the product may be successful in the market. With better process and product outcomes, the chances of market performance of the project would be greater. Therefore, hypothesis 7 is that the higher these multiple product development performance outcomes, the more likely the product will experience successful market performance.

Hypothesis 7: The greater the extent of the product development outcomes, the greater the extent of market performance.

2.4. SUMMARY OF THE MODEL

Table 2.7. summarizes the underlying considerations of this research model in light of the above diverse literature streams and research objectives. In chapter three, the research methodology will be presented on how this research model is empirically tested through a pilot study and a large survey.

Table 2.7. Summary of the Research Model

Key Constructs	Key Assumptions/Processes
Role Changes	1. Qualification /Training requirements; 2. Power/ Influence; 3. Technical /Behavioral skills; 4. Job characteristics (i.e., complexity, enlargement, enrichment and satisfaction).
Team Vision	1. Team vision enhances the extent of knowledge exploitation; 2. The extent of team vision indicates control mechanism (i.e., goal integration) of the team; 3. Project is related to organizational purpose /vision/ mission, strategic fit, clarity of project targets ensure knowledge exploitation.
Shared Knowledge	1. Shared knowledge enhances the extent knowledge exploration among IPD members; 2. The extent of shared knowledge indicates the nature/extent of trust/sharing among IPD teams; 3. Key knowledge components in IPD are both internal (i.e., knowledge of products and internal capabilities) and external (i.e., knowledge of customers, suppliers and competitors) entities.
Process Performance of IPD	1. Time element (i.e., time to market); 2. Team effectiveness (i.e., teamwork); 3. Process effectiveness (i.e., development productivity).
Manufacturing Performance of IPD	1. Ease of manufacturing (i.e., manufacturability); 2. Cost of producing product (i.e., manufacturing cost).
Customer Performance of IPD	1. Performance of products (i.e., product performance); 2. Customer responses (i.e., value to customer).
Market Performance of the Project	1. Final performance of the project completed in terms of the degree of success in the market.

Chapter Three

Research Methodology and Pilot Study

One of the primary goals of this study is to develop valid and reliable scales to measure "Role Changes" (RC), Team Vision (TV), Shared Knowledge (SK), Product Development Performance (PDP) and Market Performance (MP). These valid and reliable measures (i.e., instruments) are useful for benchmarking knowledge integration practices against competitors. These instruments develop quick feedback mechanisms for intervening in organizations to improve product development performance. In addition, empirical studies based on good instruments will improve the quality of research in integrated product development.

These effective instruments are useful only when they contain several measurement characteristics: construct validity, convergent validity, discriminant validity, predictive validity and reliability. Construct validity refers to an effective instrument that covers the content domain of each construct (Nunnally, 1978). Convergent validity is concerned with the extent to which multiple measures of the same construct agree with each other (Campbell and Fisk, 1959). Predictive validity refers to the extent to which scores of one construct are empirically related to scores of other conceptually related constructs (Bagozzi, et al. 1992). Discriminant validity is evident if items underlying each dimension load as different factors (i.e., discriminate with measures of the other constructs) (Pitt et al. 1995). Each construct should have a reliability of 0.80 (Cronbach's alpha) or more (Nunnally, 1978), and the instrument should be short and easy to use. To increase the usefulness of this instrument for basic research, it should be generalizable across industries and firms of varing sizes (Koufteros et al. 1998).

To achieve these goals, the process of developing measures is based on commonly accepted methods for developing standardized instruments (Nunnally, 1978; Churchill, 1979). An extensive literature review ensures that a research model is grounded in theory. In addition, case studies and structured interviews with product development executives helped to define the domain of the constructs and facilitated item generation. A pre-test was completed to enhance content validity. A pilot study was conducted utilizing respondents similar to the target respondents. These steps were taken to insure the above-mentioned desirable measurement characteristics.

3.1. ITEM GENERATION

The unit of analysis is the project team since all items pertain to the practices for the product development team. The following steps were taken to insure the content validity of each variable. First, possible items were adapted from articles published in major journals in the fields of marketing, product development, strategy, teamwork, organizational learning, knowledge and quality management. Questions were then developed to measure a particular variable (e.g., Shared Knowledge of Customers) of an individual construct (e.g., Shared Knowledge).

The goal of the literature review in chapter 2 is to generate a comprehensive list of items to match the domain of "Role Changes" (identical items for design and manufacturing engineers), Team Vision (four variables), Shared Knowledge (five variables), Process Outcomes (three variables) and Product Outcomes (four variables) identified in the research framework. A five-point Likert scale was used where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

To provide additional support for content validity, the items were grouped according to their theoretical construct and presented to ten product development managers during structural interviews. For each construct, the managers were asked to discuss knowledge integration practices and compare them with these constructs and items. The key questions were: (1) what did they think about the importance of shared knowledge in product development; (2) what aspects of knowledge were critical from their standpoint; (3) whether they could answer all the questions based on their experiences. Their qualitative comments from the structured interviews were compared with the responses to items measuring each of the four components. This was done to verify that they understood the questions. Based on suggestions by these managers, items were added, changed, or deleted for a revised instrument and these items were grouped into 18 variables. Market Performance has only one item question.

3.2. PRETEST

In assessing the extent of shared knowledge in teams, it was important to get a broad section of responses. Twelve individuals (three were CEO's, four were design engineers, one was a consultant, and the other four were design or manufacturing engineers) were all selected as key informants for the pretest.

The first criterion was position. The participants were all involved in the cross-functional product development project. They identified their project. Their responses were based on the particular project they experienced with the other team members. The key question was, "Was the informant in a position knowledgeable to answer regarding the extent of shared knowledge in the team?" (Seidler, 1974). All the individuals in the positions mentioned above were active participants in project development work so that they were able to share their perceptions about the level of the shared knowledge of their teams.

Next, a knowlegeability 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 inquiry after answering the questionnaire. On a scale of five (1=not very knowledgeable, 2=a little knowledgeable, 3=somewhat knowledgeable 4=moderately knowledgeable 5= very knowledgeable), the mean response was 4.25 (std. dev. = 0.71). The mean was greater than 4, thus showing evidence of knowledge ability. This ensures that the respondents with appropriate positions and knowledge answered the questionnaire. The very first page of the survey clearly stated as follows: "This questionnaire should be answered by those (e.g., project leaders, product development managers, vice presidents and CEOs) who have recently participated in a cross-functional product development team."

The next procedure to promote content validity involved presenting the entire list of potential items to the seven academic experts from business and engineering who were given the opportunity to keep, modify, and/or drop items. They were also encouraged to provide suggestions for additional items if they perceived them in order to cover the intended domain of the variable. Representatives from business and engineering were included because some of the factors, including internal capabilities and product development performances (e.g., Manufacturability, Product Performance), involved both disciplines. The academic experts and managers suggested a modification to 17 items. Where any expert suggested that the domain of a construct should be more adequately covered, additional items were generated to capture the domain of each construct. The total number of items after the expert evaluation and revision for the pilot study was 128.

3.3. PILOT STUDY

The pilot questionnaire was compiled after a number of modifications were suggested by the industry and academic experts. Upon completion, it was sent in the form of a questionnaire to 500 various managers from manufacturing firms. The Society of Automotive Engineers (SAE) provided names and addresses of

500 managers randomly selected from their membership with parameters such as: product development managers, position titles, geographical areas, and four industries (i.e., fabricated metal products, industrial machinery/equipment, electronic/other electrical equipment, and automotive parts and suppliers). These industries are under the standard industrial classification (SIC) codes 34, 35, 36, and 37 respectively. They were primarily drawn from the Midwest (i.e., Ohio, Indiana, Illinois, Michigan and Pennsylvania). The pilot study responses were later excluded in the large-scale study, and the companies selected to participate in the pilot study were excluded from the large-scale mailing. A cover letter signed by an executive from SAE encouraging its members to respond to the survey was mailed along with a cover letter on a University of Toledo letterhead and the questionnaire.

The items were grouped together according to the constructs. The first group is Shared Knowledge (i.e., Knowledge of Customers, Internal Capabilities, Suppliers, Products, and Competitors). The second group is Team Vision (i.e., Mission, Strategic Fit, Clarity, Tradeoff of Project Targets). The third group is Process Outcomes (i.e., Time to Market, Teamwork, and Development Productivity) and Product Outcomes (i.e., Manufacturability, Value to Customers, Product Performance, and Manufacturing Cost). The final group is Role Changes of Design and Manufacturing Engineers.

The demographic and respondent questions were about specific information about the type of industry, the size of the firm, knowledge intensity of product development, OEM or Suppliers, the position in the supplier chain, product/process complexity, rate of market change, and the rate of technological change.

As described by Churchill (1979), the instrument was purified by examining the corrected-item total correlations (CITCs: each item's correlation with the sum of the other items in its category) of the items with respect to a particular variable (e.g., Shared Knowledge of Suppliers) of a specific construct (e.g., Shared Knowledge). The item inter-correlation matrices provided by SPSS9.0 were utilized to drop items if they did not strongly contribute to Cronbach's alpha for the variable under consideration (Flynn, Schroeder & Sakakibara, 1995; Tracey, Vonderembse, and Lim, 1999). Some items that did not show high CITCs (less than 0.60), but whose content was considered important to the research, were selected for further modification.

Exploratory factory analysis was used to assess the internal consistency (i.e, the dimensionality) of the remaining items of each variable (e.g., Shared Knowledge of Customers) and, where appropriate, was used to eliminate items that were not factorially pure (Koufteros, Vonderembse and Doll, 1998). Principal components and oblimin were used as the means of extraction and method of rotation, respectively. Items, which load below 0.60, were generally eliminated at this stage. Not all items, however, were indiscrimately eliminated based on its factor loading alone. Rather, an item's importance to the research objective was carefully considered as well (Dillon & Goldstein, 1985). Some items (e.g., Shared Knowledge of Customers), which showed weaker loadings, were modified instead of being eliminated. To streamline the factor interpretation process, loadings below 0.40 were not reported. Reliability (internal consistency) of the remaining items comprising each variable was evaluated using Cronbach's alpha. Items were eliminated if Cronbach's alpha was at least 0.80 and the content of the scale was not significantly altered. In addition, each variable was expected to have a simple factor structure and factor loadings (one clear factor with high loadings with a minimum of 0.75).

The external consistency of each construct (e.g., Shared Knowledge, Team Vision) was appraised by submitting the items remaining for the entire construct (e.g., all five Shared Knowledge variables, all four Team Vision variables) to exploratory factor analysis to uncover significant cross-loadings. Again principal components and oblimin were used as the means of extraction and method of rotation, respectively. Loadings below 0.30 were not reported. The Kaiser-Meyer-Olkin (KMO) measure lists KMO measures: in the 0.90's as outstanding, in the 0.80's as very good, in the 0.70's as average, in the 0.60's as tolerable, in the 0.50's as miserable, and below 0.50 as 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 necessary for the variables, which showed reliabilities near the minimum standard of 0.80, (e.g., Shared Knowledge of Customers, with alpha, 0.83).

3.4. PILOT STUDY RESULTS

Thirty responses were received. This was a large enough sample to perform some initial statistical analysis. In this way the pilot test provided a means for assessing the preliminary reliability, convergent validity and discriminant validity in developing the instrument. Reliability was assessed by calculating Cronbach's alpha, convergent validity was assessed by a simple factor structure and high factor loading (>0.75), discriminant validity was assessed by using the Multitrait-Multimethod (MTMM) approach. In this section, the four components of knowledge integration (i.e., Role Changes of Engineers, Team Vision, Shared Knowledge, and Product Development Performances) were examined one by one.

3.4.1. Role Change of Engineers

The Role Changes (RC) construct represents two variables: role changes for design engineers (RCDE) and role changes for manufacturing engineers (RCME). Each variable has 10 items. Table 3.1. and Table 3.2. display the factor loadings and corrected item total correlations (CITCs) generated for each item related to RCDE and RCME. RCDE shows initially two factors but RCME shows only one factor. Both scales show high reliability (0.91 and 0.94). Role changes seem to occur as companies adopt the integrated product development. Both design engineers and manufacturing engineers are affected by these changes (average mean, 3.525 and 3.493). An interesting difference is that design engineers tend to negatively view the increasing complexity and enlargement of their job responsibilities due to IPD, while manufacturing engineers regard these changes as positive.

Table 3.1. Design Engineers--Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC) (Pilot Study)

Role Changes (Design Engineers)					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.807					
Items	**Descriptions**	**Factor Loadings**		**CITC**	**Avg.**
RC1	Qualifications required for design engineers have been upgraded.	0.53		0.65	3.32
RC2	Training required for design engineers has been more extensive.	0.74		0.63	3.25
RC3	Power of design engineers in product development team has increased.	0.89		0.62	3.28
RC4	Influence of design engineers in product development team has increased.	0.63		0.59	3.60
RC5	Technical skills required for design engineers have been more rigorous.	0.70		0.75	3.68
RC6	Behavioral skills (e.g., teamwork, inter-communication) required for design engineers have been more important.	0.88		0.69	3.89
RC7	Design engineers' jobs have become more complex.	x	0.91	0.68	3.75
RC8	Design engineers' jobs have been enlarged.	x	0.94	0.61	3.71
RC9	Design engineers' jobs have been enriched.	0.58	0.33	0.74	3.39
RC10	Overall, design engineers feel more satisfied with their work.	0.76		0.70	3.36
		Cronbach's Alpha 0.91			

For design engineers, the items that show high average (>3.60) are influence, technical skills, behavioral skills requirement and job enlargement. It seems that their job task characteristics become more demanding and their influence grows; but their qualification, training, rewards and power remain the same. As a result, the overall job satisfaction is somewhat low (3.36).

For manufacturing engineers, the items showing high averages (>3.60) are behavioral skills requirement, job complexity, and job enlargement. It seems that as manufacturing engineers' jobs become more complex and enlarged, their influence is not necessarily enhanced. Their job satisfaction measure is slightly

Table 3.2. Manufacturing Engineers--Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC) (Pilot Study)

Role Changes (Manufacturing Engineers)				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.847				
Items	**Descriptions**	**Factor Loadings**	**CITC**	**Avg.**
RC11	Qualifications required for manufacturing engineers have been upgraded.	0.83	0.78	3.20
RC12	Training required for manufacturing engineers has been more extensive.	0.72	0.66	3.27
RC13	Power of manufacturing engineers in product development team has increased.	0.82	0.78	3.47
RC14	Influence of manufacturing engineers in product development team has increased.	0.84	0.79	3.53
RC15	Technical skills required for manufacturing engineers have been more rigorous.	0.79	0.74	3.43
RC16	Behavioral skills (e.g., teamwork, inter-communication) required for manufacturing engineers have been more important.	0.85	0.81	3.77
RC17	Manufacturing engineers' jobs have become more complex.	0.85	0.81	3.70
RC18	Manufacturing engineers' jobs have been enlarged.	0.80	0.75	3.67
RC19	Manufacturing engineers' jobs have been enriched.	0.84	0.80	3.37
RC20	Overall, manufacturing engineers feel more satisfied with their work.	0.82	0.77	3.43
		Cronbach's Alpha 0.94		

higher than that of design engineers (3.43). Some items of RCDE (e.g., RC4, RC8) were somewhat low but CITCs of all other items were all sufficiently high. On the other hand, all RCME items were high (Cronbach's alpha>0.65). Since all items of RCDE and RCME are the same, to further examine these differences, all ten items were retained for the large survey.

3.4.2. Team Vision

For the pilot study, the Team Vision (TV) construct was conceptualized as having three variables (i.e., Mission, Strategic Fit, and Project Targets). Each variable has 6-11 items. Tables 3.3. and 3.4. show the initial factor loadings and

Table 3.3. Mission and Strategic Fit-- Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Mission

Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loading
TV1	This product development team had a good work plan.	0.88	0.82	0.89
TV2	This product development team had a well-focused mission.	0.90	0.85	0.91
TV3	This product development team had a well-communicated mission.	0.93	0.87	0.95
TV4	This product development team had a clear product concept.	0.79	0.71	0.83
TV5	This product development team had a clear plan of action.	0.62	0.51	x
TV6	Overall, this product development team had a shared understanding of the project mission.	0.94	0.90	0.94
		0.92	**Alpha**	**0.94**

Strategic Fit

Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loading
TV7	Our firm's overall product strategy guided the design of this product.	0.80	0.73	0.81
TV8	Our firm's overall technology strategy guided the design of this product.	0.78	0.72	0.79
TV9	Project targets were consistent with our firm's business strategy.	0.86	0.78	0.90
TV10	Project priorities were consistent with our firm's business strategy.	0.86	0.78	0.89
TV11	Our senior management provided overall strategic direction.	0.82	0.66	x
TV12	Our senior management provided an integrated set of project priorities.	0.76	0.70	x
TV13	Overall, this product development team had a shared understanding of how well this project fit within the firm's business strategy.	0.80	0.71	x
		0.91	**Alpha**	**0.89**

corrected item total correlations (CITCs) generated for each item related to a particular variable of TV. It also gives the initial Cronbach's alpha for each scale and Cronbach's alpha for those items retained after dropping a few items. Items which showed poor CITCs (< 0.60) were dropped (e.g., TV5's CITC=0.51). So TV 5 it was first dropped out. Although TV5 "This product development team had a clear plan of action" is about a plan of action, the respondents seem to identify more with clarity and accordingly showed poor factor loading. Factor loadings of individual constructs were mostly in the range 0.71 to 0.80. Four items (TV1, TV2, TV3, TV4, TV6) were retained for Mission.

All the strategic fit variable show relatively high CITC (>0.60). However, four items (TV7, 8, 9, and 10) are related to the characteristics of project targets while three items (TV11, 12 and 13) are related to senior managers' involvement in project teams. In this project level research, knowledge leadership is defined among team members rather than through senior management directives. Therefore, items related to senior management involvement were all dropped.

The Role Changes construct deals with a leadership issue for integration of product design and manufacturing process design. Team vision is affected or directed by team leaders more than by senior managers. Strategic fit of project targets is not merely based on what senior managers say but on the teams' understanding of project targets in relation to overall business, product and technology strategy. Project targets are more about team members' perceptions of their mission, congruence between strategy and project targets, and clarity and tradeoff of project targets. The focus of inquiry was how much project team leaders exercise leadership in setting the mission of a project, its strategic fit, clarity and tradeoff. Therefore, items about senior managers' influence were dropped. For the pilot analysis purpose, only four items (TV7, TV8, TV9, and TV10) were retained.

In Table 3.4, Project Targets showed initially three different factors (Clarity, Consistency and Tradeoff of Project Targets). Items (TV19 and TV22) were dropped because of their low CITC. TV24 was also dropped because it describes the general characteristics of project targets. Afterwards, project targets were identified as two factors: Clarity of Project Targets (TV14,15, 21, and 23) and Consistency of Project Targets (TV 16, 17, 18, and 20).

After the initial analysis, four variables (Mission, Strategic Fit, Clarity, and Consistency of Project Targets) were derived. With the retained items (a total of 16 items), exploratory factor analysis was conducted (Table 3.5). The factor structure is unstable. Mission is cross-loaded with Clarity. Violations of discriminant validity occur between Mission and Clarity (Table 3.6.). Two possible explanations are: (1) 30 responses are not enough to provide stable structure for 16 items; (2) Mission and Clarity of Project Targets may have a causal relationship. If scales of Mission are high, overall shared understanding of Mission would result in setting up clear project targets.

Table 3.4. Project Targets-- Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Project Targets								
Items	**Descriptions**	**Initial Factor Loadings**			**CITC**	**Retained Factor Loadings**	
TV14	Our project targets were clear.	0.75			0.80	0.93	
TV15	Our project targets were based on realistic customer requirements.	0.72			0.71	0.88	
TV16	Our project targets reflected the competitive situation.		0.71		0.67		0.80
TV17	Our project targets were consistent with our manufacturing capabilities.		0.95		0.60		0.83
TV18	Our project targets were consistent with our suppliers' capabilities.		0.73		0.67		0.84
TV19	Our project targets were consistent with our resources.		0.63		0.51	x	x
TV20	Technical risks were considered in setting project targets.		0.57	0.47	0.60		0.76
TV21	The relative priority of each project target was clear.	0.82			0.83	0.91	
TV22	Tradeoffs (e.g., time vs. cost) were considered to determine priorities.			0.89	0.35	x	x
TV23	A single integrated set of project targets (objectives) was defined.	1.01			0.75	0.91	
TV24	Overall, this product development team had a shared understanding of the project targets.	0.88			0.66	x	x
		0.90				**A**	**B**

A – Retained items (Clarity) Alpha 0.93

B - Retained items (Consistency) Alpha 0.82

Table 3.5. Factor Analysis for all Team Vision Constructs (Retained Items)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.788				
Items	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
TV1			0.460	0.610
TV2	0.684		**Mission**	
TV3	0.661			0.482
TV6				0.707
TV7	0.540			
TV8		**Strategic**	0.694	
TV9		**Fit**	0.866	
TV10			0.891	
TV14	0.865			
TV15	0.993	**Clarity**		
TV21	0.629			
TV23	0.748			
TV16		0.715		
TV17	**Consist-**	0.756		
TV18	**ency**	0.697		
TV20		0.796		
Eigen Value	**8.908**	**2.038**	**1.185**	**1.017**
% of Variance	**55.672**	**12.737**	**74.05**	**63.55**
Cumulative % Of Variance	**55.672**	**68.409**	**75.815**	**82.170**

Table 3.6. Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Test for Team Vision

	TV1	TV2	TV3	TV6	TV7	TV8	TV9	TV10	TV14	TV15	TV21	TV23	TV16	TV17	TV18
TV1	1.00														
TV2	0.69	1.00													
TV3	0.72	0.89	1.00												
TV6	0.84	0.77	0.86	1.00											
TV7	0.49	0.66	0.69	0.65	1.00										
TV8	0.44	0.64	0.50	0.35	0.48	1.00									
TV9	0.73	0.68	0.61	0.63	0.62	0.71	1.00								
TV10	0.65	0.61	0.64	0.54	0.59	0.65	0.91	1.00							
TV14	0.50	0.82	0.69	0.57	0.55	0.62	0.52	0.47	1.00						
TV15	0.33	0.74	0.62	0.45	0.50	0.56	0.43	0.40	0.86	1.00					
TV21	0.56	0.77	0.71	0.57	0.39	0.61	0.53	0.52	0.76	0.65	1.00				
TV23	0.62	0.78	0.75	0.69	0.51	0.55	0.54	0.53	0.71	0.70	0.85	1.00			
TV16	0.40	0.47	0.31	0.33	0.22	0.43	0.45	0.31	0.46	0.39	0.51	0.33	1.00		
TV17	0.31	0.38	0.34	0.37	0.12	0.18	0.21	0.09	0.56	0.44	0.44	0.22	0.62	1.00	
TV18	0.45	0.53	0.39	0.42	0.15	0.61	0.44	0.31	0.59	0.48	0.57	0.47	0.49	0.61	1.00
# of Violations	1	3	1	0	**6**	**7**	3	3	1	1	2	2	1	0	**4**
Mean	3.97	4.10	3.86	3.79	3.52	3.66	3.21	3.72	3.86	3.66	3.55	3.52	3.59	3.66	3.41
Std Dev	0.91	0.98	1.25	0.98	1.24	1.08	1.45	1.03	1.09	1.04	1.30	1.38	0.95	0.97	1.09

3.4.3. Shared Knowledge

For the pilot study, the Shared Knowledge (SK) construct was represented by five variables (i.e., Shared Knowledge of: Knowledge of Customers. Competitors, Internal Capabilities, Suppliers, and Products). For the pilot study, Shared Knowledge was assessed in two ways: (1) by individual member (Table 3.7. and 3.8.); (2) by the team as a whole (Table 3.9. and 3.10.). The assessment by an individual member was not about his/her expert knowledge but rather about adequate knowledge of an area, which may not necessarily fall within his/her functional specialty. For example, the items that measured the degree of Shared Knowledge of Customers included the design engineers' understanding of the changing needs of customers. Design engineers, compared to marketing managers, may not be so knowledgeable about the changing needs of customers. If design engineers, who are mostly concerned about the technical aspects of design, have an adequate understanding of customers' needs, it may indicate an overall high level of shared knowledge of customers among team members. In the same token, marketing managers may not be so knowledgeable about internal capabilities. Therefore, the marketing managers' level of understanding of internal manufacturing capabilities might be an indicator of the extent of shared knowledge of the internal capabilities of the team.

Another way to assess the extent of shared knowledge of a team is to learn about the perception of how much the team as a whole knows about a particular aspect of shared knowledge. The respondents were mostly product managers or project leaders who managed product development projects. They probably had fairly good perception about how much their team members understood about certain aspects of shared knowledge.

Tables 3.7., 3.8., 3.9., and 3.10. show the initial factor loadings of all items, corrected item total correlations (CITCs) of each item, and Cronbach's alpha for each variable. Overall, Cronbach's alpha of Shared Knowledge by individual members is lower than that of the product team as a whole. For example, the range of Cronbach's alpha for individual members is 0.58-0.90, while the counterpart for the entire team as a whole is 0.82-0.94. The items for the entire team appear to better measure the variables of shared knowledge. Therefore, the Shared Knowledge by individual members was dropped and instead, only the Shared Knowledge by team members was adopted for further analysis.

In Table 3.9., Shared Knowledge of Competitors (SKCOMP) shows good CITC and high factor loadings, except OC10. Cronbach's alpha for retained items is 0.91. Shared Knowledge of Suppliers (SKSUPPL) shows both a very high CITC and factor loadings. So all three items were kept. A few more items were added for the final survey (i.e., "Our suppliers' capabilities to meet time requirements", "Our suppliers capabilities to meet quality requirements," and "Our suppliers' capabilities to volume and mix changes").

In each table, all items marked with an x were dropped. For example, in Table 3.7. and 3.8. all items are marked with an x. This means that none of these items were used for the large survey. This is because all Shared Knowledge items by individual members were lower than the counterparts by teams.

Table 3.7. **Shared Knowledge of Customers, Competitors and Internal Capabilities: Items for Individual Members--Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)**

Shared Knowledge of Customers (Individual Members)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TC1	Our product design engineers had an adequate knowledge of the changing needs of customers.	0.81	0.60	x
TC2	Our process engineers had an adequate knowledge of how customers use our products.	0.90	0.76	x
TC3	Our manufacturing experts had an adequate knowledge of customer satisfaction ratings.	0.88	0.69	x
		Cronbach Alpha		0.83

Shared Knowledge of Competitors (Individual Members)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TC4	Our marketing people had an adequate knowledge of our competitors' technology.	0.58	0.37	x
TC5	Our product design engineers had an adequate knowledge of our competitors' strengths in marketing and distribution.	0.82	0.63	x
TC6	Our process engineers had an adequate knowledge of our competitors' products.	0.78	0.54	x
TC7	Our manufacturing people had an adequate knowledge of our competitive opportunities.	0.79	0.56	x
		Cronbach Alpha		0.73

Shared Knowledge of Internal Capabilities (Individual Members)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TP1	Our product design engineers had an adequate knowledge of our firm's internal manufacturing capabilities.	0.88	0.79	X
TP2	Our marketing people had an adequate knowledge of our engineering design capabilities.	0.82	0.69	x
TP3	Our product design engineers had an adequate knowledge of our manufacturing capabilities.	0.92	0.84	x
TP4	Our manufacturing people had an adequate knowledge of our engineering design capabilities.	0.87	0.75	x
		Cronbach Alpha		0.90

Table 3.8. Shared Knowledge of Suppliers and of Products : Items for Individual Members--Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Shared Knowledge of Suppliers (Individual Members)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TP5	Our product design engineers had an adequate knowledge of our suppliers' manufacturing capabilities	0.93	0.83	x
TP6	Our marketing people had an adequate knowledge of our suppliers' design capabilities.	0.70	0.51	x
TP7	Our product design engineers had an adequate knowledge of our suppliers' capabilities to make component parts.	0.78	0.58	x
TP8	Our manufacturing people had an adequate knowledge of our suppliers' design capabilities.	0.77	0.59	x
		Cronbach Alpha		0.81

Shared Knowledge of Products (Individual Members)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TP9	Our marketing people had an adequate knowledge of the major components of our product.	0.71	0.36	x
TP10	Our manufacturing people had an adequate knowledge of the product history.	0.74	0.39	x
TP11	Our design engineers accurately estimated the product cost.	0.75	0.40	x
		Cronbach Alpha		0.58

All Shared Knowledge variables, except Shared Knowledge of Customers, showed a single factor structure. In Table 3.9. all other items are about customers' characteristics, while OC3 and OC5 are about customer characteristics in relation to products. Item OC4 ("How the product created customer value") and OC6 ("How well we were doing on customer satisfaction ratings") show low factor loading. By dropping these two items, Shared Knowledge of Customers (SKCUST) has a simple factor structure with high factor loading. Shared Knowledge of Products (SKPROD) shows high CITC and good factor loading, except for OP3 and OP6. These two items were dropped.

Finally, Shared Knowledge of Internal Capabilities (SKINTCP) shows all high CITC and factor loading. So all items were retained.

Table 3.9. Shared Knowledge of Customers and Competitors: Items for Product Development Team as a Whole—Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Shared Knowledge of Customers (Team)					
Items	Descriptions	Initial Factor Loadings		CITC	Retained Factor Loadings
This product development team has shared knowledge of :					
OC1	How customer needs were changing.	0.71	-0.36	0.80	0.88
OC2	Important value to customer attributes.	0.77		0.66	0.84
OC3	How customers used our products.	0.93	0.34	0.40	x
OC4	How the product created customer value.	0.63		0.56	0.75
OC5	How satisfied our customers were with our products.		-0.97	0.52	x
OC6	How well we were doing on customer satisfaction ratings.		-0.81	0.65	0.74
		0.83		**Cronbach Alpha**	**0.82**

Shared Knowledge of Competitors (Team)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
This product development team has shared knowledge of :				
OC10	Competitive opportunities that our firm anticipated.	0.69	0.62	x
OC11	Competitive threats that our firm faced.	0.75	0.69	0.74
OC12	Advantages of our competitors.	0.88	0.83	0.89
OC13	Disadvantages of our competitors.	0.89	0.84	0.91
OC14	Strengths of our competitors.	0.89	0.86	0.90
OC15	Weaknesses of our competitors.	0.78	0.69	0.77
OC16	Competitors' products.	0.77	0.70	0.78
OC17	Competitors' product technologies.	0.87	0.83	0.88
		0.93	**Cronbach Alpha**	**0.91**

Shared Knowledge of Products shows a simple factor structure and the CITC are generally high. OP3 and OP6 are relatively low compared to other items, so these items were dropped for purification.

Table 3.10. Shared Knowledge of Internal Capabilities, Products and Suppliers: Items for Product Development Team as a Whole-- Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Shared Knowledge of Internal Capabilities (Team)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
This product development team has Shared Knowledge of :				
OP 8	The capabilities of our process technologies used.	0.87	0.82	0.87
OP 9	The strengths of our engineering design capabilities.	0.91	0.80	0.91
OP10	The weaknesses of engineering design capabilities.	0.91	0.87	0.91
OP11	The strengths of our manufacturing facilities.	0.87	0.78	0.87
OP12	The weaknesses of our manufacturing facilities.	0.87	0.80	0.87
		0.93	Cronbach Alpha	**0.93**

Shared Knowledge of Products (Team)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
This product development team has shared knowledge of :				
OP1	Our product's history.	0.78	0.71	0.79
OP2	The strengths of our product.	0.85	0.78	0.86
OP3*	The weaknesses of our product.	0.70	0.60	X
OP4	The advantages of our product.	0.88	0.82	0.87
OP5	The disadvantages of our product.	0.90	0.86	0.86
OP6*	The design problems of our product.	0.72	0.65	X
OP7	The product technologies we used.	0.80	0.72	0.81
		0.91	Cronbach Alpha	**0.89**

Shared Knowledge of Suppliers(Team)				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
This product development team has shared knowledge of:				
OC7	Our suppliers' process capabilities.	0.95	0.89	0.95
OC8	Our suppliers' design capabilities.	0.93	0.85	0.93
OC9	Our suppliers manufacturing capabilities.	0.95	0.89	0.95
		0.94	Cronbach Alpha	**0.94**

Table 3.11. Factor Analysis for all Shared Knowledge of Retained Items

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.62

Items	Internal Capabilities	Competitors	Products	Customers	Suppliers
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
OC 1			0.73		
OC 2			0.90	Customers	
OC 4	0.57				
OC 6			0.78		
OC 7				0.77	
OC 8				0.74	Suppliers
OC 9				0.77	
OC11		0.72			
OC12		0.87			
OC13		0.87	Competitors		
OC14		0.92			
OC15		0.68			
OC16		0.76			
OC17		0.85			
OP 1					0.55
OP 2					0.59
OP 4					0.66
OP 5					0.54
OP 7	0.69				
OP 8	0.78				Products
OP 9	0.95	Internal Capabilities			
OP10	0.90				
OP11	0.83				
OP12	0.71				
Eigen Value	9.77	3.05	1.43	1.30	1.19
% of Variance	46.50	14.50	6.80	6.20	5.70
Cumulative % Of Variance	46.50	61.10	67.90	74.00	79.70

Table 3.11. shows the factor analysis of all the retained items of Shared Knowledge. Again maximum likelihood extraction with direct oblimin rotation was utilized. The factor structure is somewhat unstable (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.62). Specifically OC4, OP1, and OP2 are loaded with other variables. It might be because the small sample size (30) is not large enough to provide a stable factor structure for 24 items. For the large survey, these items (e.g., Shared Knowledge of Customers, Internal Capabilities, and Suppliers) were modified and added.

Table 3.12. shows a test of discriminant validity by the Multitrait-Multimethod (MTMM) approach. The discriminant validity is not quite evident in the following items: Shared Knowledge of Customers (OC1, OC4), Products (OP7, 8), Internal Capabilities (OP11), and Competitors (OC10).

3.4.4. Process Outcome

The Process Outcome (PRO) construct was represented by three variables (i.e., Teamwork, Development Productivity, and Time to Market). Each variable has 4-7 items. In Table 3.13., the initial factor loadings and corrected item total correlations (CITCs) are generated for each item related to a particular variable of TV. It also gives the Cronbach's alpha for initial items and for the retained items.

In Table 3.13, Teamwork shows two sub-factors. First, SO8 is dropped because it has the lowest CITC among all items. Next, SO13 (identified manufacturing problems *early*) and SO14 (identified design-problems *early*) are dropped because these two items seemed to be more associated with SO6 (resolved conflicts *quickly*). The final retained items are based on high CITC's, good model fit according to the LISREL measurement model. (Note: For all the variables of each construct, LISREL analysis was conducted to test the model fit. The items that provide the best model fit are mostly similar to those that show high CITC. The results of this LISREL analysis are not reported here).

Table 3.12. Item Correlation Matrix, Descriptive Statistics and Discriminant Validity Test for Shared Knowledge

		SKCUST				SKSUPPL			SKCOMP				SKPROD				SKINTCP	
	OC1	OC2	OC4	OC6	OC7	OC8	OC9	OC10	OC11	OC14	OC15	OP1	OP4	OP5	OP7	OP8	OP9	OP10	OP11
OC1	1.00																		
OC2	0.68	1.00																	
OC4	0.56	0.48	1.00																
OC6	0.53	0.49	0.39	1.00															
OC7	0.62	0.35	0.56	0.29	1.00														
OC8	0.61	0.20	0.59	0.24	0.82	1.00													
OC9	0.52	0.27	0.58	0.17	0.87	0.82	1.00												
OC10	0.39	0.38	0.59	0.33	0.42	0.37	0.42	1.00											
OC11	0.14	0.36	0.48	0.25	0.28	0.05	0.36	0.57	1.00										
OC14	0.12	0.21	0.37	0.23	0.34	0.14	0.32	0.48	0.60	1.00									
OC15	0.16	0.22	0.25	0.36	0.27	0.15	0.23	0.52	0.35	0.61	1.00								
OP1	0.37	0.31	0.45	0.22	0.50	0.52	0.48	0.50	0.43	0.56	0.35	1.00							
OP4	0.45	0.15	0.54	0.53	0.52	0.48	0.36	0.28	0.16	0.36	0.38	0.51	1.00						
OP5	0.52	0.20	0.57	0.45	0.61	0.63	0.49	0.37	0.18	0.54	0.37	0.63	0.82	1.00					
OP7	0.41	0.23	0.76	0.28	0.45	0.52	0.53	0.46	0.33	0.19	0.22	0.52	0.59	0.57	1.00				
OP8	0.61	0.20	0.54	0.24	0.60	0.62	0.55	0.32	0.18	0.17	0.25	0.39	0.57	0.53	0.51	1.00			
OP9	0.58	0.29	0.63	0.26	0.46	0.50	0.42	0.43	0.15	0.18	0.31	0.28	0.58	0.57	0.65	0.81	1.00		
OP10	0.46	0.27	0.65	0.21	0.57	0.59	0.55	0.33	0.23	0.11	0.20	0.38	0.41	0.52	0.53	0.69	0.71	1.00	
OP11	0.51	0.39	0.70	0.31	0.67	0.67	0.60	0.45	0.36	0.19	0.24	0.41	0.45	0.51	0.52	0.68	0.64	0.87	1.00
# of Violations	5	0	13	2	0	0	0	1	5	2	3	2	5	2	4	0	1	0	3
Mean	3.79	3.83	3.76	3.66	3.38	3.45	3.24	3.86	3.48	3.41	3.52	4.03	4.17	3.93	3.90	3.83	3.86	3.52	3.52
Std Dev	0.90	0.93	0.95	1.11	0.98	1.02	1.02	0.83	1.12	1.12	0.99	0.78	0.71	0.88	0.90	0.97	0.83	0.78	0.95

Table 3.13. Process Outcomes: Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Teamwork

Items	Descriptions	Initial Factor Loadings		CITC	Retained Factor Loadings
This product development team:					
SO 6	Resolved conflicts quickly.		0.84	0.72	0.79
SO 7	Implemented decisions effectively.	0.80		0.70	0.79
SO 8	Solved problems creatively.	0.66		0.62	X
SO 9	Communicated effectively.	0.76		0.80	0.89
SO 10	Coordinated activities well.	0.55		0.72	0.85
SO 11	Worked well together.	0.88		0.72	0.85
SO 12	Resolved conflicts constructively.	0.99		0.66	x
SO 13	Identified manufacturing problems early.		0.94	0.77	x
SO 14	Identified design-manufacturing problems early.		0.92	0.66	x
		0.91		**Alpha**	**0.89**

Development Productivity

Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
This product development team:				
SO15	Was productive.	0.82	0.70	0.82
SO16	Used product engineering hours effectively.	0.74	0.61	0.74
SO17	Allocated personnel realistically.	0.86	0.77	0.86
SO18	Used financial resources sensibly.	0.79	0.66	0.79
SO19	Used all product development resources rationally.	0.82	0.70	0.82
		0.92	**Alpha**	**0.92**

Time to Market

Items	Descriptions	Initial Factor Loadings		CITC	Retained Factor Loadings
This product development team:					
SO 1	Introduced products to market ahead of competitors.		0.97	0.18	x
SO 2	Developed products on schedule.	0.92		0.67	0.87
SO 3	Met its deadline for market introduction.	0.86		0.83	0.91
SO 4	Reduced the product development time.	0.83		0.65	0.81
SO 5	Met the target date for our project.	0.86		0.81	0.90
		0.82		**Alpha**	**0.90**

For all the retained items of Process Outcomes, exploratory factor analysis was done. Again maximum likelihood extraction with direct oblimin rotation was utilized. Because of the causal relationship between Teamwork and Development Productivity, Development Prouctivity was done separately. Table 3.14. shows the result.

Table 3.14. Factor Analysis for all Process Outcomes (Retained Items; Pilot Study)

ITEM	Development Productivity	ITEM	Teamwork	Time to Market
SO15	0.82	SO6	0.66	
SO16	0.74	SO7	0.84	
SO17	0.86	SO9	0.99	
SO18	0.79	SO10	0.73	
SO19	0.82	SO11	0.76	
		SO 2		-0.85
		SO3		-0.90
		SO4		-0.89
		SO5		-0.78
Eigen Value	3.25	Eigen Value	4.91	1.63
% of Variance	65.06%	% of Variance	54.53	18.13
Cumulative % of Variance	65.06%	Cumulative % of Variance	54.53	72.66
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.80	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.78	

Table 3.15. shows discriminant validity for all the retained items of Process Outcomes. Violations occur mostly in Development Productivity. Further examination seems to indicate that Teamwork and Development Productivity might have a causal relationship. It is quite probable that the higher the level of Teamwork, the higher the level of Development Productivity.

Table 3.15. Process Outcomes--Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

	Time to Market				Teamwork				Development Productivity					
	SO2	**SO3**	**SO4**	**SO5**	**SO6**	**SO7**	**SO9**	**SO10**	**SO11**	**SO15**	**SO16**	**SO17**	**SO18**	**SO19**
SO2	1.00													
SO3	0.91	1.00												
SO4	0.62	0.69	1.00											
SO5	0.88	0.93	0.75	1.00										
SO6	0.25	0.25	0.16	0.38	1.00									
SO7	0.41	0.28	0.20	0.43	0.76	1.00								
SO9	0.63	0.53	0.45	0.69	0.70	0.77	1.00							
SO10	0.45	0.41	0.38	0.61	0.65	0.65	0.86	1.00						
SO11	0.50	0.50	0.41	0.59	0.66	0.61	0.67	0.72	1.00					
SO15	0.41	0.40	0.36	0.51	0.64	0.59	0.65	0.61	0.68	1.00				
SO16	0.39	0.41	0.38	0.48	0.54	0.35	0.47	0.46	0.57	0.76	1.00			
SO17	0.45	0.38	0.42	0.47	0.61	0.59	0.61	0.53	0.67	0.60	0.65	1.00		
SO18	0.44	0.36	0.56	0.40	0.41	0.33	0.50	0.33	0.38	0.46	0.53	0.70	1.00	
SO19	0.24	0.19	0.36	0.35	0.49	0.48	0.61	0.61	0.74	0.60	0.56	0.71	0.55	1.00

	SO2	**SO3**	**SO4**	**SO5**	**SO6**	**SO7**	**SO9**	**SO10**	**SO11**	**SO15**	**SO16**	**SO17**	**SO18**	**SO19**
# of Violations	1	0	0	0	0	0	0	0	2	6	2	3	2	3
Mean	3.71	3.75	3.42	3.83	3.75	3.42	3.42	3.63	3.58	3.88	3.42	3.50	3.58	3.33
Std Dev	1.08	1.11	1.10	1.09	0.85	1.18	1.14	1.01	0.97	0.90	0.72	0.93	0.93	1.05

3.4.5. Product Outcomes—Manufacturing and Customer Outcomes

The Product Outcomes construct is represented by four variables (i.e., Manufacturability, Manufacturing Cost, Value to Customer, and Product

Performance) and each variable has 4-6 items. All these variables reflect the characteristics of products in terms of manufacturing and customer performance elements. Tables 3.16. and 3.17. display that all items show high CITC and therefore, no items are dropped. Each variable demonstrates simple factor structure with high reliability.

Table 3.16. Product Outcomes (Manufacturing Outcomes--Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Manufacturability				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TO1	This product design was simplified.	0.91	0.83	0.91
TO2	The number of parts was reduced.	0.84	0.72	0.84
TO3	The product is easy to assemble.	0.85	0.72	0.85
TO4	Manufacturing problems were minimized.	0.87	0.76	0.87
		0.89	Alpha	**0.89**

Manufacturing Cost				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TO14	The material cost of this product is considerably lower than the industry average.	0.91	0.82	0.91
TO15	The labor cost of this product is considerably lower than the industry average.	0.93	0.85	0.93
TO16	The overhead cost of this product was considerably lower than the industry average.	0.94	0.86	0.94
TO17	The overall Manufacturing Cost of this product is quite competitive in the market.	0.74	0.61	0.74
		0.90	Alpha	**0.90**

Table 3.17. Product Outcomes (Customer Outcomes: Items, Descriptions, Initial Factor Loadings, Corrected Item Total Correlations (CITC), Retained Items Factor Loadings (Pilot Study)

Value to Customer				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TO5	This product had a high quality.	0.88	0.81	0.88
TO6	This product was successful in the market place.	0.86	0.78	0.86
TO7	Customers highly valued this product.	0.93	0.90	0.93
TO8	This product created a high customer value.	0.92	0.87	0.92
TO9	This product exceeded customer expectations.	0.93	0.88	0.93
		0.94	Alpha	**0.94**

Product Performance				
Items	Descriptions	Initial Factor Loadings	CITC	Retained Factor Loadings
TO10	The overall performance of this product was excellent.	0.96	0.92	0.96
TO11	The technical performance of this product was excellent.	0.92	0.86	0.92
TO12	The components worked well together.	0.94	0.89	0.94
TO13	The system performance of this product was excellent.	0.95	0.90	0.95
		0.96	Alpha	**0.96**

The external consistency of Product Outcomes construct was appraised by submitting all the retained items to exploratory factor analysis to uncover significant cross-loadings. Again maximum likelihood extraction with direct oblimin rotation was utilized. Loadings below 0.30 were not reported. The items for Value to Customer and Product Performance were loaded together as one factor. This was understandable in that Value to Customer and Product Performance have some causal relationships. A product with high level of Value to Customer has high level of Product Performance, so for the factor analysis, Value to Customer was separated from the other three variables.

Table 3.18. Factor Analysis for Product Outcomes (Manufacturing and Customer Outcomes: Pilot Study)

item	Value to Customer
TO5	0.88
TO6	0.86
TO7	0.93
TO8	0.92
TO9	0.93
Eigen Value	4.09
% of Variance	81.77
Cumulative % of Variance	81.77
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.87

item	Product Performace	Manufacturing Cost	Manufact-urability
TO1			0.85
TO2			0.84
TO3			0.47
TO4			0.56
TO10	0.99		
TO11	0.87		
TO12	0.92		
TO13	0.97		
TO14		0.88	
TO15		0.81	
TO16		0.92	
TO17		0.76	
Eigen Value	6.96	1.85	1.14
% of Variance	58.02	15.43	9.49
Cumula-tive % of Variance	58.02	73.45	82.95
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.80		

The result shows in Table 3.18. Value to Customer shows high factor loadings (all >0.86) and the variance explained is 81.77%. The other three variables show external consistency. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the three variables (i.e., Product Performance, Manufacturability, and Manufacturing Cost) is sufficient (0.80). Cumulative variance explained is 82.95%.

According to Table 3.19, item correlation matrix, most violations for Discriminant Validity occur with Manufacturability and Value to Customer, especialy item TO 4 ("Manufacturing problems were minimized"), TO 5 ("This product had a high quality"), and TO9 ("This product exceeded customer expectations").

Table 3.19. Product Outcomes -- Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

	Manufacturability				Value to Customer					Product Performance				Manufacturing Cost			
	TO1	TO2	TO3	TO4	TO5	TO6	TO7	TO8	TO9	TO10	TO11	TO12	TO13	TO14	TO15	TO16	TO17
TO1	1.00																
TO2	0.81	1.00															
TO3	0.74	**0.58**	1.00														
TO4	0.74	0.69	0.73	1.00													
TO5	0.64	0.50	0.52	0.81	1.00												
TO6	0.47	0.37	0.31	0.52	**0.70**	1.00											
TO7	0.46	0.43	0.35	0.62	0.76	0.81	1.00										
TO8	0.44	0.44	0.42	0.65	0.75	0.75	0.95	1.00									
TO9	0.44	0.51	0.45	0.72	0.79	0.66	0.85	0.89	1.00								
TO10	0.59	0.43	0.58	0.74	0.80	0.66	0.76	0.72	0.79	1.00							
TO11	0.52	0.42	0.59	0.59	0.65	0.44	0.56	0.56	0.69	0.83	1.00						
TO12	0.61	0.43	0.56	0.73	0.79	0.62	0.69	0.65	0.72	0.95	**0.82**	1.00					
TO13	0.55	0.42	0.58	0.66	0.72	0.57	0.66	0.62	0.76	0.94	0.85	0.93	1.00				
TO14	0.35	0.44	0.56	0.44	0.39	0.11	0.21	0.33	0.40	0.35	0.47	0.39	0.36	1.00			
TO15	0.46	0.51	0.60	0.56	0.51	0.14	0.28	0.34	0.45	0.50	0.57	0.55	0.52	0.82	1.00		
TO16	0.25	0.45	0.37	0.41	0.39	0.02	0.21	0.29	0.47	0.31	0.38	0.35	0.36	0.69	0.84	1.00	
TO17	0.10	0.27	0.23	0.40	0.36	0.21	0.36	0.43	0.46	0.36	0.27	0.45	0.33	0.67	**0.62**	0.72	1.00

	Manufacturability				Value to Customer					Product Performance				Manufacturing Cost			
	TO1	TO2	TO3	TO4	TO5	TO6	TO7	TO8	TO9	TO10	TO11	TO12	TO13	TO14	TO15	TO16	TO17
Mean	3.50	3.46	3.42	3.42	4.13	3.54	3.75	3.75	3.71	3.92	3.92	3.92	3.79	3.29	3.33	3.25	3.63
Std Dev	0.98	1.02	1.14	1.14	1.08	1.28	1.26	1.33	1.27	0.97	1.02	0.88	0.93	0.95	0.87	1.07	1.13
# of Violations	0	0	2	4	3	0	0	0	5	0	0	0	0	0	0	0	0

3.5. MODIFICATION AFTER PILOT STUDY

After the pilot study, the overall model remains unchanged as presented in Figure 2.3. in chapter two. However, items of some variables (e.g., shared knowledge of customers and most of the team vision varaibles) were modified or new items were added. All other variables were retained items from the pilot study.

Before the large-sample administration, the variables were examined with respect to the research objectives and the overall pilot study results. Special attention was focused on the variables that had one or more of the following characteristics--a poor factory loading, low reliability and/or weak disriminant validity. Accordingly, shared knowledge of customers and team vision variables, especially project targets and teamwork needed to be modified.

A few items were added to shared knowledge of customers and team vision variables. Based on the findings of the pilot study, shared knowledge of customers was modified. These items were added:(1) "customer requirements" (Cooper, 1984, 1987, 1991; Cooper and Kleinschmidt, 1993); (2)"How customers make purchase decisions" (Holak and Lehmann, 1990; Cordell et al., 1996); (3)"Which features were most valued by target customers"; (4)"Which customer groups we were targeting"; (5)"Our target customers" (Slater and Naver, 1994b); (6)"Current customer needs" and (7)"What our customers want" (Slater and Naver, 1994a; Slater and Narver, 1998, 1999). A few more items were added to shared knowledge of suppliers such as: (1)"Our suppliers' capabilities to meet cost targets" (Hahn, Watts, Kim, 1990); (2)"Our suppliers' capabilities to meet time requirements" (Davis, 1993); (3)"Our suppliers' capabilities to meet quality requirements" (Dyer, Cho and Chu, 1998); (4) "Our suppliers' capabilities to respond to volume and mix changes" (Davis, 1993; McDuffle and Helper, 1998). For knowledge of internal capabilities, the following items were added: (1) The capabilities of our engineering staff (Clark and Wheelwright, 1993; Numata, 1996); (2) The capabilities of our manufacturing staff (Adler, Mandelbaum, Ngyyen and Schwerer, 1996); (3) Our manufacturing capabilities (White, 1996).

Items for team vision construct were also modified with theoretical considerations. In the pilot study, the focus was on types of plan, mission, concept and action. So in the pilot questionnaire, the items were expressed as follows: This product development team had "a good work plan", "well-focused mission", "well-communicated mission". In the final survey it is expressed in somewhat different ways. The focus now is on the extent of shared understanding of team members in regard to the project purpose, mission and goals. The critical question is, "Were project purpose, mission, and goals well defined, communicated and understood by team members?" The key is not the plans, mission and goals they had; but rather, how they were presented, accepted and utilized by the team members. The extent of team members' understanding became the focus (Rosenthal and March, 1986; Jarke, 1986; Hackman, 1990; Ancona and Caldwell, 1992). In addition, to further probe the specific nature of project targets, the items that describe the nature of projects in terms of clarity, consistency and tradeoffs are all included as part of project targets in the final survey instruments. A few more items that describe the nature of trade-off of the project targets were added as well. The new items added were: (1) "Project targets clearly specified tradeoffs between quality and cost" ; (2) "Project targets clearly specified tradeoffs between performance and cost".

3.6. SURVEY METHODS AND SAMPLE CHARACTERISTICS

Four industries with SIC Code numbers 34, 35, 36, and 37 were selected to test the model. The sampling frame was obtained from Society of Automotive Engineers (SAE). The initial mailing started with 2,500, and then two more follow-up letters were sent out. For the actual mailing, only 2,262 were used because 35 simply declined to receive the questionnaire, 25 questionnaires were returned undelivered, 15 were returned with no answers, 10 had incomplete answers, 3 had unusable responses, and the system did not process the addresses of an additional 150 because it did not meet the predefined parameters. From the remaining pool, 205 usable responses were received, which resulted in the effective response rate of 9.1%. [205 / (2500-35-25-15-13-150) = 0.091]

3.6.1. Sample Characteristics

The usable responses are from Fabricated Metal Products (22.93%), Industrial and Commercial Machinery (7.32%), Electronic and Electrical Equipment and Machinery (17.56%), Transportation Equipment (30.12%), and Miscellaneous (16.32%).

The respondents' positions are: CEO/Presidents (2.44%), Senior Managers (36.10%), Project Managers (32.68%), and Others (28.29%). More than 70% of respondents have actual experiences in leading and managing cross-functional project teams.

The size of the respondents' is: less than 500 (40.00%), 500-599 (15.12%), 1,000-4,999 (22.44%), 5,000-9,999 (8.78%) and over 10,000 (12.20%). Firms that have more than 1,000 employees account for 43.42% of the sample. These sample characteristics are not significantly different from the corresponding population parameters of the original sample that the Society of Automotive Engineers provided. This implies little difference in characteristics between respondents and non-respondents.

There were telephone follow-ups for a random sample of ten out of 205 respondents, These individuals all had different positions (CEO, Product Development Manager, Design or Manufacturing Engineers). These individuals stated that based on their experiences they were quite comfortable to answer all the questions. The majority of respondents (more than 70%) were senior managers who have had experience in managing product development. In view of the respondents' positions in cross-functional product development work, the vast majority of respondents were assumed to be fairly competent to answer these questions. Those who were not able to answer certain questions did not answer. For example, quite a few design engineers did not answer questions on role changes of manufacturing engineers. When projects were completed very recently, many did not write down either product or market performance. Based on the above findings, it is assumed that the level of respondents' knowledge was sufficient.

The project period is: 1997 (12.20%), 1998 (32.68%), 1999 (38.05%). More than 82% of respondents answered the survey questions based on their project experiences within the last two years.

On the first page of the questionnaire, it stated, "This questionnaire should be answered by those (e.g., design or manufacturing engineers, product development managers, vice-presidents, and CEOs,) who have been recently involved in a cross-functional product development team." It was also clearly stated that all the responses should be based on the particular project they identified on the very first page. This was done so that the answers were to be consistent on the particular project experience they had. Each was also asked to identify a particular project they were involved in and to rate the market performance of the project (1=Very disappointing, 2=Somewhat disappointing, 3=Average, 4=Moderate success, 5=A great success).

3.6.2. Missing Data and Outliers

Some respondents were eliminated for further analysis. Ten respondents were eliminated because they had not responded to at least one whole section of the questionnaire. Three respondents were eliminated as outliers because all their scores were marked as 3 (neutral) with no variation. An overall total of 13 respondents were eliminated in a useful sample of 218 for hypothesis testing, so 205 responses were used for the final analysis.

Table 3.20. T-TEST OF THE LARGE SURVEY (Team Vision)

Variables		Test by Type of Respondent Medium: Mail Response (n = 167)	Test by Type of Respondent Medium: Internet Response (n =38)	Test by Mailing Sequence: 1st mailing (n=116)	Test by Mailing Sequence: 2nd mailing (n=51)
Shared Team Purpose and Mission [BA1, BC1, BM1, BP1, BZ1] (5)	Mean	19.04	18.79	19.07	18.98
	S.D	4.17	4.14	4.33	3.80
	Sig. (2-tailed)	0.60	0.60	0.27	0.27
Strategic Fit of Project Targets--Environment [BD1, BJ1, BL1, BQ1, BY1] (5)	Mean	17.86	17.58	17.72	18.16
	S.D	3.56	3.00	3.67	3.31
	Sig. (2-tailed)	0.09	0.09	0.14	0.14
Clarity of Project Targets [BE1, BG1, BK1, BN1, BX1] (5)	Mean	18.38	18.42	18.48	18.16
	S.D	4.28	3.92	4.35	4.15
	Sig. (2-tailed)	0.22	0.22	0.82	0.82
Tradeoff of Project Targets [BB1, BR1, BT1, BV1] (4)	Mean	13.00	12.55	13.13	12.73
	S.D	3.09	3.32	3.33	2.46
	Sig. (2-tailed)	0.69	0.69	0.12	0.12

(1) Mean
(2) Standard Deviation
(3) T-test (Equal variance is assumed): Significance (Two-tailed)

3.6.3. Respondents' Differences

The respondents' differences were tested through T-test. Tables 3.20., 3.21., 2.22., and 3.23. show T-test results on Team Vision, Shared Knowledge, Process and Product Outcomes. The total composite value of each variable was calculated by adding the value of all the retained items of each variable. T-test was done for two different groups. The first group was done by the type of response medium. Most respondents responded by mail. A website was also developed so that managers had an option to respond via the Internet. A total of 167 respondents responded by mail and 38 responses were made via the

Internet. In Table 4.1., mean and standard deviation of all 6 variables show no statistically substantial difference.

Table 3.21. T-TEST OF THE LARGE SURVEY (Shared Knowledge)

Variables		Test by Type of Respondent Medium		Test by Mailing Sequence	
		Mail Response (n = 167)	Internet Response (n =38)	1st mailing (n=116)	2nd mailing (n=51)
Shared Knowledge of Customers [A1D, A1H, A2D, A2K, A3D] (5)	Mean	19.69	19.53	19.67	19.73
	S.D	3.34	4.18	3.33	3.40
	Sig. (2-tailed)	0.80	0.80	0.68	0.68
Shared Knowledge of Competitors [A1B, A2A, A2L, A3B, A3K] (5)	Mean	16.83	16.05	17.03	16.39
	S.D	4.01	3.62	3.98	4.07
	Sig. (2-tailed)	0.23	0.23	0.91	0.91
Shared Knowledge of Internal Capabilities [A1F, A1I, A3C, A3E,A3H] (5)	Mean	18.98	19.00	18.94	19.09
	S.D	3.16	3.30	3.18	3.15
	Sig. (2-tailed)	0.80	0.80	0.66	0.66
Shared Knowledge of Suppliers [A1G, A1K, A2C,A2J] (4)	Mean	12.56	11.74	12.59	12.49
	S.D	3.16	3.16	3.13	3.28
	Sig. (2-tailed)	0.85	0.85	0.26	0.26
Shared Knowledge of Products [A1E, A2B, A2H, A3F, A3G] (5)	Mean	15.08	15.92	15.02	15.24
	S.D	2.51	2.24	2.65	2.19
	Sig. (2-tailed)	0.21	0.21	0.08	0.08

(1) Mean
(2) Standard Deviation
(3) T-test (Equal variance is assumed): Significance (Two-tailed)

Second, early respondses and late respondses were compared (Armstrong and Overton, 1977). The first 116 responses were classified as early responses (1st questionnaire with follow-up reminders). The last 51 responses were considered late responses and were deemed representative of firms that ultimately responded to the survey after receiving the 2nd mailing. T-test (means, s.d. and p value) were conducted for all 16 variables and also shows little or no real difference in these two different groups of responses.

Table 3.22. T-TEST OF THE LARGE SURVEY (Outcomes)

Variables		Test by Type of Respondent Medium: Mail Response (n = 167)	Test by Type of Respondent Medium: Internet Response (n =38)	Test by Mailing Sequence: 1st mailing (n=116)	Test by Mailing Sequence: 2nd mailing (n=51)
Teamwork [C1C, C1F, C1H, C1M, C1N] (5)	Mean	14.23	14.05	14.24	14.20
	S.D	2.85	3.25	2.89	2.80
	Test of Variance	0.89	0.89	0.89	0.89
Development Productivity [C1A, C1D, C1G, C1J, C1L] (5)	Mean	14.23	14.05	14.24	14.20
	S.D	2.85	3.25	2.89	2.80
	Test of Variance	0.89	0.89	0.89	0.89
Time to Market [C1B, C1E, C1I, C1K] (4)	Mean	14.10	14.63	14.13	14.02
	S.D	3.96	3.80	3.88	4.18
	Test of Variance	0.38	0.38	0.76	0.76
Manufacturability [C2B, C2F, C2J, C2N] (4)	Mean	13.45	13.79	13.47	13.39
	S.D	2.95	3.03	2.77	3.38
	Test of Variance	0.63	0.63	0.11	0.11
Manufacturing Cost [C2E, C2G, C2I, C2O] (4)	Mean	11.40	12.18	11.28	11.69
	S.D	3.07	3.17	3.13	2.95
	Test of Variance	0.43	0.43	0.33	0.33
Value-to-Customer [C2A, C2C, C2K, C2M, C2P] (5)	Mean	15.25	14.71	15.30	15.14
	S.D	3.54	4.09	3.63	3.34
	Test of Variance	0.40	0.40	0.33	0.33
Product Performance [C2D, C2H, C2L, C2Q] (4)	Mean	15.58	15.92	15.69	15.33
	S.D	3.24	3.35	3.27	3.20
	Test of Variance	0.75	0.75	0.91	0.91

(4) Mean
(5) Standard Deviation
(6) T-test (Equal variance is assumed): Significance (Two-tailed)

All the observed means and standard deviations in the two samples are fairly similar. The null hypothesis is that in each group the two samples come from populations with the same variances using the Levene test. If the observed significance level for the Levene test is small, the null hypothesis is rejected. But if the significance level for the Levene test is large, then the null hypothesis is not rejected. For both groups, the observed significance levels are all large. There is no significant difference between these groups (the smallest is 0.09; the majority is 0.50 and higher). So the null hypothesis that the two population variances are equal is not rejected. Accordingly, it is assumed that non-response bias does not appear to be a significant problem. All samples are combined for analysis assuming that the samples are not significantly different.

3.7. LARGE-SCALE RESEARCH METHODS: MEASUREMENT MODEL

To develop good measures of three knowledge integration components and product development outcomes, it was necessary to purify items, perform exploratory factor analysis, check reliability, test for convergent and discriminant validity, and assess predictive validity. Different from the pilot study, the large-survey questionnaire was randomly placed according to five groups: Role Changes, Shared Knowledge, Team Vision, Process Outcomes, and Product Outcomes.

3.7.1. Purification

Items were purified, as recommended by Churchill (1979). Items were eliminated before further large sample analysis if their corrected item correlation was below 0.60 (Koufteros et al., 1998). Items with low factor loadings of each variable were carefully examined before elimination. The minimum Cronbach's alpha for the retained items after purification was to be at least 0.80. In addition, LISREL analysis was conducted to examine model fit of each variable. Items that contributed a poor model fit were eliminated step by step.

3.7.2. Factor Analysis

To examine construct validity, an exploratory factor analysis was conducted by each construct (i.e., Team Vision with four variables, Shared Knowledge with five variables, Process Outcomes with three variables and Product Outcomes with four variables). Items with factor loadings below 0.60 or with cross-loadings above 0.30 were eliminated. The number of factors extracted in this study was based on Kaiser's eigenvalues greater than 1 (Nunnally, 1978, 1995). This rule suggests that only factors that explain more variance than the average amount explained by one of the original items should be retained.

To achieve a stable factor structure, Tinsley and Tinsley (1987) suggest that the ratio of respondent to items should be at least 5 or 10 to 1. Comrey (1988) states that a same size of 200 is normally adequate for factor analysis involving fewer than 40 items.

3.7.3. Convergent and Discriminant Validity

In addition to factor analysis, discimninant validity was assessed at the item-level using a single method, multiple-trait approach (Campell and Fiske, 1959). The lowest correlation for a particular item and any other item within the factor was compared to correlation of that item and all items outside of the factor. If the former correlation was less than the latter, then a violation occurred (i.e., a violation occurred when the within factor correlation was less than the between factor correlation).

In addition, linear structural equation modeling (LISREL) methodology (Bagozzi and Philips, 1982) was used to test discriminant validity between pairs of variables. These tests were run with the correlation between the latent variables fixed at 1.0 and with correlation between the latent variables freed to assume any value. Large $\chi 2$ differences between the fixed and freed solution provide evidence of discriminant validity.

Discriminant validity was also tested by comparing the average variance extracted with the squared correlation between variables (e.g., Shared Knowledge of Customers and Shared Knowledge of Internal Capabilities). Fornell and Larcker (1981) suggest that discriminant validity exists if the items share more common variance with their respective variable than any variance that variable shares with other variables. Therefore, the average variance extracted for a construct should be substantially higher than the squared correlation between that variable and all the other variables.

3.7.4. Reliability

The reliability of all scales was examined using Cronbach's alpha and the average variance extracted. The average variance extracted (Fornell and Larcker, 1981) measures the amount of variance for specified items that is accounted for by latent construct. The average variance extracted is a complementary measure of the construct reliability value. Bagozzi and Yi (1988) suggest that the average variance extracted for construct should exceed 0.50.

It is in general desirable to develop variables that are reliable across groups of respondents. Such instruments may be useful in different contexts. In this study, Cronbach's alpha was calculated for each variable (e.g., Shared Knowledge Of Suppliers, Clarity Of Project Targets, Teamwork) below the constructs (e.g., shared knowledge, team vision, process outcomes), and was calculated across four industries (sample sizes from other target industries were not adequate for reliability evaluations). In general, reliabilities across industries above 0.80 would indicate that scales perform well (Nunnally, 1978).

3.7.5. Predictive Validity

To assess predictive validity, the two role change variables, the four team vision variables, and the five shared knowledge variables were correlated with the seven product development performance variables. Literature on product development performance identifies seven key product development performance outcomes (Tables 2.5. and 2.6. have details).

Product development outcomes were assessed using 5-point Likert scales. The scales are: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree. The reliabilities (alpha) of each variable are: Teamwork (0.90), Development Productivity (0.82), Time to Market (0.88), Manufacturability (0.76), Manufacturing Cost (0.87), Value to Customer (0.91) and Product Performance (0.91). Because market performance was a single item scale, reliability cannot be calculated. Standardizing the scales and summing them obtained a composite measure of these seven product development performance variables. This 29-item composite measure had a reliability of 0.87.

3.8. LARGE-SCALE RESEARCH METHODS: STRUCTURAL MODEL

LISREL (Joreskog and Sorbom, 1999) was used to test the structural relationship identified in Figure 2.3. In LISREL, Role Changes of Engineers was treated as an exogenous variable and the other constructs (i.e., Team Vision, Shared Knowledge, Product Development Performances) were endogenous. This is consistent with the ideas of Paashuis (1998) and Sobek (1997); that the roles of engineers are quite stable in their organizational characteristics and such changes gradually occur over a long period of time. Role changes of engineers do not occur on a project-by-project basis. Therefore, Role Changes of Engineers are regarded as an antecedent to other knowledge integration components (i.e., Team Vision and Shared Knowledge).

To assess the overall fit of the model to the data, $\chi 2$, degree of freedom, the comparative fit index (CFI), Bonnet non-normed fit index (NNFI), and the expected cross-validation index (ECVI) were used (Bentler, 1990, Koufteros, 1999). These indices range from 0.0 (no fit) to 1.0 (perfect fit). Values between 0.80 and 0.89 represented a good fit while values of 0.90 or better represented a very good fit. If the model fits the data adequately, the magnitude of the gamma coefficients (from exogenous to endogenous) and beta coefficients (from endogenous to endogenous) could then be examined for statistical significance. The test for significance compared the estimated parameter to its standard error and had a t-distribution (Marsch and Hocebar, 1985). A t-statistic greater than 1.96 was significant at $P < 0.05$ and greater than 2.33 was significant at $P < 0.01$.

Chapter Four

Instrument Development Results

The method of presentation in this chapter is to show the instrument development results in terms of unidimensionality, convergent validity, discriminant validity, reliability and predictive power of each independent variable. The process of purification is similar to that of the pilot study. However, to make this presentation simple and clear, the detailed processes of how the items were chosen are not presented here. In choosing retained items, in addition to CITC, unidimensionality and model fit indices were examined. Ultimately, the items were retained for their theoretical significance.

This large survey data set enables the reexamination of reliability and the assessment of factorial validity with a large sample. The corrected-item correlation (CITCs) for all 53 items for the three knowledge integration components (i.e., Role Changes, Team Vision and Shared Knowledge) after purification is shown in Tables 4.1.1., 4.1.2., and 4.1.3. Items with CITC below 0.60, with a few exceptions, were eliminated. Overall, 28 items were eliminated. The corrected-item correlation (CITCs) for 29 items of product development

development performance outcomes after purification (i.e., process and product outcomes) is shown in Table 4.1.4.

Table 4.1.1. Role Changes (Retained Items)
Corrected-item total correlations for knowledge integration components of product development in large-scale survey (n =205)

Items		Corrected-item total correlation
ROLE CHANGES (RC)		
(1) Role Changes of Design Engineers (RCDE)		
D1A	Qualifications required for design engineers have been upgraded.	0.68
D1D	Influence of design engineers in product development team has increased.	0.76
D1E	Technical skills required for manufacturing engineers have become more rigorous.	0.69
D1F	Behavioral skills (e.g., team work, inter-communication) required for manufacturing engineers have become more important.	0.53
D1H	Manufacturing engineers' jobs have been enlarged.	0.69
(2) Role Changes of Manufacturing Engineers (RCME)		
D2A	Qualifications required for manufacturing engineers have been upgraded.	0.66
D2D	Influence of manufacturing engineers in product development team has increased.	0.64
D2E	Technical skills required for manufacturing engineers have become more rigorous.	0.73
D2F	Behavioral skills (e.g., team work, inter-communication) required for manufacturing engineers have become more important.	0.55
D2H	Manufacturing engineers' jobs have been enlarged.	0.69

Table 4.1.2. Team Vision (Retained Items)

Corrected-item total correlations for knowledge integration components of product development in large-scale survey (n =205)

Items		Corrected-item total correlation
TEAM VISION (TV)		
(1) Shared Team Purpose and Mission (STMPRM)		
BA1	The project purpose was well understood by the entire team.	0.71
BC1	The project Mission was well communicated to all team members.	0.82
BM1	The project Mission was well defined for all team members.	0.85
BP1	This product development team had a well defined Mission.	0.79
BZ1	The project Mission was well understood by the entire team.	0.85
(2) Strategic Fit –Environment (STFENV)		
BD1	Our firm's overall technology strategy guided the setting of project targets.	0.57
BJ1	Project targets were consistent with our firm's overall business strategy.	0.61
BQ1	Project targets reflected the competitive situation.	0.49
BY1	Our firm's overall product strategy guided the setting of project targets.	0.62
(3) Clarity of Project Targets (CLARITY)		
BE1	A clear set of project targets guided development efforts.	0.77
BG1	Project targets were clearly understood by all team members.	0.76
BK1	Project targets were clearly communicated to all team members.	0.78
BN1	Project targets were clear.	0.81
(4) Tradeoff of Project Targets (TRADEOFF)		
BB1	Project targets clearly specified tradeoffs between performance and cost.	0.65
BR1	The relative priority of each project target was clear.	0.69
BT1	Project targets clearly specified tradeoffs between time and cost.	0.66
BV1	Project targets clearly specified tradeoffs between quality and cost.	0.53

Table 4.1.3. Shared Knowledge (Retained Items)
Corrected-item total correlations for knowledge integration components of product development in large-scale survey (n =205)

Items		Corrected-item total correlation
SHARED KNOWLEDGE (SK)		
(1) Shared Knowledge of Customers (SKCUST)		
A1D	Customer requirements.	0.56
A1H	How well we were doing on customer satisfaction ratings.	0.63
A2D	Which features were most valued by target customers.	0.71
A2K	Current customer needs.	0.74
A3D	What our customers want.	0.77
(2) Shared Knowledge of Competitors (SKCOMP)		
A2A	Advantages of our competitors.	0.74
A2L	Strengths of our competitors.	0.79
A3B	Competitors' product technologies.	0.61
A3K	Competitors' products.	0.77
A3L	Weaknesses of our competitors.	0.80
(3) Shared Knowledge of Internal Capabilities (SKINTCP)		
A1F	The capabilities of our engineering staff.	0.60
A1I	The strengths of our engineering design capabilities.	0.55
A3C	Our manufacturing capabilities.	0.75
A3E	The strengths of our manufacturing facilities.	0.80
A3H	The capabilities of the process technologies we used.	0.60
(4) Shared Knowledge of Suppliers (SKSUPPL)		
A1G	Our suppliers' process capabilities.	0.73
A1K	Our suppliers' capabilities to meet cost targets.	0.71
A2C	Our suppliers' design capabilities.	0.65
A2J	Our suppliers' capabilities to meet time requirements.	0.70
A3A	Our suppliers' capabilities to meet quality requirements.	0.70
(5) Shared Knowledge of Products (SKPROD)		
A1E	The advantages of our product.	0.42
A2B	The disadvantages of our product.	0.45
A2H	The product technologies we used.	0.42
A3F	Our product's history.	0.51
A3G	Strengths of our product.	0.60

Table 4.1.4. Outcomes (Retained Items)
Corrected-item total correlations for knowledge integration components of product development in large-scale survey (n =205)

Items		Corrected-item total correlation
Teamwork		
C1C	Worked well together.	0.80
C1H	Coordinated activities well.	0.77
C1M	Implemented decisions effectively.	0.79
C1N	Communicated clearly.	0.79
Development Productivity		
C1D	Was productive.	0.60
C1G	Used financial resources sensibly.	0.56
C1J	Used all product development resources rationally.	0.66
C1L	Used product engineering hours efficiently.	0.67
Time to Market		
C1B	Met its deadline for market introduction.	0.63
C1E	Developed products on schedule.	0.55
C1I	Reduced the product development time.	0.52
C1K	Met the target date for our project.	0.52
Manufacturability		
C2B	The manufacturing processes were simplified.	0.65
C2F	Manufacturing problems were minimized.	0.70
C2J	The number of parts was reduced.	0.72
C2N	The product is easy to assemble.	0.72
Manufacturing Cost		
C2E	The material cost of this product is considerably lower than the industry average.	0.84
C2G	The overhead cost of this product is considerably lower than the industry average.	0.85
C 2 I	The labor cost of this product is considerably lower than the industry average.	0.85
C2O	The overall Manufacturing Cost of this product is lower than the industry average.	0.79
Value to Customer		
C2A	This product had a high quality.	0.91
C2C	This product exceeded customer expectations.	0.89
C2K	This product created a high customer value.	0.89
C2M	This product was successful in the marketplace.	0.89
Product Performance		
C2D	The components worked well together.	0.91
C2H	The system performance of this product was excellent.	0.88
C2L	The technical performance of this product was excellent.	0.88
C2Q	The overall performance of this product was excellent.	0.87

4.1. UNIDIMENSIONALITY AND CONVERGENT VALIDITY

Unidimensionality has been defined as the existence of one latent trait of construct underlying a set of measures (Anderson et al., 1987). Based on an evaluation of the fit of a one-dimensional model for each variable, iterative modifications were undertaken in the spirit of a specification search (Joreskog and Sorbom, 1989; Sethi and King, 1994). Modifications were made to improve the model fit as well as to derive parameters that have real significance and substantive meaning. As recommended, only one parameter was changed at every step (Joreskog and Sorbom, 1989). Model modification was continued until all parameter estimates and overall fit measures were judged to be statistically and substantially satisfactory.

The exact modification procedure that was undertaken to derive a set of relatively parsimonious and "pure" indicator is detailed in Tables 4.2.1., 4.2.2., 4.2.3., 4.2.4., 4.2.5., 4.2.6., 4.2.7., 4.2.8., 4.2.9. For simplicity, Tables 4.2.1. and 4.2.2. show the procedures of selecting the best model fit. Tables 4.2.3. - 4.2.9. show the summary of the results of each variable.

Table 4.2.1. Assessment of Unidimensionality (& Convergent Validity) of the Role Changes of Design Engineers

	Role Change (Design Engineers)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	D1A, D1B, D1C, D1D, D1E, D1F, D1G, D1H, D1I, D1J(10)	272.95	35.00	0.00	0.19	1.59	0.72	0.78
	The hypothesized model was rejected because of both low NNFI and low CFI. An exploratory factor analysis (EFA) using SPSS indicated that this construct consisted of two dimensions. To improve the fit of the hypothesized model, items that show their loading patterns that did not display a simple structure were deleted.							
Iteration 1	D1A, D1B, D1D, D1E, D1F, D1G, D1H, D1I, D1J(9)	194.98	27.00	0.00	0.18	1.17	0.74	0.80
	D1C was deleted in this iteration because its loading pattern did not display a simple structure.							
Iteration 2	D1A, D1B, D1D, D1E, D1F, D1G, D1H, D1J (8)	120.03	20.00	0.00	0.16	0.77	0.80	0.85
	D1I was dropped because it had significantly large correlations with the other three items, thus suggesting only a weak relationship with the construct.							
Iteration 3	D1A, D1B, D1D, D1E, D1F, D1H, D1J (7)	40.78	14.00	0.00	0.10	0.35	0.92	0.95
Iteration 4	D1A, D1B, D1D, D1E, D1F, D1H(6)	16.20	9.00	0.06	0.06	0.20	0.97	0.98
Iteration 5	D1A, D1D, D1E, D1F,D1G, D1H(6)	66.21	9.00	0.00	0.18	0.46	0.79	0.87
Iteration 6	**D1A, D1D, D1E, D1F,D1H(5)**	**7.05**	**5.00**	**0.22**	**0.05**	**0.14**	**0.99**	**0.99**
	D1B, D1G, D1H, D1J were successfully deleted in iterations 3, 4, and 5 because either their errors exhibited covariation or they were found to be associated with both dimensions. Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI=0.99, CFI=0.99, and RMSEA=0.05.							

Table 4.2.2. Assessment of Unidimensionality (& Convergent Validity) of the Role Changes of Manufacturing Engineers

	Role Changes (Manufacturing Engineers)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	D2A, D2B, D2C, D2D, D2E, D2F, D2G, D2H, D2I, D2J(10)	265.85	35.00	0.00	0.18	1.55	0.71	0.78
	The hypothesized model was rejected because of both low NNFI and low CFI. An exploratory factor analysis (EFA) using SPSS indicated that this construct consisted of two dimensions. To improve the fit of the hypothesized model, items that show their loading patterns that did not display a simple structure were to be deleted.							
Iteration 1	D2A, D2B, D2D, D2E, D2F, D2G, D2H, D2I, D2J(9)	153.17	27.00	0.00	0.15	0.96	0.80	0.85
	D2C was deleted in this iteration because its low CITC and its loading pattern did not display a simple structure.							
Iteration 2	D2A, D2B, D2D, D2E, D2F, D2G, D2I, D2J(8)	81.05	20.00	0.00	0.12	0.57	0.87	0.91
	D2H was dropped because it had significantly large correlations with the other three items, thus suggesting only a weak relationship with the construct.							
Iteration 3	D2A, D2B, D2D, D2E, D2F, D2H, D2J (7)	36.54	14.00	0.00	0.09	0.33	0.94	0.96
Iteration 4	D2A, D2B, D2D, D2E, D2G, D2I(6)	14.23	9.00	0.11	0.05	0.19	0.98	0.99
Iteration 5	D2A, D2D, D2E, D2F, D2G, D2H(6)	58.46	9.00	0.00	0.17	0.42	0.83	0.90
Iteration 6	**D2A, D2D, D2E, D2F, D2H(5)**	**11.31**	**5.00**	**0.05**	**0.08**	**0.16**	**0.96**	**0.98**
	D2B, D2G, D2H, D2J were successfully deleted in iterations 3, 4, and 5 because either their errors exhibited covariation or they were found to be associated with both dimensions. Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI=0.96, CFI=0.98, and RMSEA=0.08.							

Table 4.2.3. Assessment of Unidimensionality (& Convergent Validity) : Shared Team Purpose and Mission

	Shared Team Purpose and Mission (STMPRP)	Chi-Square	Df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	BA1, BC1, BH1, BM1, BP1, BU1, BW1, BZ1 (8)	49.62	20.00	0.00	0.09	0.40	0.96	0.98
	BA1 and BH1are highly correlated (correlation=0.743). Not surprisingly, their error correlations showed significance also. For the sake of parsimony, BH1 was dropped because it has more to do with project targets than project mission. Although NNFI and CFI showed a good fit, with relatively low RMSEA, the iteration continued.							
Iteration 1	BA1, BC1, BM1, BP1, BU1, BW1, BZ1(7)	18.25	14.00	0.20	0.04	0.23	0.00	1.00
Iteration 2	BC1, BH1, BM1, BP1, BU1, BZ1(6)	14.35	9.00	0.11	0.05	0.19	0.99	0.99
Iteration 3	**BA1, BC1, BM1, BP1, BZ1 (5)**	**6.94**	**5.00**	**0.22**	**0.04**	**0.13**	**1.00**	**1.00**
	BU1 and BW1 were successfully deleted in iterations 2 and 3, respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

Table 4.2.4. Assessment of Unidimensionality (& Convergent Validity): Strategic Fit of Project Targets

	Strategic Fit (STF)	Chi-Square	Df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	BD1, BF1, BJ1, BL1, BO1, BQ1, BS1, BY1 (8)	72.15	21.00	0.01	0.11	0.51	0.82	0.87
	The hypothesized model was rejected because of both low NNFI and low CFI. The hypothesized model was rejected because of low RMSEA, NNFI and low CFI. The error terms of items BF1 and BS1 were highly correlated. BF1 was dropped because of it did not display simple factor structure.							
Iteration 1	BD1, BJ1,BL1, BO1, BQ1, BS1, BY1(7)	27.01	9.00	0.00	0.10	0.25	0.89	0.94
	The error terms of items BD1 and BL1 were highly correlated. BL1 was dropped because it did not display simple factor structure.							
Iteration 2	BD1, BF1, BJ1, BQ1, BS1, BY1, (6)	4.91	5.00	0.43	0.14	0.20	0.91	0.95
Iteration 3	BD1, BJ1, BL1, BY1 (5)	2.47	2.00	0.29	0.08	0.12	0.95	0.96
Iteration 4	**BD1, BJ1, BQ1, BY1 (4)**	**3.93**	**2.00**	**0.14**	**0.07**	**0.10**	**0.97**	**0.99**
	BO1 and BS1 were successfully deleted in iterations 2, 3, and 4 respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

Table 4.2.5. Assessment of Unidimensionality (& Convergent Validity): Clarity of Project Targets and Tradeoff

	Clarity of Project Targets (CLARITY)	Chi-Square	Df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	BB1,BE1,BG1,BI1,BK1,BN1,BR1,BT1,BV1,BX1(10)	145.75	35.00	0.00	0.12	0.91	0.89	0.91
	The hypothesized model was rejected because of low RMSEA. An Exploratory factor analysis (EFA) using SPSS indicated that this construct consisted of two dimensions (BE1, BG1, BI1, BK1, BN1) and (BB1, BR1, BT1, BV1). Therefore, each dimension is separately analyzed. BI1 was dropped because it had significantly large error correlation with other items, thus suggesting only a weak relationship with the construct.							
Iteration 1	**BE1,BG1,BK1,BN1(4)**	**4.92**	**2**	**0.085**	**0.06**	**0.10**	**0.99**	**0.99**
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI=0.99, and CFI =0.99, RMSEA=0.06.							

	Tradeoff of Project Targets (TRADEOFF)	Chi-Square	Df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	BB1,BE1,BG1,BI1,BK1,BN1,BR1,BT1,BV1,BX1(10)	145.75	35.00	0.00	0.12	0.91	0.89	0.91
	The hypothesized model was rejected because of low RMSEA. An Exploratory factor analysis (EFA) using SPSS indicated that this construct consisted of two dimensions (BE1, BG1, BI1, BK1, BN1) and (BB1, BR1, BT1,BV1).							
Iteration 1	**BR1,BT1,BV1(4)**	**5.46**	**2.00**	**0.07**	**0.08**	**0.11**	**0.96**	**0.99**
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI=0.96, CFI =0.99, and RMSEA=0.08.							

Table 4.2.6. Assessment of Unidimensionality (& Convergent Validity): Customers and Competitors

	Shared Knowledge of Customers (SKCUST)	**Chi-Square**	**df**	**p value**	**RMSEA**	**ECVI**	**NNFI**	**CFI**
Hypothesized Model	A1A, A1D, A1H, A1J, A2D, A2G, A2K, A3D, A3J (9)	123.28	27.00	0.00	0.13	0.58	0.85	0.89
	The hypothesized model was rejected because of low RMSEA. A2G was dropped because error terms were highly correlated with A3J.							
Iteration 1	A1A, A1D, A1H, A1J, A2D, A2K, A3D, A3J (8)	71.44	20.00	0.00	0.11	0.51	0.90	0.93
Iteration 2	A1A, A1D, A1H, A2D, A2K, A3D, A3J (7)	30.49	14.00	0.01	0.08	0.29	0.96	0.97
Iteration 2	A1A, A1D, A1H, A2D, A2K, A3D (6)	16.28	9.00	0.06	0.063	0.20	0.98	0.99
Iteration 4	**A1D, A1H, A2D, A2K, A3D (5)**	**4.31**	**5.00**	**0.51**	**0.00**	**0.12**	**1.00**	**1.00**
	A1A and A1J were successfully deleted in iterations 2 , 3, and 4 respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

	Shared Knowledge of Competitors (SKCOMP)	**Chi-Square**	**df**	**p value**	**RMSEA**	**ECVI**	**NNFI**	**CFI**
Hypothesized Model	A1B,A2A,A2F,A2L,A3B,A3K, A3L (7)	33.16	14.00	0.00	0.08	0.30	0.96	0.98
Iteration 1	A2A,A2F, A2L,A3B,A3K, A3L (6)	14.84	9.00	0.10	0.06	0.19	0.99	0.99
Iteration 2	**A2A,A2L,A3B,A3K, A3L (5)**	**5.96**	**5.00**	**0.31**	**0.03**	**0.13**	**1.00**	**1.00**
	A1B and A2F were successfully deleted in iterations 1 and 2 respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

Table 4.2.7. Assessment of Unidimensionality (& Convergent Validity): Internal Capabiliites and Products

	Shared Knowledge of Internal Capabilities (SKINTCP)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	A1F, A1I, A2E, A2I, A3C, A3E, A3H (7)	99.46	14.00	0.00	0.17	0.62	0.83	0.89
Iteration 1	A1F, A2E, A2I, A3C, A3E, A3H (6)	19.51	9.00	0.02	0.08	0.21	0.97	0.98
Iteration 2	A1F, A1I, A3C, A3E, A3H (5)	77.81	5.00	0.00	0.27	0.48	0.67	0.83
Iteration 3	**A1F, A2I, A3C, A3E, A3H (5)**	**77.81**	**5.00**	**0.23**	**0.04**	**0.13**	**0.99**	**1.00**
	A1I and A2E were successfully deleted in iterations 1, 2 and 3 respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

	Shared Knowledge of Suppliers (SKSUPPL)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	A1C, A1G, A1K, A2C, A2J, A3A, A3I(7)	19.54	14.00	0.15	0.04	0.23	0.99	0.99
Iteration 1	A1G, A1K, A2C, A2J, A3A, A3I(6)	9.57	9.00	0.39	0.02	0.16	1.00	1.00
Iteration 2	**A1G, A1K, A2C, A2J, A3A (5)**	**1.47**	**5.00**	**0.92**	**0.00**	**0.11**	**1.02**	**1.00**
	A1C and A3I were successfully deleted in iterations 1 and 2 respectively, because either their errors showed covariation or their loadings did not display a simple structure. The results show in the final model.							

	Shared Knowledge of Products (SKPROD)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	**A1E, A2B, A2H, A3F, A3G(5)**	**30.25**	**5.00**	**0.00**	**0.10**	**0.25**	**0.88**	**0.88**
Iteration 1	A2B, A2H, A3F, A3G (4)	9.73	2.00	0.01	0.09	0.23	0.86	0.85
	The hypothesized model was accepted, although the indices are not the best. Removing A1E does not improve the model fit substantially.							

Table 4.2.8. Assessment of Unidimensionality (& Convergent Validity): Teamwork, Development Productivity, Time to Market

Hypothesized Model	Teamwork (TEAMWK)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
	C1C, C1F, C1H, C1M, C1N (5)	8.39	5.00	0.14	0.06	0.14	0.99	0.99
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI =0.99, and CFI =0.99, RMSEA=0.06.							

Hypothesized Model	Development Productivity (DEVPROD)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
	C1A, C1D, C1G, C1J, C1L (5)	**1.38**	**5.00**	**0.93**	**0.00**	**0.10**	**1.02**	**1.00**
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI =1.02, and CFI=1.00, RMSEA=0.00.							

Hypothesized Model	Time to Market (TIMEMKT)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
	C1B, C1E, C1I, C1K	**19.41**	**2.00**	**0.00**	**0.10**	**0.18**	**0.90**	**0.97**
	Further modifications were terminated because the model fit indices justified statistically and substantially with NNFI=0.90 and CFI=0.97.							

Table 4.2.9. Assessment of Unidimensionality (& Convergent Validity): Manufacturability, Manufacturing Cost, Value to Customer and Product Performance

	Manufacturability (MANUFAC)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	C2B, C2F, C2J, C2N (4)	6.80	2.00	0.03	0.11	0.11	0.92	0.97
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI =0.92, and CFI =0.97, although RMSEA=0.11 is somewhat larger than the desirable level (RMSEA<0.08).							

	Manufacturing Cost (MFGCOST)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	C2E, C2G, C2I, C2O(4)	1.61	2.00	0.45	0.00	0.09	1.00	1.00
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI =1.00, CFI =1.00, and RMSEA=0.00.							

	Value to Customer (VALCUST)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	C2A, C2C, C2K, C2M, C2P(5)	20.50	5.00	0.00	0.13	0.21	0.95	0.98
	The hypothesized model was rejected because of high RMSEA (0.13). A2P was deleted because factor loadings did not display a simple structure.							
Iteration 1	C2A, C2C, C2K, C2M (4)	2.57	2.00	0.75	0.00	0.08	1.01	1.00
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI=1.01, CFI=1.00, and RMSEA=0.00.							

	Product Performance (PRODPERF)	Chi-Square	df	p value	RMSEA	ECVI	NNFI	CFI
Hypothesized Model	C2D, C2H, C2L, C2Q(4)	7.78	2.00	0.02	0.07	0.12	0.97	0.99
	Further modifications were terminated because the model fit indices justified statistically and substantially, with NNFI =0.97, CFI =0.99, and RMSEA=0.07.							

4.2. FACTOR ANALYSIS

An exploratory factor analysis was conducted on three constructs (i.e., Role Changes, Team Vision and Shared Knowledge) and Product Development Performances. An exploratory factor analysis was conducted on the items of each construct proposed after the pilot using principal components as the means of extraction and direct oblimin as the method of rotation. The ratio of respondents to items was 20.05 (Role Changes), 17.08 (Team Vision), 8.2 (Shared Knowledge), 25.63 (Process Outcomes), 17.08 (Product Outcomes) and meets the general guidelines.

For each exploratory factor analysis, the number of factors was not specified. Only factors with eigenvalues greater than 1 were shown. For simplicity, all tables show only factor loadings above 0.30. All items were loaded on their respective factors and there were no items with cross loadings greater than 0.30. In general, it was desirable to have all items with loadings greater than 0.60. According to Comrey (1988), when item groupings are identified prior to factoring, a result that is consistent with these grouping provides evidence of factorial validity.

In Table 4.3, a factor analysis of Role Changes (RC) was done separately because the same items were used to assess role changes of design engineers (RCDE) and role changes of manufacturing engineers (RCME). Each showed a single factor that explained 57.38 and 57.81% of the variance. Factor loadings of each item were all above 0.70, with Cronbach's alpha being 0.86 and 0.87 and

Kaiser-Meyer-Olkin Measure of Sampling Adequacy being 0.83 and 0.82 respectively.

Table 4.3. Role Changes–Design and Manufacturing Engineers

	Alpha=0.86	Alpha=0.87
ITEM	ROLE CHANGES DESIGN ENGINEERS	ROLE CHANGES MANUFACTURING ENGINEERS
D1A	0.80	
D1D	0.77	
D1E	0.81	
D1F	0.70	
D1H	0.73	
D2A		0.76
D2D		0.70
D2E		0.84
D2F		0.73
D2H		0.77
Eigen Value	2.87	2.89
% of Variance	57.38	57.81
Cumulative % of Variance	57.38	57.81
	Kaiser-Meyer-Olkin Measure of Sampling Adequacy 0.83	Kaiser-Meyer-Olkin Measure of Sampling Adequacy 0.82

Table 4.4. shows that the Team Vision construct has four variables (shared team purpose and mission, clarity of project targets, tradeoff of project targets, and strategic fit,). Shared team purpose and mission (STMPRM) was separated from the other three variables because it has a causal relationship with

the other three variables. It shows high factor loadings (>0.75) for each variable, except strategic fit of environment (BD1=0.63) and tradeoff of project targets (BR1=0.62).

Table 4.4. Exploratory Factor Analysis for Team Vision

Alpha	0.93
ITEM	STMPRM
BA1	0.85
BC1	0.91
BM1	0.93
BP1	0.84
BZ1	0.80
Eigen Value	3.92
% of Variance	78.3%
Cumulative % of Variance	78.33%
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.95

Alpha	0.90	0.81	0.76
	CLARITY	TRADEOFF	STFENV
BD1			0.63
BJ1			0.73
BQ1			0.64
BY1			0.84
BE1	0.80		
BG1	0.80		
BK1	0.97		
BN1	0.93		
BB1		0.67	
BR1		0.62	
BT1		0.77	
BV1		0.94	
Eigen Value	6.86	1.14	0.89
% of Variance	49.00	8.15	6.33
Cumulative % of Variance	49.00	57.15	63.48
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.93		

In Table 4.5., Shared Knowledge shows five factors as expected and the cumulative variance extracted by the five factors is 63.72%. Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.86. Cronbach's alpha for each variable is larger than 0.80, except 0.76 for Shared Knowledge of Products.

Table 4.5. Exploratory Factor Analysis for Shared Knowledge

Alpha	0.86	0.85	0.87	0.82	0.72
ITEM	SKCUST	SKSUPPL	SKCOMP	SKINTCP	SKPROD
A1F				0.76	
A1I				0.70	
A3C				0.77	
A3E				0.76	
A3H				0.71	
A1B			0.60		
A2A			0.83		
A2L			0.84		
A3B			0.83		
A3K			0.88		
A1G		0.81			
A1K		0.82			
A2C		0.74			
A2J		0.81			
A3I		0.73			
A1D	0.75				
A1H	0.51				
A2D	0.80				
A2K	0.85				
A3D	0.84				
A1E					0.50
A2B					0.64
A2H					0.56
A3F					0.83
A3G					0.63
Eigen Value	7.43	2.78	2.60	1.70	1.42
% of Variance	29.73	11.14	10.40	6.78	5.68
Cumulative % of Variance	29.73	40.86	51.26	58.04	63.72
Kaiser-Meyer-Olkin Measure of Sampling Adequacy				0.864	

Among the five variables, SKPROD is regarded the weakest in terms of reliabilities and overall factor loadings. The number of factors was not specified; yet, the result of the factor anlaysis displays five factors.

In Table 4.6., Process Outcomes shows two dimensions. Teamwork (TEAMWK) seems to affect Development Productivity (DEVPRD) and Time to Market (TIMEMKT). Because of the causal relationship, TEAMWK was separated from DEVPROD and TIMEMKT. The results show clean factor structure and high factor loadings (>0.75), except C1I (0.69) and C1D(0.67).

Table 4.6. Exploratory Factor Analysis for Process Outcomes

Alpha	0.88	Alpha	0.81	0.91
ITEM	TEAMWK	ITEM	DEVPROD	TIMEMKT
C1C	0.88	C1B	0.95	
C1F	0.81	C1E	0.83	
C1H	0.88	C1I	0.69	
C1M	0.88	C1K	0.97	
C1N	0.88	C1D		0.67
		C1G		0.83
		C1J		0.80
		C1L		0.72
Eigen Value	3.66	Eigen Value	4.25	1.23
% of Variance	73.26	% of Variance	53.18	15.34
Cumulative % of Variance	73.26	Cumulative % of Variance	53.18	68.52
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.886		Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.842		

The cumulative variance extracted by teamwork, development productivity and time to market is 73.26% and 68.52% respectively. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.89 and 0.84 respectively. Cronbach's alpha for each variable is all 0.80.

Table 4.7. Exploratory Factor Analysis for Product Outcomes

Alpha	0.91
Item	**Value to Customer**
C2A	0.82
C2C	0.89
C2K	0.87
C2M	0.87
Eigen Value	2.97
% of Variance	74.21
Cumulative % of Variance	74.21
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	**0.84**

Alpha	0.87	0.91	0.76
Item	**Mfg. Cost**	**Prod Perf.**	**Manufact-urability**
C2B			0.91
C2F			0.60
C2J			0.78
C2N			0.62
C2E	0.86		
C2G	0.82		
C2I	0.78		
C2O	0.91		
C2D		0.80	
C2H		0.91	
C2L		0.90	
C2Q		0.94	
Eigen Value	5.04	2.14	1.28
% of Variance	42.03	17.82	10.66
Cumulative % of Variance	42.03	59.85	70.51
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	**0.80**		

In Table 4.7., product outcomes shows two dimensions. Value to Customer (VALCUST) and Product Performance (PRODPERF) seem to have a causal relationship. Products that have a high Value to Customer will perform well. In other words, products that perform well have a high value to customer. Because of the causal relationship, VALCUST was separated from the other three variables. The results show clean factor structure, high factor loadings (>70), except C2F and C2N. Cronbach's alpha for the four variables are all larger than 0.80 except 0.76 for manufacturability.

4.3. CONVERGENT AND DISCRIMINANT VALIDITY BY MTMM METHOD.

Test for convergent validity and discriminant validity were conducted at the item-level using single method, multiple trait. Item Correlation Matrix, Descriptive Statistics (i.e., mean and standard deviation), and # of violations are denoted in Table 4.8. (Team Vision), Table 4.9. (Shared Knowledge), 4.10. (Process Outcomes), And Table 4.11. (Product Outcomes). Since Role Changes Of Design and Manufacturing Engineers are using the same items, a separate table was not prepared.

4.3.1. Team Vision

The correlation matrix in Table 4.11 reveals a total of 13 violations out of 289 total comparisons. For Shared Knowledge (SK), most violations occur in relation to items of Shared Knowledge of Products (SKPROD). For Team Vision (TV), most violations occur between Shared Team Mission (STMPRM; BA1, BC1, BM1, BP1, BZ1) and Clarity of Project Targets (CLARITY; BE1, BJ1, BQ1, BY1). The primary reason is that STMPRP and CLARITY seem to have a causal relationship. Some STMPRP items are highly correlated with CLARITY items. For example, three STMPRM items, BA1 ("The project purpose was well understood by the entire team"), BC1 ("The project Mission was well communicated to all team members"), BZ1 ("Project Mission was well understood by the entire team") are highly correlated with three CLARITY items, BE1 ("A clear set of project targets guided development efforts"), BG1 ("Project targets were clearly understood by all team members) and BK1 ("Project targets were clearly communicated to all team members").

The Shared Team Purpose and Mission (STPRPM) has to do with the overall meaning and direction of the project, while Clarity and Tradeoff of Project Targets (CLARITY and TRADEOFF) has to do with task specific goals. When the overall mission is well defined, understood and communicated, the next level of project specific targets seems to be well defined, understood and communicated. Other than that, all other variables converge and discriminate well in that item correlation within a variable is high but inter-item correlation outside of each variable is low.

4.3.2. Shared Knowledge

The correlation matrix in Table 4.9 reveals a total of 12 violations out of 529 total comparisons. Most violations occur in relation to items of Shared Knowledge of Products. Among five variables, the items of this particular variable show weak item correlation (the lowest 0.28 and the highest 0.64). All items converge within each variable) but discriminate with items outside of the variable. Therefore, all variables of Shared Knowledge construct, except Shared Knowledge of Products, demonstrate a high level of convergent and discriminant validity.

Table 4.8. Team Vision -- Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

	BA1	BC1	BM1	BP1	BZ1	BD1	BJ1	BQ1	BY1	BE1	BG1	BK1	BN1	BB1	BR1	BT1	BV1
BA1	1.00																
BC1	0.70	1.00															
BM1	0.62	0.72	1.00														
BP1	0.63	0.69	0.74	1.00													
BZ1	0.55	0.72	0.80	0.74	1.00												
BD1	0.34	0.42	0.43	0.45	0.49	1.00											
BJ1	0.40	0.46	0.42	0.44	0.48	0.58	1.00										
BQ1	0.33	0.30	0.34	0.35	0.40	0.53	0.47										
BY1	0.46	0.48	0.48	0.47	0.52	0.48	0.57	0.49	1.00								
BE1	0.52	0.62	0.62	0.62	0.66	0.53	0.49	0.36	0.47	1.00							
BG1	0.62	0.68	0.69	0.65	0.69	0.46	0.54	0.32	0.52	0.65	1.00						
BK1	0.58	0.71	0.75	0.66	0.68	0.48	0.44	0.32	0.48	0.73	0.74	1.00					
BN1	0.63	0.70	0.73	0.65	0.66	0.40	0.46	0.39	0.51	0.73	0.72	0.74	1.00				
BB1	0.47	0.51	0.44	0.46	0.46	0.40	0.37	0.34	0.39	0.40	0.38	0.37	0.39	1.00			
BR1	0.44	0.50	0.56	0.52	0.53	0.46	0.40	0.36	0.42	0.58	0.55	0.59	0.62	0.55	1.00		
BT1	0.38	0.40	0.48	0.42	0.49	0.38	0.35	0.26	0.38	0.49	0.50	0.49	0.50	0.58	0.49	1.00	
BV1	0.34	0.30	0.38	0.33	0.42	0.35	0.30	0.20	0.34	0.37	0.38	0.32	0.36	0.57	0.47	0.64	1.00
	BA1	BC1	BM1	BP1	BZ1	BD1	BJ1	BQ1	BY1	BE1	BG1	BK1	BN1	BB1	BR1	BT1	BV1
Mean	4.15	3.90	3.68	3.86	3.71	3.33	3.80	3.77	3.45	3.60	3.60	3.73	3.70	3.34	3.36	3.10	3.12
Std.Dev.	0.85	0.96	0.92	0.93	0.96	1.04	0.99	0.88	0.98	1.05	1.04	0.92	0.94	1.06	0.90	0.96	1.00
# of violations	3	1	1	0	2	0	0	0	0	1	3	1	1	0	0	0	0

Table 4.9. Shared Knowledge -- Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

	Customers					Competitors					Suppliers				Products				Internal Capabilities				
	A1D	**A1H**	**A2D**	**A2K**	**A3D**	**A2A**	**A2L**	**A3B**	**A3K**	**A3L**	**A1G**	**A1K**	**A2C**	**A2J**	**A1E**	**A2B**	**A3F**	**A3G**	**A1F**	**A1I**	**A3C**	**A3E**	**A3H**
A1D	1.00																						
A1H	0.45	1.00																					
A2D	0.41	0.32	1.00																				
A2K	0.54	0.40	0.63	1.00																			
A3D	0.54	0.42	0.68	0.77	1.00																		
A2A	0.21	0.22	0.20	0.19	0.27	1.00																	
A2L	0.14	0.20	0.22	0.21	0.25	0.50	1.00																
A3B	0.21	0.19	0.32	0.32	0.31	0.52	0.66	1.00															
A3K	0.17	0.21	0.19	0.22	0.23	0.45	0.59	0.63	1.00														
A3L	0.12	0.12	0.22	0.23	0.28	0.47	0.60	0.68	0.67	1.00													
A1G	0.12	0.14	0.11	0.04	0.09	0.12	0.07	0.03	0.14	0.04	1.00												
A1K	0.10	0.17	0.17	0.11	0.14	0.26	0.19	0.17	0.23	0.19	0.62	1.00											
A2C	0.01	0.15	0.15	0.08	0.15	0.17	0.27	0.25	0.26	0.21	0.52	0.56	1.00										
A2J	0.15	0.12	0.15	0.17	0.15	0.24	0.17	0.10	0.20	0.16	0.56	0.59	0.53	1.00									
A1E	0.28	0.29	0.30	0.29	0.36	0.26	0.26	0.26	0.16	0.23	0.04	0.05	0.15	0.01	1.00								
A2B	0.24	0.19	0.33	0.29	0.35	0.20	0.15	0.18	0.18	0.20	0.16	0.15	0.12	0.11	0.28	1.00							
A3F	0.24	0.25	0.15	0.20	0.16	0.24	0.12	0.29	0.16	0.24	0.05	0.10	0.03	0.08	0.32	0.35	1.00						
A3G	0.26	0.27	0.19	0.33	0.28	0.21	0.28	0.39	0.34	0.40	0.09	0.14	0.08	0.09	0.38	0.35	0.64	1.00					
A1F	0.31	0.31	0.32	0.35	0.35	0.18	0.13	0.21	0.19	0.19	0.35	0.24	0.19	0.24	0.47	0.21	0.18	0.28	1.00				
A1I	0.29	0.42	0.33	0.34	0.39	0.14	0.12	0.16	0.21	0.09	0.31	0.25	0.20	0.17	0.42	0.21	0.18	0.30	0.69	1.00			
A3C	0.24	0.22	0.22	0.26	0.30	0.15	0.05	0.13	0.17	0.06	0.26	0.28	0.23	0.33	0.22	0.20	0.23	0.28	0.48	0.41	1.00		
A3E	0.20	0.27	0.19	0.26	0.31	0.13	0.05	0.14	0.09	0.11	0.23	0.32	0.23	0.32	0.21	0.22	0.35	0.37	0.46	0.42	0.74	1.00	
A3H	0.20	0.19	0.19	0.22	0.26	0.05	0.08	0.15	0.13	0.13	0.18	0.19	0.17	0.28	0.26	0.21	0.33	0.36	0.43	0.49	0.49	0.56	1.00
	A1D	**A1H**	**A2D**	**A2K**	**A3D**	**A2A**	**A2L**	**A3B**	**A3K**	**A3L**	**A1G**	**A1K**	**A2C**	**A2J**	**A1E**	**A2B**	**A3F**	**A3G**	**A1F**	**A1I**	**A3C**	**A3E**	**A3H**
Mean	4.18	3.60	3.93	3.93	4.02	3.37	3.29	3.08	3.29	3.11	3.10	3.02	2.98	3.28	4.13	3.54	3.76	4.00	3.95	3.91	3.78	3.73	3.61
Std. Dev.	0.84	0.87	0.94	0.94	0.91	0.96	0.96	0.94	0.97	0.97	0.92	0.99	0.95	1.01	0.88	0.98	0.92	0.76	0.80	0.82	0.84	0.79	0.84
# of Violations	0	1	2	0	0	0	0	0	0	0	0	0	0	0	6	2	1	0	0	0	0	0	0

4.3.3. Process Outcomes

In Table 4.10., most violations occur between Teamwork and Development Productivity for Process Outcomes and Value to Customer and Product Performance. Because of causal relationships, some items of Teamwork are highly correlated with the items of Development Productivity. For example, C1D ("This product development team was productive") was highly correlated with all items of Teamwork (C1C, C1H, CIM, and C1M). Other than that, the variables show sufficient discriminant validity among them.

Table 4.10. Process Outcomes -- Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

	Time to Market				Team work				Development Productivity			
	C1B	C1E	C1I	C1K	C1C	C1H	C1M	C1N	C1D	C1G	C1J	C1L
C1B	1.00											
C1E	0.71	1.00										
C1I	0.44	0.59	1.00									
C1K	0.85	0.80	0.54	1.00								
C1C	0.36	0.53	0.40	0.40	1.00							
C1H	0.34	0.49	0.39	0.41	0.71	1.00						
C1M	0.33	0.53	0.36	0.42	0.71	0.68	1.00					
C1N	0.31	0.46	0.33	0.34	0.68	0.71	0.70	1.00				
C1A	0.36	0.31	0.26	0.35	0.34	0.42	0.40	0.34				
C1D	0.40	0.59	0.47	0.50	0.67	0.60	0.59	0.59	1.00			
C1G	0.28	0.29	0.25	0.28	0.47	0.45	0.46	0.46	0.49	1.00		
C1J	0.29	0.44	0.47	0.39	0.41	0.46	0.43	0.47	0.48	0.48	1.00	
C1L	0.37	0.55	0.44	0.45	0.56	0.58	0.58	0.54	0.53	0.47	0.60	1.00
Mean	3.69	3.60	3.28	3.66	3.82	3.51	3.56	3.52	3.96	3.58	3.32	3.32
SD	1.18	1.11	1.13	1.14	0.92	0.98	0.95	0.97	0.85	0.91	0.98	0.95
# of Violations	0	0	0	0	0	0	0	0	6	0	0	0

4.3.4. Product Outcomes

In Table 4.11., Value to Customer and Product Performance are correlated. The item C2A ("This product had a high quality") is correlated with all the items of Product Performance (C2D, C2H, C2L, C2Q).

Table 4.11. Product Outcomes -- Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity

Manufacturability Value to Customer Product Performance Mfg. Cost

	C2B	C2F	C2J	C2N	C2A	C2C	C2K	C2M	C2D	C2H	C2L	C2Q	C2E	C2G	C2I	C2O	
C2B	1.00																C2B
C2F	0.55	1.00															C2F
C2J	0.50	0.35	1.00														C2J
C2N	0.43	0.41	0.45	1.00													C2N
C2A	0.39	0.36	0.22	0.40	1.00												C2A
C2C	0.25	0.32	0.20	0.33	0.64	1.00											C2C
C2K	0.29	0.33	0.30	0.29	0.59	0.72	1.00										C2K
C2M	0.20	0.29	0.18	0.32	0.60	0.69	0.68	1.00									C2M
C2D	0.28	0.34	0.22	0.36	0.62	0.66	0.56	0.61	1.00								C2D
C2H	0.27	0.34	0.25	0.34	0.65	0.69	0.60	0.63	0.68	1.00							C2H
C2L	0.26	0.32	0.24	0.33	0.65	0.60	0.62	0.60	0.66	0.75	1.00						C2L
C2Q	0.23	0.34	0.14	0.35	0.67	0.69	0.64	0.74	0.64	0.82	0.79	1.00					C2Q
C2E	0.18	0.38	0.34	0.32	0.23	0.22	0.22	0.34	0.22	0.18	0.18	0.21	1.00				C2E
C2G	0.24	0.39	0.28	0.23	0.22	0.26	0.29	0.33	0.18	0.27	0.17	0.27	0.58	1.00			C2G
C2I	0.29	0.32	0.36	0.35	0.27	0.24	0.23	0.34	0.26	0.22	0.22	0.25	0.56	0.54	1.00		C2I
C2O	0.21	0.41	0.32	0.35	0.26	0.25	0.25	0.34	0.28	0.23	0.20	0.23	0.71	0.65	0.70	1.00	C2O
Mean	3.39	3.24	3.33	3.56	3.98	3.55	3.91	3.79	3.90	3.85	4.01	3.94	2.87	2.82	2.97	2.92	Mean
Std. Dev.	1.01	1.00	0.99	0.88	0.96	1.08	0.97	1.11	0.88	0.91	0.91	0.94	0.96	0.90	0.88	0.95	Std. Dev.
# of Violations	0	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	# of Violations

In addition, all other variables show discriminant validity indicated by their high correlation within the variable and low correlation with items of other variables. In summary, all the variables show convergent validity and discriminant validity except for two variables in team vision (i.e., shared team purpose and mission and clarity of project targets), process outcomes (teamwork and development productivity), and product outcomes (value to customer and product performance). However, these variables are still separately treated because the LISREL indices show enough discriminant validity between these variables. In addition, stepwise regression results show that these variables behave differently. This issue will be further discussed in the next section.

4.4. DISCIMINANT VALIDITY BY USING LISREL

LISREL methodology was employed to test for discriminant validity between pairs of scales of the four constructs (i.e., Team Vision, Shared Knowledge, Process and Product Outcomes). Table 4.12, Table 4.13, Table 4.14, and Table 4.15 show the results.

A total of sixteen models showing pairs of latent variables and their observable variables were run: (1) with the correlation between the latent variables fixed at 1.0, and (2) with the correlation between the latent variables free to assume any value. The difference in Chi-square values for the fixed and free solutions indicate whether a unidimensional model would be sufficient to account for the inter-correlations among the observed variables in each pair. For 16 comparisons, the Chi-square value for any pair must be greater than or equal to approximately 7.88 for significance at the $p<0.05$ (Cohen and Cohen, 1983). All pairs are significant at p<0.01 and every single pair shows that the Chi-square difference is much greater than 26.09 even in the case of Clarity of Project Targets and Shared Purpose and Mission, indicating discriminant validity to all variables of each construct.

Table 4.12. Team Vision
Descriptive Statistics, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Team Vision

Scales	Means	S.D.	1	2	3	4
Shared Team Purpose and Mission (1)	3.78	0.84	0.93(a) [0.78](b)			
Strategic Fit—Environment (2)	3.53	0.69	0.67** 58.54*	0.74(a) [0.50](b)		
Clarity of Project Targets (3)	3.66	0.84	0.87** 26.09*	0.71** 38.86*	0.90(a) [0.72](b)	
Tradeoff of Project Targets (4)	3.22	0.78	0.64** 86.89*	0.63** 41.20*	0.68** 56.23*	0.81(a) [0.64] (b)

(a) Reliability alphas for retained items are in parentheses.
(b) Average Variance extracted for retained items are on the diagonal brackets.
** Correlation significant at 0.01
* Chi-square differences ($\chi 2$).
Difference in $\chi 2$ for 1 degree of freedom is significant at 0.05.

An inspection of the alpha coefficient reveals that, among the thirteen alpha coefficients, all are either equal to or greater than 0.70, which indicates reliability (Nunnally, 1978). The alpha coefficient for Shared Knowledge of Products (0.72), Strategic Fit (0.79), and Manufacturability (0.72) are somewhat smaller but higher than a satisfactory level of 0.70.

The reliability of all the variables was examined using Cronbach's alpha along with computations of average variance extracted. Average variance extracted (Fornell and Larcker, 1981) is similar to the LISREL measure of composite reliability, but differs in that the standardized loadings are squared before summing them. It measures the amount of variance for the specified indicators accounted for by the latent construct. Higher variance extracted measure is a complementary measure to the construct reliability value. Guidelines suggest that the variance extracted value exceed 0.50 for a construct (Bagozzi and Yi, 1988). In Tables 4.12.- 4.15. the variance extracted value each exceeded 0.50, indicating discriminant validity and construct reliability value for all sixteen variables out of nineteem variables in the model. Two variables of Role Changes were excluded because they used the same items for design engineers and manufacturing engineers. "Market Performance" was excluded because it had only one item question.

Table 4.13. Shared Knowledge
Descriptive Statistics, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Shared Knowledge

Scales	Means	S.D.	(1)	(2)	(3)	(4)	(5)
Shared Knowledge of Customers (1)	3.92	0.68	0.86(a) [0.58](b)				
Shared Knowledge of Competitors (2)	3.32	0.79	0.34** 400.12*	0.87(a) [0.66](b)			
Shared Knowledge of Suppliers (3)	3.10	0.80	0.18** 295.15*	0.26** 272.61*	0.82(a) [0.67](b)		
Shared Knowledge of Products (4)	3.79	0.63	0.45** 90.46*	0.40** 107.46*	0.15** 149.61*	0.72(a) [0.52](b)	
Shared Knowledge of Internal Capabilities (5)	3.79	0.64	0.45** 393.97*	0.20** 482.08*	0.39** 236.08*	0.49** 80.64*	0.85(a) [0.61](b)

(a) Reliability alphas for retained items are in parentheses.
(b) Average Variance extracted for retained items are on the diagonal brackets.
** Correlation significant at 0.01
* Chi-square differences.
Difference in Chi-Square for 1 degree of freedom is significant at 0.05.

Table 4.14. Process Outcomes
Descriptive Statistics, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Process Outcomes

Scales	Means	S.D.	(1)	(2)	(3)
Time to Market (1)	3.57	0.97	0.88(a) [0.75](b)		
Teamwork (2)	3.52	0.73	0.62** 335.46*	0.90(a) [0.77](b)	
Development Productivity (3)	3.46	0.71	0.62** 107.06*	0.97** 13.66*	0.80(a) [0.63](b)

(a) Reliability alphas for retained items are in parentheses.
(b) Average Variance extracted for retained items are on the diagonal brackets.
** Correlation significant at 0.01
* Chi-square differences
Difference in Chi-Square for 1 degree of freedom is significant at 0.05.

In summary, the above results in Table 4.12., Table 4.13., Table 4.14., and Table 4.15. suggest that all the variables display the substantial degree of discriminant validity. Even variables like Shared Team Purpose and Mission (STMPRM), Clarity Of Project Targets (CLARITY), Teamwork (TEAMWK), Development Productivity (DEVPROD), Value To Customer (VALCUST) and Product Performance (PRODPERF) all show sufficient degree of discriminant validity.

Table 4.15. Product Outcomes
Descriptive Statistics, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Product Outcomes

Scales	Means	S.D.	(1)	(2)	(3)	(4)
Manufacturability (1)	3.39	0.74	0.76(a) [0.58](b)			
Value to Customer (2)	3.77	0.92	0.43** 114.76*	0.91(a) [0.74](b)		
Product Performance (3)	3.90	0.82	0.42** 120.93*	0.83** 28.89*	0.91(a) [0.79](b)	
Manufacturing Cost (4)	2.89	0.78	0.48 95.95*	0.38** 311.16*	0.31** 345.48*	0.87(a) [0.72] (b)

(a) Reliability alphas for retained items are in parentheses.
(b) Average Variance extracted for retained items are on the diagonal brackets.
** Correlation significant at 0.01

- Chi-square differences are indicated with numbers with
  Difference in Chi-Square for 1 degree of freedom is significant at 0.05.

4.5. PREDICTIVE POWER : STEPWISE REGRESSION

Regression analysis was conducted to examine predictive power of eleven variables of three constructs (i.e., Role Changes, Team Vision and Shared Knowledge) on seven product development performance outcomes. The results are summarized in Tables 4.19. and 4.20. (Note: Predictive validity in the construct level is examined in the following chapter as the causal models are explained and hypotheses are tested.)

As observed in Tables 4.8., - 4.11. (pp. 138-141) all the scales that showed violations according to the MTMM approach [i.e., Team Vision (Shared Team Purpose and Mission vs. Clarity of Project Targets), Process Outcomes (Teamwork and Development Productivity) and Product Outcomes (Value to Customer and Product Performance)], all behave differently in their predictive power. Shared Team Pupose/Mission does not behave in the same way as Clarity of Project Targets in influencing process and product outcomes. For example, Shared Team Purpose and Mission shows impact on Time to Market ($P<0.01$), but Clarity of Project Targets affects Teamwork and Development Productivity. This is true with Process outcomes and Product Outcomes. Only Teamwork and Value to Customer affects Market Performance at $P<0.01$. In brief, all the scales are substantially different from each other in terms of discriminant validity and their predictive power. The following section shows details of the predictive power of each scale on Process and Product Outcomes.

4.5.1. Process Outcomes

Table 4.16. shows that time to market is associated with shared knowledge of internal capabilities ($b=0.26$, $p<0.01$) and shared team purpose and mission ($b=0.31$, $p<0.01$). Team work Is positively associated with Shared Knowledge of Customers ($b=0.25$, $p<0.01$) and Shared Knowledge of Internal Capabilities ($b=0.20$, $p<0.00$), Clarity of Project Targets($b=0.24$, $P<0.01$), and Tradeoff of Project Targets ($b=0.18$, $P<0.01$). Development Productivity is positively associated with Shared Knowledge of Suppliers ($b=0.20$, $p<0.01$), Internal Capabilities ($b=0.19$, $P=0.00$), Clarity of Project Targets ($b=0.34$, $p<0.01$), and Tradeoff of Project Targets ($b=0.13$, $p<0.05$)

4.5.2. Product Outcomes

Table 4.16. also shows that manufacturability Is positively associated with Shared Knowledge of Suppliers ($b=0.25$, $p<0.01$), Shared Knowledge of Products ($b=0.26$ $p<0.01$) and Role Changes of Design Engineers ($b=0.15$, $p<0.05$). Manufacturing Cost Is positively associated with Shared Knowledge of Suppliers ($b=0.27$, $p<0.01$), Shared Knowledge of Products ($b=0.31$, $p<0.01$), and yet is negatively associated with Shared Knowledge of Competitors ($b=-0.19$, $p<0.01$).

Value to Customers is positively associated with Shared Knowledge of Customers ($b=0.24$, $t=3.25$, $p<0.01$), Shared Knowledge of Internal Capabilities ($b=0.18$, $p<0.01$), Clarity ($b=0.38$, $p<0.01$), and Srategic Fit--Environment ($b=0.30$, $p<0.01$). Product Performance is positively associated with Shared Knowledge of Customers ($b=0.19$, $P<0.01$), Internal Capabilities ($b=0.19$, p

<0.05), Clarity and Strategic Fit--Environment ($b=0.30$, $p<0.01$), and Role Changes of Design Engineers ($b=0.13$, $P<0.05$).

4.5.3. Market Performance

Table 4.17. shows that "Market Performance" is positively associated with Shared Knowledge of Customers ($b=0.28$, $p<0.01$), Strategic Fit of Project Targets ($b=0.34$, $P<0.01$), and Role Changes of Design Engineers ($b=0.14$, $P<0.05$) The stepwise regression indicates that Shared Team Purpose and Mission and Clarity interact differently with performance outcomes. For example, Shared Team Purpose and Mission is a key determining factor for time to market, while Clarity of Project Targets impacts Teamwork and Development Productivity.

In a similar way, although Teamwork and Development Productivity are highly correlated and are expressed as one aggregate factor, each interacts differently with other performance outcomes. For example, Teamwork seems to be an important variable that influences Market Performance, while Development Productivity is not. Therefore, although Teamwork and Development Productivity are highly related, they interact differently with Market Performance. In light of the different predictive power of these variables, it is justified to regard these (Shared Team Purpose and Mission, Clarity of Project Targets, Teamwork and Development Productivity) as separate variables.

In summary, all the 2nd order constructs of the three knowledge integration constructs ("Role Changes", "Team Vision", and "Shared Knowledge") in one way or another have predictive power which is statistically substantial and significant.

Table 4.16.
Stepwise Regression I (Shared Knowledge, Team Vision and Role Changes)

Scale	Time to Market	Team-work	Develop-ment Produc-tivity	Manu fac-tur-ability	Value to Custo-mers	Product Perfor-mance	Manufac-turing Cost
R-Square	**0.24**	**0.48**	**0.44**	**0.22**	**0.46**	**0.37**	**0.16**
Shared Knowledge							
Customers		0.25 (0.00)			0.21 (0.00	0.19 (0.01)	
Competitors							**-0.19 (0.01)**
Suppliers			0.20 (0.01)	0.25 (0.00)			0.27 (0.00)
Products				0.26 (0.00)			0.31 (0.00)
Internal Capabilities	0.26 (0.00)	0.20 (0.00)	0.19 (0.00)		0.18 (0.01)	0.19 (0.03)	
Team Vision							
Shared Team Purpose and Mission	0.31 (0.00)						
Strategic Fit -- Environment					0.30 (0.00)	0.27 (0.00)	
Clarity of Project Targets		0.24 (0.01)	0.34 (0.01)		0.38 (0.00		
Tradeoff of Project Targets		0.18 (0.01)	0.13 (0.04)				
Role Changes							
Design Engineers				0.15 (0.04)		0.13 (0.04)	
Manufacturing Engineers							

Table 4.17. Stepwise Regression II (Process and Product Outcomes)

Scale	Market Performance
R-Square	**0.57**
Process Outcomes	
Time to Market Teamwork Development Productivity	0.13, (0.04)
Product Outcomes	
Manufacturability	
Value to Customers	0.67, (0.00)
Product Performance	
Manufacturing Cost	

4.6. GENERALIZABILITY OF THE SCALES

Table 4.18. displays that the internal consistency of each scale holds up well over the various industry classifications and firm sizes. With a little modification, similar analysis could test the generalizability of the instrument in regard to different types of industries such as information technologies and even services firms. Confirmatory factor analysis could be utilized in the future to substantiate the appropriateness of the instrument. For scales to achieve wide spread application, they must be generalizable across different groups of respondents. This is an attractive feature because researchers may use such scales in different contexts.

Reliability (Cronbach's alpha) was calculated for the four industries that had an adequate number of responses. The purpose was to assess the generalizablity of the scales across industries. With two exceptions (Shared Knowledge of Products and Strategic Fit of Project Targets), all other scales had alphas above 0.80. In addition, reliability was assessed by firm size. For small firms and larger firms, the reliabilities were all above 0.80 except Shared Knowledge of Products, Strategic Fit of Project Targets and Manufacturability. This can be attributed to the application of sound methodology that is followed by other disciplines (e.g., psychology and marketing) with a rich tradition in empirical research. These reliabilities provide preliminary evidence that the scales can be used across industries and across firm sizes.

Table 4.18. Reliabilities by Industry and Firm Size for Knowledge iltegration Scales

	SIC 34 47 cases	SIC 35 15 cases	SIC 36 36 cases	SIC 37 97 cases	Others 10 cases	Large firms (Employees > 1,000) 89 cases	Small firms (Employees < 1,000) 113 cases
Role Changes (Design Eng.)	0.82	0.86	0.93	0.83	0.85	0.88	0.83
Role Changes (Mfg. Eng.)	0.88	0.89	0.91	0.83	0.92	0.88	0.83
Shared Team Purpose and Mission	0.90	0.86	0.88	0.95	0.97	0.92	0.94
Strategic Fit of Proj. Targets	0.75	0.80	0.79	0.71	0.81	0.76	0.75
Clarity of Proj. Targets	0.87	0.81	0.86	0.93	0.91	0.92	0.94
Tradeoff of Proj. Targets	0.72	0.75	0.88	0.83	0.88	0.83	0.79
Shared Knowledge of Customers	0.86	0.82	0.76	0.87	0.89	0.84	0.89
Shared Knowledge of Competitors	0.88	0.90	0.92	0.88	0.93	0.90	0.90
Shared Knowledge of Suppliers	0.82	0.84	0.91	0.87	0.81	0.88	0.89
Shared Knowledge of Products	0.70	0.69	0.83	0.72	0.91	0.77	0.71
Shared Knowledge of Internal Capabilities	0.81	0.80	0.84	0.90	0.82	0.88	0.84
Time to Market	0.88	0.87	0.89	0.88	0.92	0.90	0.85
Teamwork	0.87	0.90	0.94	0.90	0.95	0.88	0.93
Development Productivity	0.77	0.81	0.73	0.83	0.94	0.81	0.82
Manufacturability	0.78	0.78	0.80	0.80	0.85	0.74	0.77
Manufacturing Cost	0.83	0.85	0.73	0.92	0.77	0.84	0.89
Value to Customer	0.85	0.87	0.94	0.93	0.97	0.89	0.94
Product Performance	0.87	0.90	0.94	0.92	0.88	0.88	0.94

4.7. SUMMARY OF MEASUREMENT ANALYSIS

Table 4.19 contains a summary of measurement analysis (Flynn, Schroeder & Sakakibara, 1994) regarding the reliability and construct validity of the items/measures resulting from the instrument development described in chapter four.

Table 4.19. Summary of Measurement Analysis

Construct	Scales/Factor	Items	Alpha	KMO	Eigen Value
Role Changes	Design Engineers	5	0.81	0.83	2.87
	Manufacturing Engineers	5	0.82	0.82	2.89
Team Vision	Shared Team Mission	5	0.93	0.90	3.92
	Strategic Fit--Environment	4	0.74	0.74	2.56
	Clarity of Project Targets	4	0.90	0.88	3.60
	Tradeoff of Project Targets	4	0.81	0.78	2.56
Shared Knowledge	Customers	5	0.86	0.86	3.50
	Competitors	5	0.87	0.87	3.32
	Suppliers	4	0.82	0.82	2.69
	Products	5	0.72	0.66	2.11
	Internal Capabilities	5	0.85	0.85	3.26
Process Outcomes	Time to Market	4	0.88	0.77	2.99
	Teamwork	5	0.90	0.85	3.09
	Development Productivity	4	0.82	0.84	2.89
Product Outcomes	Manufacturability	4	0.76	0.74	2.31
	Value to Customer	4	0.91	0.84	2.97
	Product Performance	4	0.91	0.83	3.15
	Manufacturing Cost	4	0.87	0.81	2.87
Performance	Market Performance of the Project	1	*		

The final alpha value, Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy, and eigenvalue for each of the scales is displayed. In each case the KMO indicates that factor analysis is appropriate (Kaiser, 1970). The concluding within-scale factor analysis shows that the eigenvalue for each of the scales exceeds the minimum acceptable eigenvalues of 1.00 (Ghiselli, Campbell, & Zedek, 1981).

Table 4.20 displays the results of submitting composite measures of the independent variables to SPSS9.0 to determine the Pearson product-moment correlations. The composite measures were calculated by summing the individual scores for each of the items of a dimension and then dividing by the number of items. For example, the retained items of Shared Knowledge of Customers (A1D, A1H, A2D, A2K, A3D) were summed. The mean score (μ) and their standard deviation (σ) are given in the first two columns.

Table 4.21 shows the results of submitting composite measures of the dependent variables to SPSS9.0 to determine the Pearson product-moment correlations. The composite measures were calculated by summing the individual scores for each of the items of a dimension and then dividing by the number of items. For example, the retained items of Time to Market (C1B, C1E, C1I, C1K) were summed. The mean score (μ) and their standard deviation (σ) are given in the first two columns.

Table 4.20. Correlations Between the Composite Measures of the Independent Variables

Dimensions (# of Items)	Mean	Std. Dev.	RCDE	RCME	STMPRP	STENV	CLAR-ITY	TRADE-OFF	CUST	COMP	INTCP	SUPPL	PROD
RCDE (5)	18.56	3.14	1.00										
RCME (5)	18.25	3.08	0.56	1.00									
STM (5)	19.90	4.20	0.30	0.32	1.00								
STFENV (4)	13.64	3.01	0.36	0.26	0.64	1.00							
CLARITY (4)	14.55	3.49	0.39	0.32	0.87	0.67	1.00						
TRADE-OFF (4)	12.87	3.13	0.33	0.34	0.65	0.61	0.69	1.00					
SKCUST (5)	19.64	3.54	0.25	0.21	0.53	0.46	0.54	0.43	1.00				
SKCOMP (5)	16.61	3.97	0.17	0.14	0.39	0.32	0.38	0.39	0.44	1.00			
SKINTCP (5)	18.84	3.30	0.34	0.37	0.46	0.35	0.36	0.38	0.40	0.47	1.00		
SKSUPPL (5)	18.53	4.71	0.25	0.23	0.33	0.50	0.34	0.42	0.44	0.48	0.44	1.00	
SKPROD (5)	19.29	3.00	0.37	0.32	0.46	0.41	0.52	0.43	0.55	0.47	0.51	0.48	1.00

This analysis was performed to conduct a concluding discriminant validity to check for the items retained on the final instrument. Both independent variables (Table 4.20.) and dependent variables (Tables 4.21.) show the high correlation within a construct and yet the absence of strong correlations outside of the construct. This indicates that the items fairly measure what they were intended to measure and accordingly display discriminant validity (Hair, et al., 1995).

Table 4.21. Correlations Between the Composite Measures of the Dependent Variables

Scales (# of Items)	Mean	Std. Dev.	TIMEMKT	TEAMWK	DEVPROD	MANUFAC	VALCUST	PRODPERF	MFGCOST	ROLEDE	ROLEME
TIMEMKT (4)	14.27	3.88	1.00								
TEAMWK (5)	18.03	4.12	0.62	1.00							
DEVPROD (5)	17.30	3.55	0.62	0.97	1.00						
MANUFAC (4)	13.55	2.94	0.35	0.43	0.41	1.00					
VALCUST (4)	15.09	3.69	0.46	0.62	0.62	0.43	1.00				
PROD-PERF (4)	15.60	3.28	0.47	0.55	0.54	0.41	0.83	1.00			
MFGCOST (4)	11.57	3.13	0.34	0.36	0.33	0.48	0.39	0.31	1.00		

Chapter Five

Causal Model and Hypotheses Testing

5.1. THE CAUSAL MODEL

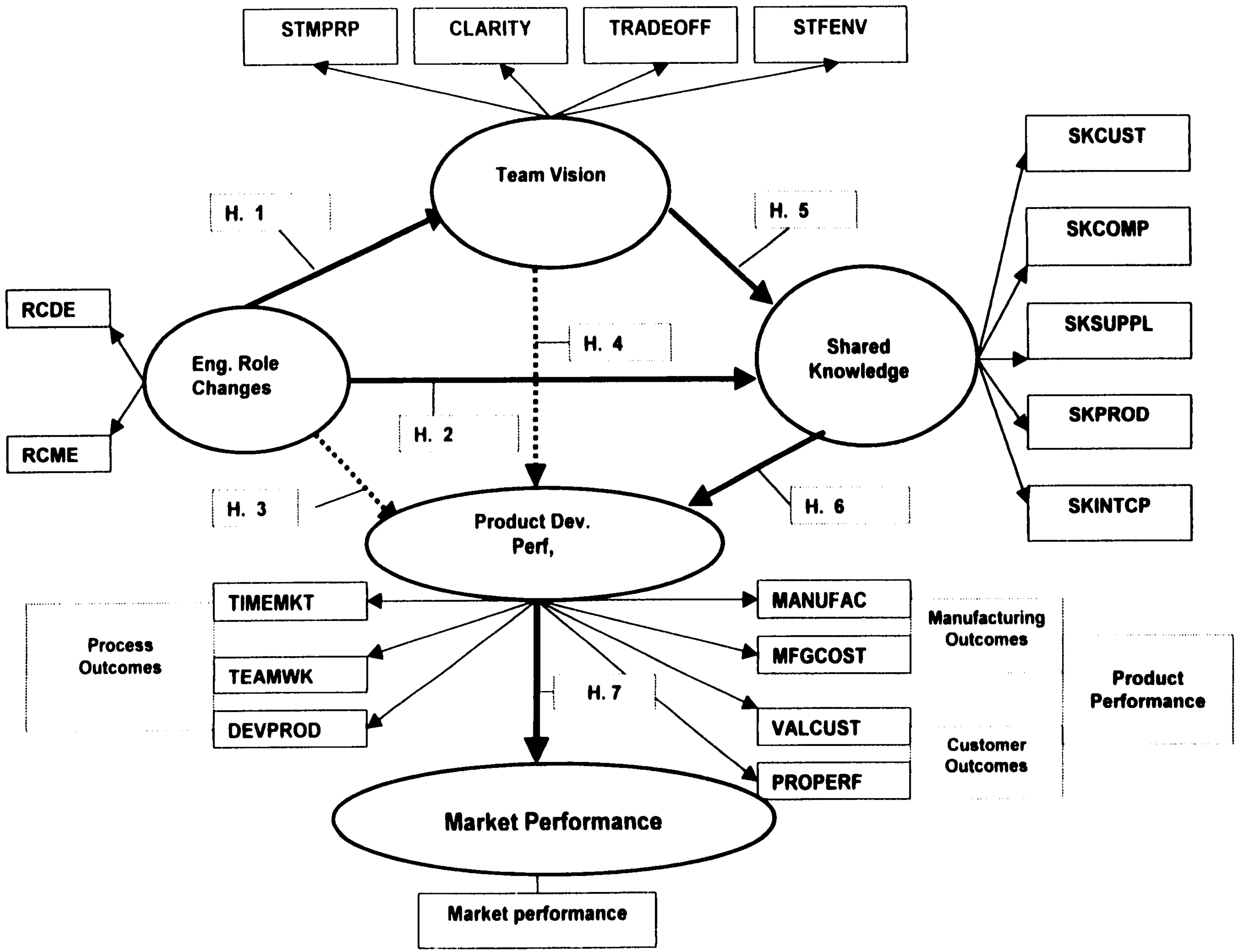
Linear structural equation modeling (LISREL) was used to explore the relationships between Role Changes, Team Vision, Shared Knowledge and Product Development Performances, In structural modeling, it is preferable to have several indicators of a construct as opposed to a single indicator (Hair et al., 1995) In this case, composite measures were used as indicators for each construct.

First, composite measures (Role Changes, Team Vision, and Shared Knowledge) were created by summing the individual scores of each item of a scale. Second, these composite measures were used as observable indicators of the exogenous latent construct (Role Changes) and the endogenous latent constructs (Team Vision and Shared Knowledge, Product Development Performance). Figure 5.1. illustrates the causal model, with composite measures as observable indicators of the endogenous latent constructs.

Role Changes has two variables (RCDE—Role Changes of Design Engineers and RCME—Role Changes of Manufacturing Engineers), "Team Vision" has five variables (STMPRP—Shared Team Purpose and Mission, Clarity of Project Targets, TRADEOFF of Project Targets, and Strategic Fit of Project Targets), Shared Knowledge has five variables (SKCUST—Shared Knowledge of Customers, SKCOMP—Shared Knowledge of Competitors, SKSUPPL—Shared Knowledge of Suppliers, SKPROD—Shared Knowledge of Products, SKINTCP—Shared Knowledge of Internal Capabilities), and Product Development Performances has seven variables with three groups. The first group is Process Outcomes of Product Development, which has three variables (TIMEMKT—Time to Market, TEAMWK—Teamwork, DEVPROD—Development Productivity). The second group is regarded as Manufacturing Outcomes of Product Development that has two variables (MANUFAC—Manufacturability, MFGCOST—Manufacturing Cost). The last group is Customer Outcomes of Product Development, which has two variables (VALCUST—Value to Customers and PRODPERF—Product Performance).

The first LISREL analysis was done based on one product development performance in which all three groups of product development performances are grouped together (See Figure 5.2.). The second LISREL analysis was done based on three groups of product development performances and market performance (See Figure 5.3.). The last LISREL analysis was done based on all the constructs with three groups of product development performances and market performance (See Figure 5.4.).

Figure 5.1. Primary Causal Model



5.2. RESULTS OF TESTING THE CAUSAL MODEL

Linear structural relationship (LISREL) provides a vigorous method for testing causal models as it is capable of simultaneously evaluating both the measurement and causal components of complex models (Dillion and Goldstein, 1984). Standardized coefficients and t-values of the causal relationship between constructs were used to test the hypothesis stated in chapter two. Factor loadings can be viewed as regression coefficients in the regression of observed variables on latent variables. The larger the factor loadings or coefficients, as compared with their standard errors and expressed by the corresponding t-values, the stronger the evidence that the measured factors represent the underlying constructs (Bollen, 1989). In general, if t-values are greater than 1.645 or 2.326 then they are considered significant at the 0.05 level and 0.01 level, respectively,

It is essential that more than one fit index is used to assure that meaningful conclusions can be reached in regard to model fit (Bagozzi and Yi, 1991; Bollen and Long, 1993). χ^2 and the degree of freedom , root mean square error of approximation (RMSEA), expected cross-validation index (ECVI), non-normed fit index (NNFI), and comparative fit index (CFI) were used to evaluate the appropriateness of the overall casual model being tested.

RMSEA is an average of the residuals between observed and estimated input matrices. Value ranging from 0.05 to 0.08 is deemed acceptable (Hair et al., 1995). The ratio of χ^2 and the degree of freedom provides information on the relative efficiency of competing models in accounting for the data.

Researchers have recommended using ratios of less than five to indicate a reasonable fit (Marsch and Hocevar, 1985). Comparative fit index (CFI) is a non-statistical measure ranging in value from 0 (poor fit) to 1.0 (perfect fit). Models exhibiting CFI and NNFI indices greater than 0.90 have adequate fit. These critical values indicate that one expects any model that adequately explains the variances and covariances in the observed data to reflect at least a 90% improvement over the null model (Koufteros, 1999).

5.3. LISREL ANALYSIS WITH SEVEN OUTCOMES AGGREGATED

202 responses were utilized in carrying out LISREL analysis. Figure 5.2. shows a partially aggregated model. Here, within each construct, variables are partially aggregated. For example, Team Vision construct has four variables (Shared Team Purpose and Mission, Strategic Fit, Clarity, and Tradeoff of Project Targets). Each variable has four or five items.

Here, causal relationships between construct were examined. Figure 5.2. shows that all seven outcome variables are grouped together as one construct. Table 5.1. summarizes the results. The standardized coefficient and t-values are shown in Table 5.2. They are all above the minimum acceptable t-value of 1.645 (at α=0.10 for the two tailed test, df=∞). Chi-square=514.12, df=129 and the ratio is 514.12/129=3.985 which is within acceptable range. However, the CFI was 0.84, while RMSEA=0.12 and NNFI=0.82.

Figure 5.2. A Knowledge Integration Model with Seven Performance Outcomes Aggregated

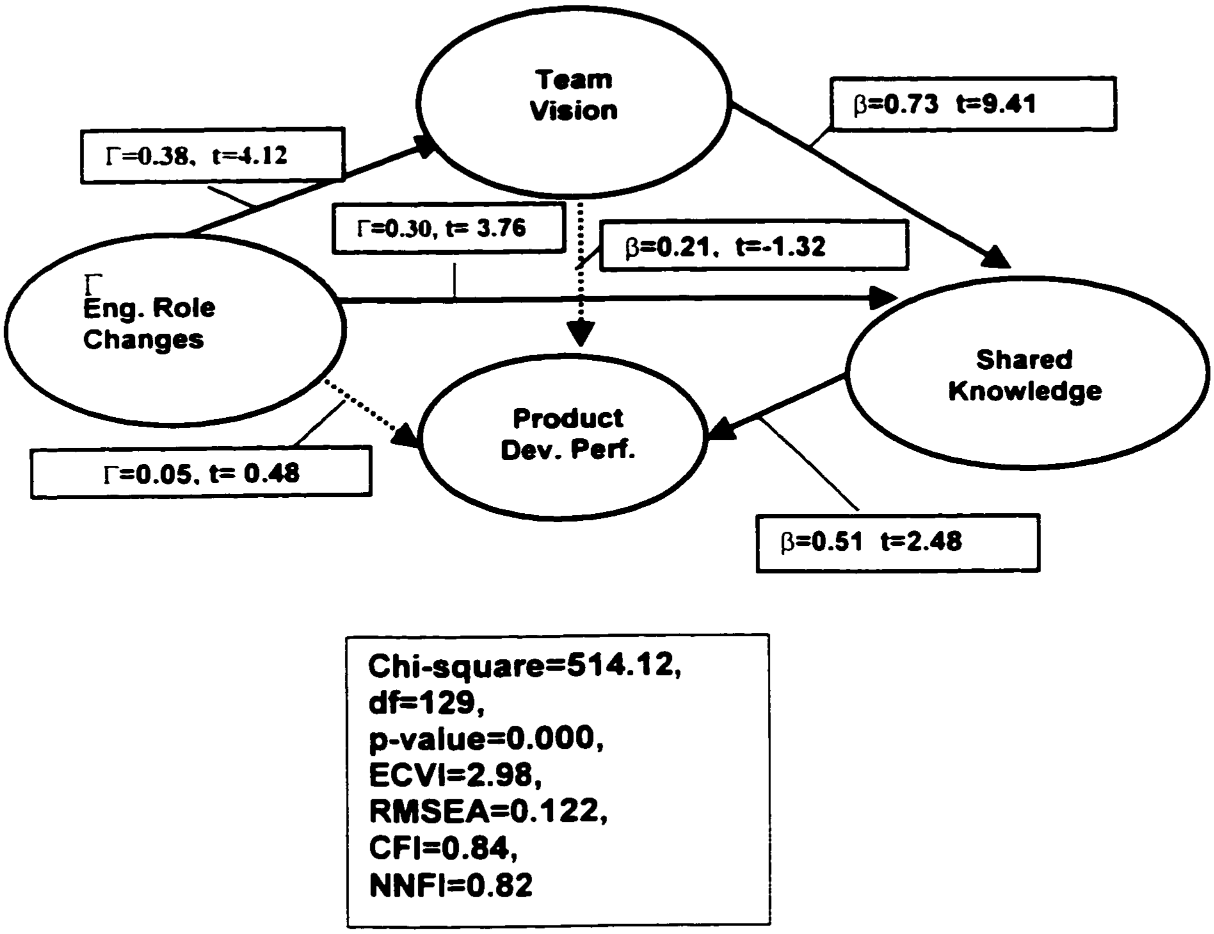


Table 5.1. Summary of LISREL Generated Data for Indicators (Seven Performance Outcomes Aggregated)

Exogenous Construct Indicators	Standardized Factor Loadings	t-values	Endogenous Construct Indicators	Standardized Factor Loadings	t-values
Role Changes					
REDE	0.77	-			
REME	0.72	5.84			
			Team Vision		
			STMPRP	0.91	-
			CLARITY	0.94	22.11**
			TRADEOFF	0.74	13.47**
			STFENV	0.73	13.10**
			Shared Knowledge		
			SKCUST	0.75	-
			SKCOMP	0.49	6.48**
			SKSUPPL	0.46	6.13**
			SKPROD	0.73	9.78**
			SKINTCP	0.61	8.13**
			Product Development Outcomes		
			TIMEMKT	0.63	-
			TEAMWK	0.99	11.35**
			DEVPROD	0.98	11.26**
			MANUFAC	0.44	5.88**
			MFGCOST	0.37	4.96**
			VALUCUST	0.64	8.18**
			PRODPERF	0.57	7.43**

Note: **Significant at α <0,01 (Two-tailed test, df = ∞)

Figure 5.2. and Table 5.1. display a summary of the data generated by LISREL related to the testing of the relationships between constructs. This is based on one product development performance in which all seven variables (Teamwork, Development Productivity, Time-To-Market, Manufacturability,

Manufacturing Cost, Value To Customer and Product Performance) are all lumped together.

5.4. EXAMINATION OF PRODUCT DEVELOPMENT PERFORMANCE OUTCOMES

In order to improve the overall model, LISREL analysis was done to examine the relationship between performance outcomes and market performance of projects. Market Performance has only one item. It asks the respondents to identify the extent of market performance with the Likert scale (1=very disappointing, 2=somewhat disappointing, 3=average, 4=moderate success, 5=a great success). For LISREL analysis, t-value of market performance was fixed.

When product development performance outcomes are further classified into three outcomes (Process, Manufacturing, and Customer Outcomes) and they are related to Market Performance, it shows an excellent model fit (RMSEA=0.049, CFI=0.99, NNFI=0.99). Both Process Outcomes and Customer Outcomes are statistically significant ($p < 0.01$).

Product development outcomes are comprehensive and relate to each other. Process Outcomes (i.e., Teamwork, Development Productivity, and Time to Market) indicate the overall effectiveness of the product development processes. Manufacturing Outcomes (i.e., Manufacturability and Manufacturing Cost) suggest the efficiency aspect of manufacturing processes. Finally, Customer Outcomes (i.e., Value to Customer and Product Performance) are determined by the customers' assessment of the products. Because of these distinct differences and their underlying causal relationships, LISREL analysis is conducted with these three performance outcomes separately.

Figure 5.3. summarizes the relationships between the three performance outcomes. The standardized coefficients of Process Outcomes, Manufacturing Outcomes and Customer Outcomes on Market Performance of projects is 0.16, -0.13, and 0.73 respectively. Among the three outcomes, the causal relationships are manifested as well. The standardized coefficients of Process Outcomes on Manufacturing Outcomes and Customer Outcomes are 0.54 and 0.47. There seems to be sequence of causal relationships among these outcome measures. Process Outcomes affect Manufacturing Outcomes and Customer Outcomes. Manufacturing Outcomes influence Customer Outcomes. It is Customer Outcomes that determine Market Performance. Therefore, it is meaningful to present the whole model with three separate product development performance measures (i.e., Process, Manufacturing and Customer Outcomes) and Market performance.

Table 5.2. displays a summary of the data generated by LISREL related to the testing of the relationships between three product development outcomes and market performance. The size of coefficients and corresponding t-value suggests that the causal relationships among variables are statistically significant.

Figure 5.3. A Causal Model of Performance Outcomes and Market Performance (Standardized Solution)

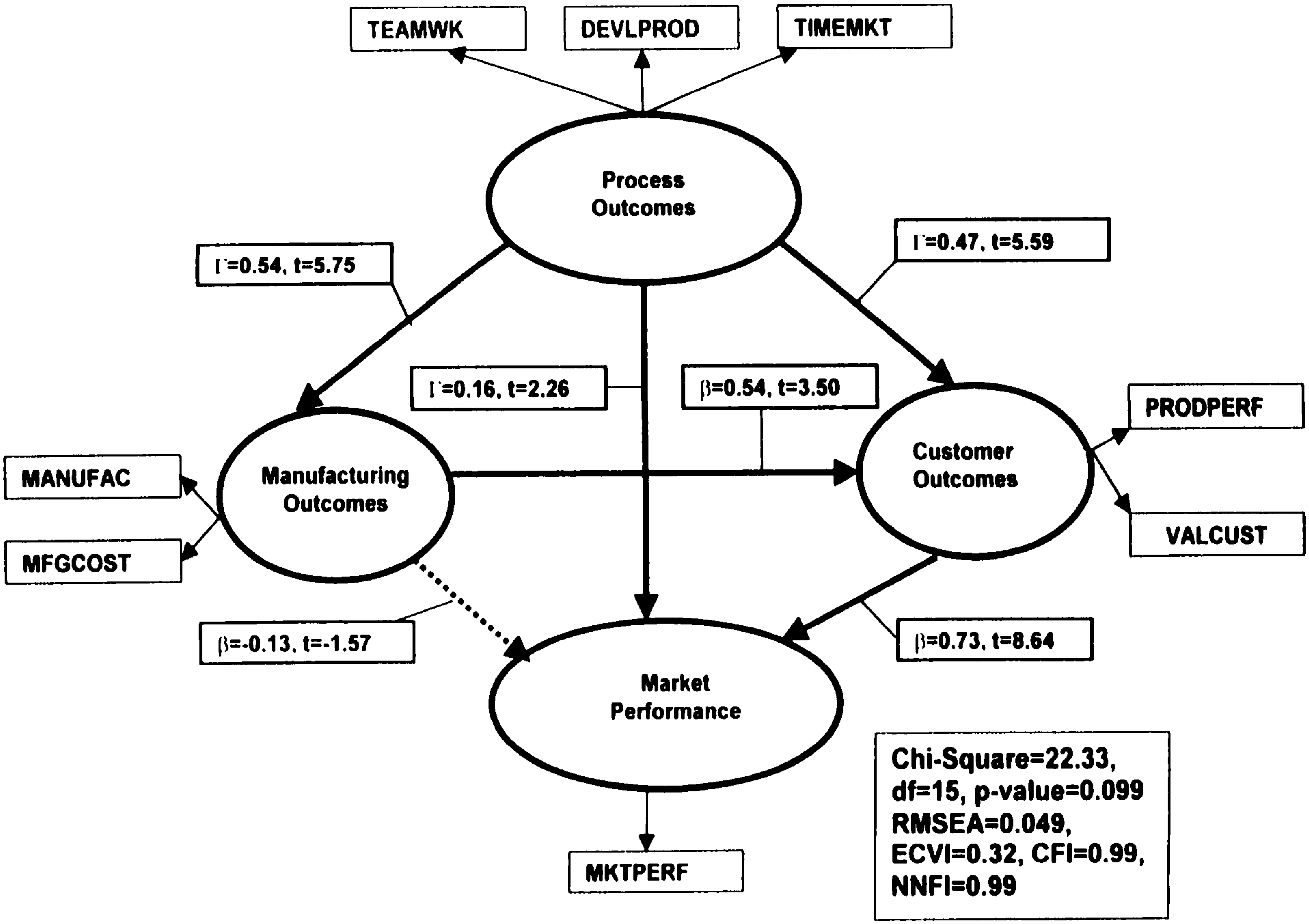


Table 5.2. Summary of LISREL Generated Data for Indicators

(Performance Outcomes and Market Performance)

Exogenous Construct Indicators	Standardized Factor Loadings	t-values	Endogenous Construct Indicators	Standardized Factor Loadings	t-values
Process Outcomes					
TIMEMKT	0.63	-			
TEAMWORK	0.99	11.19			
DEVPROD	0.98	11.18			
			Manufacturing Outcomes		
			MANUFAC	0.77	-
			MFGCOST	0.62	5.93
			Customer Performance		
			VALUCUST	0.99	-
			PRODPERF	0.84	17.49
			Market Performance		
			MKTPERM	1.00	-

5.5. LISREL ANALYSIS BASED ON THREE GROUPS OF PRODUCT DEVELOPMENT PERFORMANCE OUTCOMES

Figure 5.4., Table 5.3., and 5.4. display a summary of the data generated by LISREL related to the testing of the relationships between constructs. The model has three separate groups of performance outcomes (Process, Manufacturing and Customer) and Market Performance. It shows a good model fit (RMSEA=0.075, CFI=0.94, NNFI=0.92)

Among the seven hypotheses proposed in chapter two, hypotheses 1, 2 and 5 are fully supported; however, hypotheses 6 and 7 are partially supported. Hypotheses 3 and 4 were not supported. The results confirm the original model and support most of the hypotheses. Role Changes affects Team Vision. Team Vision affects Shared Knowledge. Both Role Changes and Team Vision do not directly affect Product Development Performances; however, both Team Vision and Role Changes indirectly influence product development performances. Shared Knowledge affects Product Development Performances. Product Development Performances affect Market Performances.

The results of data analysis suggest that IPD involves complex processes and the outcomes are affected by hierarchical relationships. Shared Knowledge is the centerpiece of the three knowledge integration components. The effects of Role Changes and Team Vision are channeled through Shared Knowledge to make impacts on Product Development Performances, but not directly on Product Development Performances. The effects of Shared Knowledge are realized through Process Outcomes, but not directly to other performance outcomes. Market Performance is primarily affected by Customer Outcomes, but not directly through Shared Knowledge. It appears that each building block of IPD needs to be carefully built before their effects are felt in the subsequent processes.

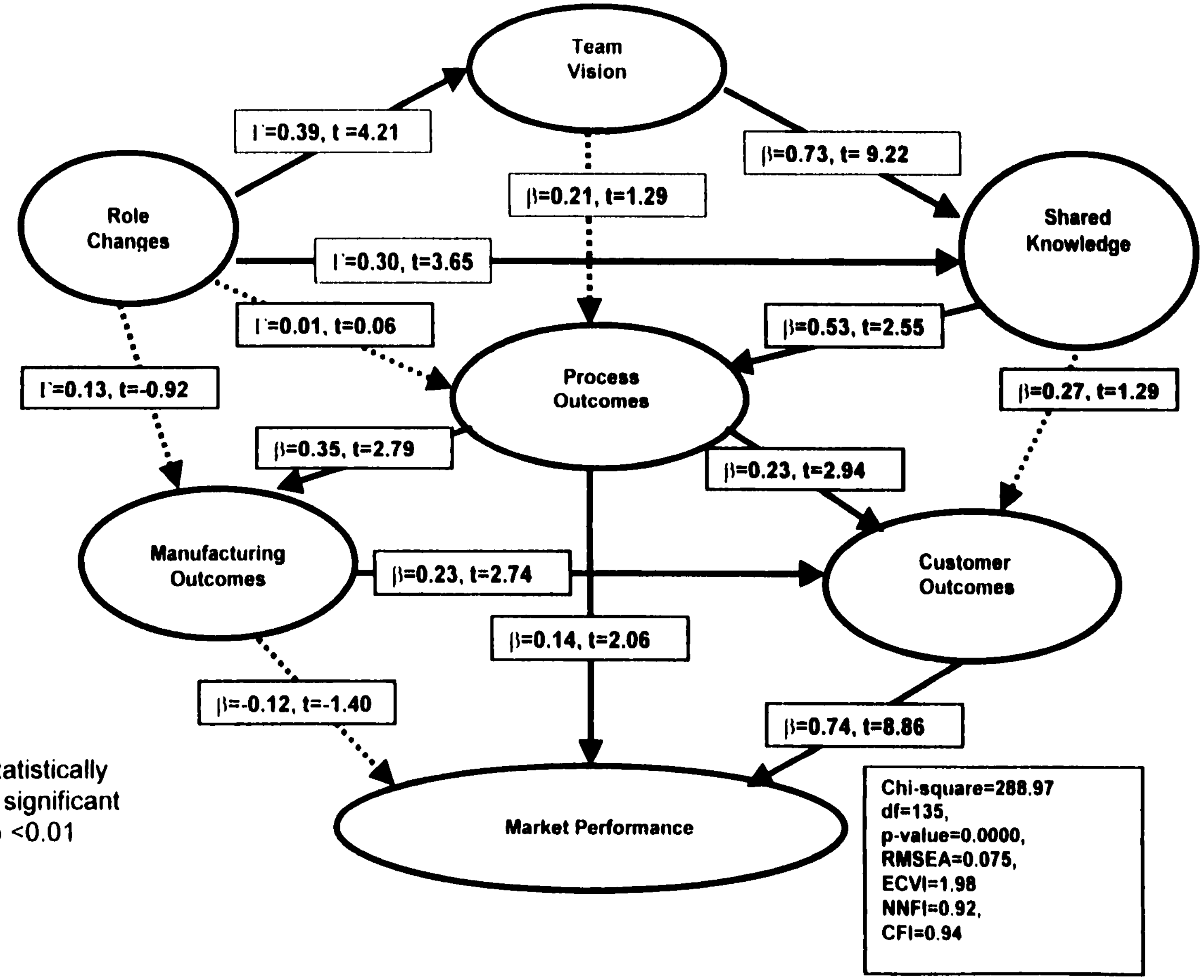
To further assess the various relationships between constructs, coefficients of direct, indirect and total effects were examined through LISREL. Coefficients of indirect effect were calculated by multiplying coefficient of direct effects that lie along the indirect path. When multiple indirect paths exists between two constructs, the sum of all possible coefficients of indirect effects is calculated to represent the indirect effect between the two constructs. Coefficient of total effects is the sum of coefficients of direct and indirect effects. The results are shown in Table 5.5.

As an example of how the coefficient of indirect effect is calculated, consider the two constructs, Team Vision (TV) and Process Outcomes (PO). Besides the direct path between the two, which has the coefficient 0.21, they also have an indirect path, which goes from (1) Team Vision (TV), Shared Knowledge (SK) to Process Outcomes (PO) (Figure 5.4.). The coefficient of indirect path is calculated by multiplying the coefficient of direct effect between TV, SK and PO (0.73 x 0.53=0.39) (See A in Table 5.5.)

All relationships turned out to be significant in total effects, including those relationships that have not been significant when only direct effects were considered. For example, Role Changes and all performance outcomes were non-significant when only direct effects were considered. But the total effects of

Role Changes on Process Outcomes, Manufacturing Outcomes and Customer Outcomes and Market Performance were all significant with t >3.91. This is true with Team Vision and all performance outcomes. The direct effects of Team Vision on performance outcomes were non-significant. But including indirect effects, the total effects of Team Vision on performance outcomes were all significant with t >2.75. This indicates that even though there may be no direct causal relationships from Role Changes to performance outcomes and Team Vision to performance outcomes, there are positive, significant indirect relationships between them, resulting in significant total effects in both relationships.

Figure 5.4. A Knowledge Integration Model with Three Groups of Product Performance Outcomes (Standardized Solution)



* Statistically not significant
** p <0.01

Table 5.3. Summary of LISREL Generated Data for Indicators (Three Groups of Performance Outcomes)

Exogenous Construct Indicators	Standardized Factor Loadings	t-values	Endogenous Construct Indicators	Standardized Factor Loadings	t-values
Role Changes					
REDE	0.79	-			
REME	0.69	5.87**			
			Team Vision		
			STMPRP	0.91	-
			CLARITY	0.94	22.25**
			TRADEOFF	0.74	13.40**
			STFENV	0.73	13.20**
			Shared Knowledge		
			SKCUST	0.73	-
			SKCOMP	0.46	6.18**
			SKSUPPL	0.47	6.29*
			SKPROD	0.72	9.69**
			SKINTCP	0.62	8.32**
			Process Outcomes		
			TIMEMKT	0.63	-
			TEAMWK	0.99	11.19**
			DEVPROD	0.98	11.14**
			Manufacturing Outcomes		
			MANUFAC	0.77	-
			MFGCOST	0.62	6.22**
			Customer Outcomes		
			VALUCUST	0.98	-
			PRODPERF	0.84	18.01**
			Market Performance		
			MKTPERF	1.00	-

Note: **Significant at α <0,01 (Two-tailed test, df = ∞)
Based on three product development performances (See Figure 5.4.)

Table 5.4. Summary of LISREL Generated Data for Hypotheses Testing

Relationship	Standardized Coefficient	t-value	Significant?	Hypotheses Testing
Role Changes → Team Vision	0.39	4.21	Yes (α <0.01)	P1: Supported
Role Changes → Shared Knowledge	0.30	3.65	Yes (α <0.01)	P2: Supported
Role Changes → Process Outcomes → Manufacturing Outcomes → Customer Outcomes	0.01 0.13 -0.02	-0.06 -0.92 -0.17	No (α >0.10)	P3: Not Supported
Team Vision → Process Outcomes → Manufacturing Outcomes → Customer Outcomes	0.21 -0.30 0.10	1.29 -1.41 -0.65	No (α >0.10)	P4: Not Supported
Team Vision → Shared Knowledge (2)	0.73	9.22	Yes (α <0.01)	P5: Supported
Shared Knowledge → Process Outcomes → Manufacturing Outcomes → Customer Outcomes	0.53 0.49 0.27	2.55 1.64 1.29	Yes (α <0.01) No (α >0.10)	P6: Partially supported
Process Outcomes → Market Performance	0.14	2.06	Yes (α <0.05)	P7: Supported
Manufacturing Outcomes → Market Performance	-0.12	-1.40	No	P7: Not Supported
Customer Outcomes → Market Performance	0.74	8.86	Yes (α <0.01)	P7: Supported

Table 5.5. Decomposition of Effects (Standardized Coefficient and T-values)

Relationship	Total Effects	Direct Effect	Indirect Effect
Role Changes → Team Vision	0.39 (4.21)**	0.39 (4.21)**	-
→ Shared Knowledge	0.58 (5.14)**	0.30 (3.65)**	0.29 (4.09)**
→ Process Outcomes	0.39 (4.06)**	0.01(-0.06)	0.38 (3.75)**
→ Manufacturing Outcomes	0.39 (3.91)**	0.13 (-0.92)	0.26 (2.91)**
→ Customer Outcomes	0.58 (4.37)**	-0.02 (-0.17)	0.61 (4.29)**
→ Market Performance	0.14 (4.08)*	-	0.14 (4.08)*
Team Vision → Shared Knowledge	0.73 (9.22)*	0.73 (9.22)*	-
→ Process Outcomes	0.59 (7.04)**	0.21(1.29)	0.39 (2.52)**
→ Manufacturing Outcomes	0.26 (2.75)	-0.30 (-1.41)**	0.56 (2.77)**
→ Customer Outcomes	0.52 (7.44)	0.10 (-0.65)	0.42 (2.95)**
→ Market Performance	0.44 (7.27)	-	0.44 (7.27)
Shared Knowledge → Process Outcomes	0.53 (2.55)**	0.53 (2.55)**	-
→ Manufacturing Outcomes	0.67 (2.27)**	0.49 (1.64)*	0.18 (2.16)
→ Customer Outcomes	0.60 (2.71)	0.27 (1.29)	0.32 (2.63)
→ Market Performance	0.44 (2.60)	-	0.44 (2.60)
Process Outcomes → Market Performance	0.37(4.41)*	0.14 (2.06)*	0.22 (3.22)
Manufacturing Outcomes → Market Performance	0.09(0.94)	-0.11 (-1.36)	0.20 (2.55)*
Customer Outcomes → Market Performance	0.74(8.86)**	0.74 (8.86)**	-

A

Note: ** Significant at (α <0.01) * Significant at ((α <0.05)

The results with the three product development performance outcomes on market performance (Table 5.5.) show different patterns. The impacts of Customer Outcomes (i.e., Value To Customers and Product Performance) and Process Outcomes (i.e., Time To Market, Teamwork and Development Productivity) are substantial and statistically significant (t>4.41). Manufacturing Outcomes show negative values (both standardized coefficient and t-value). It appears that the higher the Manufacturing Outcomes (i.e., the higher either or both of Manufacturability and Manufacturing Cost), the less likely Market Performance is affected. This does not seem to make sense. However, fewer than 15% of respondents identified cost as the primary competitive factor for their products. Most of the respondents answered that the competitive battleground is in all fronts—cost, quality, innovativeness and timely delivery. It appears that the majority of firms feel that cost alone is not the primary competitive advantage. Rather, process outcomes (i.e., Time To Market, Teamwork and Development Productivity) and Customer Outcomes (Value To Customer and Product Performance) are critical factors for successful market performance.

In brief, both of the above structural models show that there are overall positive relationships between knowledge integration constructs (Role Changes, Team Vision and Shared Knowledge) and product performance outcomes and market performance. The empirical data supports most of the hypotheses made in chapter two. Therefore, the LISREL analysis according to this data affirms the theoretical assertion that IPD teams engaging in knowledge integration experience positive product development performance outcomes.

Chapter Six
Summary, Recommendations and Conclusion

6.1. SUMMARY

This section will be divided into two parts: (1) a brief summary of the contribution and value of this research; (2) a presentation of recommendations and implications for future research. Product development researchers argue that integration is a key for effective product development outcomes across industries (Clark and Fujimoto, 1991; Iansiti, 1995; Henderson and Clark, 1990; Henderson, 1992). They further propose that knowledge integration would yield desirable results in product development. The importance of knowledge as an organizational resource has been emphasized and increasingly the literature on this important area is rapidly accumulating. Many conceptual and case study papers have been published. As a recent example, shared knowledge is regarded as a resource underlying product development capability (Hoopes and Postrel , 1999). Still, empirical studies in the area of knowledge integration in IPD are rare. This research fills the gap and contributes to the understanding of knowledge integration in IPD in a number of ways.

First, a theoretical knowledge integration framework is provided that identifies Role Changes of Design and Manufacturing Engineers, Team Vision, Shared Knowledge, three Product Development Outcomes (Process, Manufacturing and Customer Outcomes) and Market Performance of Projects. According to Sobek (1998), "many companies have tried to look for a 'work-process-cookbook', a step-by-step method that, if properly executed, produces a high-quality product quickly and efficiently. But teams seeking to reengineer development processes are often frustrated because rearranging the steps does not necessarily offer much improvement." For effective IPD implementation, integration has to occur primarily at the conceptual level because product development is knowledge intensive work. The key to success is the implementation of ideas and the integration of knowledge that is imbedded in people, processes and products. Efforts to implement a few ideas or some scattered knowledge fail because the system is tightly integrated. Yet, much more has to be learned about effective knowledge integration mechanisms. The framework of this study forms a foundation for further research in knowledge integration by identifying some of the most important dimensions of knowledge integration. Use of these constructs allows researchers to formulate and test numerous hypotheses. Other constructs may be added or modified to further examine more detailed hypotheses.

Second, a major contribution of this research has been the development of a reliable instrument that supports future research in the areas of knowledge integration in integrated product development (i.e., Role Chances, Team Vision, Shared Knowledge, and Product Development Outcomes). Nineteen Variables (two for Role Changes, four for Team Vision, five for Shared Knowledge, three for Process Outcomes, four for Product Outcomes and one for Market Performance) have been developed to measure knowledge integration constructs and relationships between these constructs have been explored. This enables research in knowledge integration in IPD, which has been receiving increasing attention, but was in need of more empirical research.

Third, this study also provides valuable benchmarking tools for product development executives to assess the extent of their knowledge integration in multiple teams. The interest for this research is high among practitioners in product development. The responses to the presentation of the results of this research in Product Development Management Association (PDMA) and Project Managers Association (PMA) have been quite good. The Society of Automotive Engineers (SAE) is committed to publishing this study and will make this book available to the general public.

Fourth, this study provides a better understanding of what types of role changes among design and manufacturing engineers occur as the result of implementing IPD teams. Cross-functional teams are regarded as a positive factor for product development performances. Exactly who plays knowledge leadership roles in IPD teams has not been well explored. This study provides better understanding about the nature of role changes of design and manufacturing engineers in IPD, the interrelationships with team vision and shared knowledge, and their impact on product development performances. In order to examine the relationships, the items of role changes of design engineers and manufacturing engineers may need further investigation. The data seems to suggest a couple of interesting issues: (1) with the implementation of IPD, engineers seem to experience increasing workloads. With additional responsibilities, necessary training, and proper support, the reward systems may not currently be sufficient; (2) the patterns of responding to IPD implementation are somewhat different between design engineers and manufacturing engineers. Still, more work is needed to experience a mature level of cooperation and collaboration between design and manufacturing engineers; (3) behavioral characteristics are becoming important in IPD but many engineers feel unprepared for these challenges. Studies of role changes of engineers would also give a better understanding of how other functional experts cope with these changes related to knowledge integration mechanisms.

Fifth, this study provides supporting evidence of previously untested statements regarding knowledge integration constructs. A clear vision, sense of purpose, specific project targets and focus are all regarded as important factors for successful product development performance. The extent of shared knowledge among team members has been regarded as an important dimension for improving product development performances, but both of these assertions have not been tested in the IPD context. This study also shows the types of relationships between team vision and shared knowledge. Team vision effects product development performance through shared knowledge. The results of this study lend support to the hypothesis that the higher the shared knowledge, the more likely IPD performances would improve.

Finally, this research is an empirical research of IPD practices in four different industries. The data was drawn from 205 cross-functional product development teams and the focus of the research was the knowledge integration aspects of manufacturing firms. As of now (June, 2000), this researcher is not aware of any research in IPD which focuses on cross industries of manufacturing firms. This research adopted a sound methodology, which resulted in more precise measurement of underlying constructs of knowledge integration and examined their inter-relationships that affect the product development outcomes, including market performance.

6.2. RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendation 1: Improve and validate the scales using firms from the same referent population and other industries. Overall, all the eighteen scales show high reliabilities (Cronbach's $\alpha > 0.80$) across industries and regardless of the size of the firms, except the scales of Shared Knowledge of Products, Strategic Fit of Project Targets and Manufacturability. After improving these scales, this instrument may be revalidated in the same and other industries.

The research cycle for developing hypothesized instruments has two steps: (1) exploratory studies that develop hypothesized measurement models based on the analysis of empirical data from a referent population; and

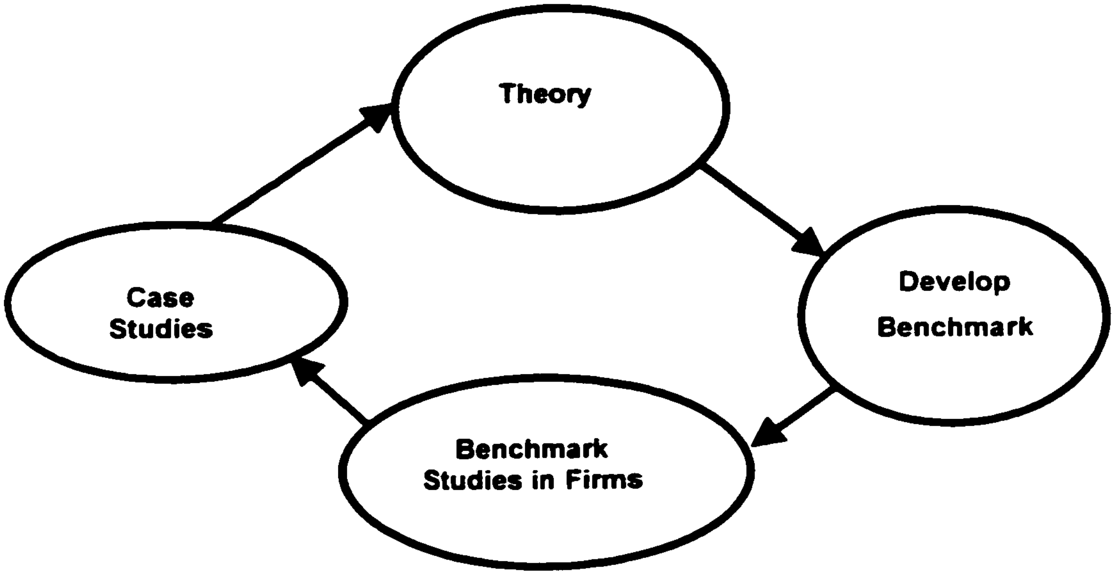
(2) confirmatory studies that test hypothesized measurement models against new data gathered from the same referent population. Confirmatory factor analysis is needed to provide a more rigorous and systematic test of alternative factor structures.

Recommendation 2: Engage in case studies to further probe the nature of Role Changes, Team Vision and Shared Knowledge from the referent population and other industries. The relationships depicted in Figure 2.3. in chapter two have been validated by LISREL. Consequently, we now have a better idea about interrelationships between Role Changes, Team Vision, and Shared Knowledge. Associations, which have been previously suggested by the literature (see chapter two) have been empirically tested and verified. It has been shown that on the project level, the extent of shared knowledge affects product development performance outcomes. While this is a significant contribution, more detailed information is needed to make these findings even more meaningful to the managers of integrated product development. To uncover the nature of knowledge integration, additional follow-up case studies might be beneficial.

Figure 6.1. shows our proposed IPD research cycle. The common approach of the product development research cycle is to engage in initial case studies, develop a theoretical framework afterward, and identify the best practices. The problem of this approach might be that there are no valid benchmarking tools to assess the best practices and provide timely feedback. Assessment is usually conducted when the project is already completed;

therefore, early intervention is not possible. Many firms engage in multiple projects and they have very limited means to compare and assess how each project is being done. Comparison of industry-wide performance is much more difficult.

Figure 6.1. AN IPD Research Cycle



A new approach of the IPD research cycle might be considered. Through initial interviews, and extensive literature review, the best practices of knowledge integration have been identified. As a result of this study, benchmarking measures in regard to various aspects of knowledge integration (i.e., Role Changes, Team Vision and Shared Knowledge) have been developed. These measures have a high level of reliability, discriminant validy, and predictive validity.

A future researcher may propose to do benchmark studies of firms, which apply the instruments (with some modifications) to assess and improve actual

IPD performances of participating firms. In-depth benchmark studies are helpful to test the usefulness of these benchmark tools and to assist these firms in improving their knowledge integration mechanisms. These benchmark and case studies further explore how IPD teams actually give timely feedback on continuous projects and make early intervention more effective in multiple team projects.

Recommendation 3: Engage in research on drivers (antecedents) of Role Changes, Team Vision and Shared Knowledge. What are the immediate process drivers of Team Vision and Shared Knowledge? According to this study, Role Changes and Team Vision affect Shared Knowledge. The organizational contexts that drive Shared Knowledge may also be further explored. In the course of exploring the drivers of Shared Knowledge, the future researcher would examine the relationships between knowledge exploration and exploitation. The respondents of this study's sample population are mostly manufacturing firms that are pressured to develop products in a timely manner. Very few firms seem to engage in basic research when the fruit of the research would come much later. According to the particular data collected, most innovation seems to occur when project development teams work on particular projects with a well-defined strategic focus and with disciplined problem solving mechanisms through sharing knowledge. But it deserves further studies of exploring exactly what internal and external factors affect the desirable level of Role Changes, Team Vision and Shared Knowledge in IPD.

Recommendation 4: Synthesize work and knowledge integration. One practical area of further inquiry is in regard to work and knowledge integration. IPD is knowledge intensive work. Shared knowledge helps team members understand and adapt to their environment and provides a common interpretive framework for their experiences (Gundry & Rousseau, 1994; Stohl, 1986) When IPD team members are conceptually connected, subsequent work integration might be easier to accomplish. In that sense, it is worth exploring the relationship between work integration and knowledge integration. For example, Koufteros (1996) developed instruments that measure the extent of work integration in product development. The instruments developed in this study and his instruments might be combined to assess the extent of both work and knowledge integration in IPD firms. Learning about the relationships between work integration and knowledge integration scales may be helpful to the quality of knowledge and work involved in IPD teams. For example, early supplier involvement is one work integration scale. Although firms may involve their suppliers in the early stages of their product development, it may not be clear what firms really know about suppliers and to what extent they actually utilize their knowledge of suppliers to improve their product development work.

Recommendation 5: Engage in organizational level research of knowledge integration. This study is project level research. The focus was on role changes of design and manufacturing engineers. On a project team level, one which has to carry out actual product development projects, the roles of engineers and their leadership may be quite critical. But on an organizational or program level, it might be somewhat different. How is knowledge integration on an organizational level different from that on a team or project level? How is organization-wide shared knowledge different from a team level of shared knowledge? More interesting studies will be possible as these questions are pursued.

Recommendation 6: Further test a more detailed level of the hypotheses, examine structural relationships, and adopt a longitudinal approach to study alleged structural relationships between Role Changes, Team Vision and Shared Knowledge. This study examined the general relationship between components of knowledge integration (i.e., Role Changes, Team Vision, and Shared Knowledge) and product development performance outcomes (i.e., Process, Manufacturing, Customer Outcomes and Market Performance). With a new data set, the more detailed relationships between each scale of knowledge components and product development performance outcomes may be further explored. For example, for products with a different level of knowledge intensity and competitive environments, how does Shared Knowledge of Products, Shared Knowledge of Customers, or Shared Knowledge of Internal Capabilities determine the project's innovativeness or the quality of products? To what extent do Role Changes of Design Engineers effect Manufacturability, Time to Market or Product Performance? Trying to find answers to more detailed questions will further refine the research content and provide contributions for product development executives.

Finally, the topics that have been covered in this study (Role Changes, Team Vision, Shared Knowledge, and Product Development Performances) contain a wide range of possibilities. In our knowledge economy, the roles of functional, professional experts change. These changes need to be dealt with in relation to the issues of knowledge integration. As businesses continue to tend to find new markets, new product development will remain as an essential and important aspect of business. Ultimately, people will do the work. The quality of their integrated, knowledge intensive work matters. If this study was useful for a better understanding of this important topic, it was worth the time and effort.

APPENDIX A: PILOT STUDY QUESTIONNAIRE

A Survey of Shared Knowledge In Integrated Product Development

New product development is a knowledge intensive process. Sharing knowledge is important for successful product development. This survey focuses on key shared knowledge practices.

The following questions ask to what extent members of your product development team have shared understanding of various knowledge components of product development (e.g., competitive realities, customers, internal capabilities, suppliers, and team vision).

This questionnaire should be answered by those who have recently managed cross-functional product development teams (e.g., product development managers, vice-presidents, CEO's).

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:

____

Market performance of this project was :	1	2	3	4	5
	Very Disappointing	Disappointing	Average	A Moderate Success	A Great Success

Please mail/fax this completed questionnaire to:

Paul Hong
The University of Toledo
College of Business Administration
Department of Information Systems and Operations Management
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I. Shared Knowledge of Functional Representatives on Customers, Competitors, and Suppliers.
The following statements describe what specific functional representatives know about customers, competitors and suppliers.
For each statement please circle the number which best describes your experience in the project you identified on the first page.
The 5 point scale is as follows:

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

Customers					
a. Our product design engineers had an adequate knowledge of the changing needs of customers.	1	2	3	4	5
b. Our process engineers had an adequate knowledge of how customers use our products.	1	2	3	4	5
c. Our manufacturing experts had an adequate knowledge of customer satisfaction ratings.	1	2	3	4	5
Competitors					
d. Our marketing people had an adequate knowledge of our competitors' technology.	1	2	3	4	5
e. Our product design engineers had an adequate knowledge of our competitors' strengths in marketing and distribution.	1	2	3	4	5
f. Our process engineers had an adequate knowledge of our competitors' products.	1	2	3	4	5
g. Our manufacturing people had an adequate knowledge of our competitive opportunities.	1	2	3	4	5
Suppliers					
h. Our product design engineers had an adequate knowledge of our suppliers' manufacturing capabilities.	1	2	3	4	5
i. Our marketing people had an adequate knowledge of our suppliers' design capabilities.	1	2	3	4	5
j. Our product design engineers had an adequate knowledge of our suppliers' capabilities to make component parts.	1	2	3	4	5
k. Our manufacturing people had an adequate knowledge of our suppliers' design capabilities.	1	2	3	4	5

2. Shared Knowledge of Functional Representatives on Products and Internal Capabilities.
The following statements describe what specific functional representatives know about products and internal capabilities.
For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

Products					
a. Our marketing people had an adequate knowledge of the major components of our product.	1	2	3	4	5
b. Our manufacturing people had an adequate knowledge of the product history.	1	2	3	4	5
c. Our design engineers accurately estimated the product cost.	1	2	3	4	5
Internal Capabilities					
d. Our product design engineers had an adequate knowledge of our firm's internal manufacturing capabilities.	1	2	3	4	5
e. Our marketing people had an adequate knowledge of our engineering design capabilities.	1	2	3	4	5
f. Our product design engineers had an adequate knowledge of our manufacturing capabilities.	1	2	3	4	5
g. Our manufacturing people had an adequate knowledge of our engineering design capabilities.	1	2	3	4	5

3. **Shared Knowledge of Overall Team on Customers, Suppliers, and Competitors.**
The following statements describe the level of the overall team knowledge about customers, competitors and suppliers.
For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

Customers

This product development team shared knowledge of :

a. How customer needs were changing.	1	2	3	4	5
b. Important customer value attributes.	1	2	3	4	5
c. How customers used our products.	1	2	3	4	5
d. How the product created customer value.	1	2	3	4	5
e. How satisfied our customers were with our products.	1	2	3	4	5
f. How well we were doing on customer satisfaction ratings.	1	2	3	4	5

Suppliers

This product development team shared knowledge of :

g. Our suppliers' process capabilities.	1	2	3	4	5
h. Our suppliers' design capabilities.	1	2	3	4	5
i. Our suppliers' manufacturing facilities.	1	2	3	4	5

Competitors

This product development team shared knowledge of :

j. Competitive opportunities that our firm anticipated.	1	2	3	4	5
k. Competitive threats that our firm faced.	1	2	3	4	5
l. Advantages of our competitors.	1	2	3	4	5
m. Disadvantages of our competitors.	1	2	3	4	5
n. Strengths of our competitors.	1	2	3	4	5
o. Weaknesses of our competitors.	1	2	3	4	5
p. Competitors' products.	1	2	3	4	5
q. Competitors' product technologies.	1	2	3	4	5

4. Shared Knowledge of Overall Team on Products and Internal Capabilities.
The following statements describe the level of the overall team knowledge about products and internal capabilities.
For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

Products

This product development team shared knowledge of :

a. Our product's history.	1	2	3	4	5
b. The strengths of our product.	1	2	3	4	5
c. The weaknesses of our product.	1	2	3	4	5
d. The advantages of our product.	1	2	3	4	5
e. The disadvantages of our product.	1	2	3	4	5
f. The design problems of our product.	1	2	3	4	5
g. The product technologies we used.	1	2	3	4	5

Internal Capabilities

This product development team shared knowledge of :

h. The capabilities of the process technologies we used.	1	2	3	4	5
i. The strengths of our engineering design capabilities.	1	2	3	4	5
j. The weaknesses of our manufacturing facilities.	1	2	3	4	5
k. The strengths of our engineering design capabilities.	1	2	3	4	5
l. The weaknesses of our manufacturing facilities.	1	2	3	4	5

5. **Team Vision**

The following statements describe the team's Mission, Strategic Fit and Project Targets. For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

Mission					
a. This product development team had a good work plan.	1	2	3	4	5
b. This product development team had a well-focused mission.	1	2	3	4	5
c. This product development team had a well-communicated mission.	1	2	3	4	5
d. This product development team had a clear product concept.	1	2	3	4	5
e. This product development team had a clear plan of action.	1	2	3	4	5
f. Overall, this product development team had a shared understanding of the project mission.	1	2	3	4	5
Strategic Fit					
g. Our firm's overall product strategy guided the design of this product.	1	2	3	4	5
h. Our firm's overall technology strategy guided the design of this product.	1	2	3	4	5
i. Project targets were consistent with our firm's business strategy.	1	2	3	4	5
j. Project priorities were consistent with our firm's business strategy.	1	2	3	4	5
k. Our senior management provided overall strategic direction.	1	2	3	4	5
l. Our senior management provided an integrated set of project priorities.	1	2	3	4	5
m. Overall, this product development team had a shared understanding of how well this project fit within the firm's business strategy.	1	2	3	4	5
Project Targets					
n. Our project targets were clear.	1	2	3	4	5
o. Our project targets were based on realistic customer requirements.	1	2	3	4	5
p. Our project targets reflected the competitive situation.	1	2	3	4	5
q. Our project targets were consistent with our manufacturing capabilities.	1	2	3	4	5
r. Our project targets were consistent with our suppliers' capabilities.	1	2	3	4	5
s. Our project targets were consistent with our resources.	1	2	3	4	5
t. Technical risks were considered in setting project targets.	1	2	3	4	5
u. The relative priority of each project target was clear.	1	2	3	4	5
v. Tradeoffs (e.g., time vs cost) were considered to determine priorities.	1	2	3	4	5
w. A single integrated set of targets (objectives) was defined.	1	2	3	4	5
x. Overall, this product development team had a shared	1	2	3	4	5
understanding of the project targets.	1	2	3	4	5

6. Process Outcomes

For each statement please circle the number which best describes the project you identified on the first page.

The 5 point scale is as follows:

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

<u>Time to Market</u>					
This product development team :					
a. Introduced products to market ahead of competitors.	1	2	3	4	5
b. Developed products on schedule.	1	2	3	4	5
c. Met its deadline for market introduction.	1	2	3	4	5
d. Reduced the product development time.	1	2	3	4	5
e. Met the target date for our project.	1	2	3	4	5
<u>Teamwork</u>					
This product development team :					
f. Resolved conflicts quickly.	1	2	3	4	5
g. Implemented decisions effectively.	1	2	3	4	5
h. Solved problems creatively.	1	2	3	4	5
i. Communicated effectively.	1	2	3	4	5
j. Coordinated activities well.	1	2	3	4	5
k. Worked well together.	1	2	3	4	5
l. Resolved conflicts constructively.	1	2	3	4	5
m. Identified manufacturing problems early.	1	2	3	4	5
n. Identified design-manufacturing problems early.	1	2	3	4	5
<u>Development Productivity</u>					
This product development team :					
o. Was productive.	1	2	3	4	5
p. Used product engineering hours effectively.	1	2	3	4	5
q. Allocated personnel realistically.	1	2	3	4	5
r. Used financial resources sensibly.	1	2	3	4	5
s. Used all product development resources rationally.	1	2	3	4	5

7. Product Outcomes

For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

Manufacturability					
a. This product's design was simplified.	1	2	3	4	5
b. The number of parts was reduced.	1	2	3	4	5
c. This product is easy to assemble.	1	2	3	4	5
d. Manufacturing problems were minimized.	1	2	3	4	5
Value-to-Customer					
e. This product had a high quality.	1	2	3	4	5
f. This product was successful in the marketplace.	1	2	3	4	5
g. Customers highly valued this product.	1	2	3	4	5
h. This product created a high customer value.	1	2	3	4	5
i. This product exceeded customer expectations.	1	2	3	4	5
Product Performance					
j. The overall performance of this product was excellent.	1	2	3	4	5
k. The technical performance of this product was excellent.	1	2	3	4	5
l. The components worked well together.	1	2	3	4	5
m. The system performance of this product was excellent.	1	2	3	4	5
Manufacturing Cost					
n. The material cost of this product is considerably lower than the industry average.	1	2	3	4	5
o. The labor cost of this product is considerably lower than the industry average.	1	2	3	4	5
p. The overhead cost of this product is considerably lower than the industry average.	1	2	3	4	5
q. The overall manufacturing cost of this product is quite competitive in the market.	1	2	3	4	5

8. Role Changes

Cross-functional product development often creates changes in job responsibilities, nature of work, and work relationships. For each statement please circle the number which best describes your perception about changes that have taken place in your firm over the past 3 years.

The 5 point scale is as follows:

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

a.	Qualifications required for design engineers have been upgraded.	1	2	3	4	5
b.	Training required for design engineers has been more extensive.	1	2	3	4	5
c.	Power of design engineers in the product development team has increased	1	2	3	4	5
d.	Influence of design engineers in the product development team has increased.	1	2	3	4	5
e.	Technical skills required for design engineers have been more rigorous.	1	2	3	4	5
f.	Behavioral skills (e.g., team work, inter-communication) required for design engineers have been more important.	1	2	3	4	5
g.	Design engineers' jobs have become more complex.	1	2	3	4	5
h.	Design engineers' jobs have been enlarged.	1	2	3	4	5
i.	Design engineers' jobs have been enriched.	1	2	3	4	5
j.	Overall, design engineers feel more satisfied with their work.	1	2	3	4	5
k.	Qualifications required for manufacturing engineers have been upgraded.	1	2	3	4	5
l.	Training required for manufacturing engineers has been more extensive.	1	2	3	4	5
m.	Power of manufacturing engineers in the product development team has increased.	1	2	3	4	5
n.	Influence of manufacturing engineers in the product development team has increased.	1	2	3	4	5
o.	Technical skills required for manufacturing engineers have become more rigorous.	1	2	3	4	5
p.	Behavioral skills (e.g., team work, inter-communication) required for manufacturing engineers have been more important.	1	2	3	4	5
q.	Manufacturing engineers' jobs have become more complex.	1	2	3	4	5
r.	Manufacturing engineers' jobs have been enlarged.	1	2	3	4	5
s.	Manufacturing engineers' jobs have been enriched.	1	2	3	4	5
t.	Overall, design engineers feel more satisfied with their work.	1	2	3	4	5

Thank you for your assistance in this project. Please give us the following information for statistical purposse.

1. **Your Title:** _____ CEO/President _____ Vice-President
_____ Director _____ Senior Manager
_____ Other: (please indicate)______________________________

2. **SIC Code** _____ 34 Fabricated Metal Products
_____ 35 Industrial & Commercial Machinery
_____ 36 Electronic, Electrical Equipment and Machinery
_____ 37 Transportation Equipment and Miscellaneous

3. **Number of Employees** _____ up to 499 _____ 500 to 999
_____ 1,000 to 4,999 _____ 5,000 to 9,999
_____ Over 10,000

4. **How would your firm be classified within the automotive industry structure?**
_______ OEMs (e.g., Chrysler, GM, Ford)
_______ First Tier Supplier owned by an OEM
_______ Independent First Tier Supplier
_______ Second Tier Supplier
_______ Third Tier Supplier
_______ Other: (please describe): ______________________________

5. **Knowledge intensity of your product development process is:**
1__________2__________3__________4__________5
very low — low — moderate — high — very high

6. **Your firm's product complexity is:**
1__________2__________3__________4__________5
very low — low — moderate — high — very high

7. **Your firm's process complexity is:**
1__________2__________3__________4__________5
very low — low — moderate — high — very high

8. **The rate of technology change that your firm currently experiences is:**
1__________2__________3__________4__________5
very slow — slow — moderate — rapid — very rapid

9. **The intensity of competition that your firm currently experiences is:**
1__________2__________3__________4__________5
very low — low — moderate — high — very high

10. **The nature of competitive environment is:**
________ Primarily on low cost
________ Primarily on innovativeness
________ Primarily on timely delivery of quality products
________ All of the above

APPENDIX B: LARGE SURVEY QUESTIONNAIRE

A Survey of Shared Knowledge In Integrated Product Development

New product development is a knowledge intensive process. Sharing knowledge is important for successful product development. This survey focuses on key shared knowledge practices.

The following questions ask to what extent members of your product development team have shared understanding of various knowledge components of product development (e.g., competitive realities, customers, internal capabilities, suppliers and team vision).

This questionnaire should be answered by those who have recently managed a cross-functional product development team (e.g., product development managers, vice-presidents, CEO's).

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: ____________________

Market performance of this project was :	1	2	3	4	5
	Very Disappointing	Somewhat Disappointing	Average	A Moderate Success	A Great Success

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A. The following statements describe the level of the overall team Shared Knowledge about *Customers, Competitors, Suppliers, Products,* and *Internal Capabilities.* They are randomly grouped together. For each statement please circle the number which best describes your experience in the project you identified on the first page. 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. How customer needs were changing.	1	2	3	4	5
b. Competitive threats that our firm faced.	1	2	3	4	5
c. Our suppliers' manufacturing facilities.	1	2	3	4	5
d. Customer requirements.	1	2	3	4	5
e. The advantages of our product.	1	2	3	4	5
f. The capabilities of our engineering staff.	1	2	3	4	5
g. Our suppliers' process capabilities.	1	2	3	4	5
h. How well we were doing on customer satisfaction ratings.	1	2	3	4	5
i. The strengths of our engineering design capabilities.	1	2	3	4	5
j. How customers make purchase decisions.	1	2	3	4	5
k. Our suppliers' capabilities to meet cost targets.	1	2	3	4	5
2. This product development team shared knowledge of :					
a. Advantages of our competitors.	1	2	3	4	5
b. The disadvantages of our product.	1	2	3	4	5
c. Our suppliers' design capabilities.	1	2	3	4	5
d. Which features were most valued by target customers.	1	2	3	4	5
e. The weaknesses of our manufacturing facilities.	1	2	3	4	5
f. Disadvantages of our competitors.	1	2	3	4	5
g. Which customer groups we were targeting.	1	2	3	4	5
h. The product technologies we used.	1	2	3	4	5
i. The capabilities of our manufacturing staff.	1	2	3	4	5
j. Our suppliers' capabilities to meet time requirements.	1	2	3	4	5
k. Current customer needs.	1	2	3	4	5
l. Strengths of our competitors.	1	2	3	4	5
3. This product development team shared knowledge of :					
a. Our suppliers' capabilities to meet quality requirements.	1	2	3	4	5
b Competitors' product technologies.	1	2	3	4	5
c. Our manufacturing capabilities.	1	2	3	4	5
d. What our customers want.	1	2	3	4	5
e. The strengths of our manufacturing facilities.	1	2	3	4	5
f. Our product's history.	1	2	3	4	5
g. Strengths of our products.	1	2	3	4	5
h. The capabilities of the process technologies we used.	1	2	3	4	5
i. Our suppliers' capabilities to respond to volume and mix changes.	1	2	3	4	5
j. Our target customers.	1	2	3	4	5
k Competitors' products.	1	2	3	4	5
l. Weaknesses of our competitors.	1	2	3	4	5

B. The following statements describe Mission which consists of *Shared Team Purpose, Strategic Fit of Project Targets*, and *Clarity of Project Targets*. They are randomly grouped together. For each statement please circle the number which best describes your experience in the project you identified on the first page.

The 5 point scale is as follows:

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

a. The project purpose was well understood by the entire team.	1 2 3 4 5
b. Project targets clearly specified tradeoffs between performance and cost.	1 2 3 4 5
c. The project mission was well communicated to all team members.	1 2 3 4 5
d. Our firm's overall technology strategy guided the setting of project targets.	1 2 3 4 5
e. A clear set of project targets guided development efforts.	1 2 3 4 5
f. Project targets were consistent with our supplier's capabilities.	1 2 3 4 5
g. Project targets were clearly understood by all team members.	1 2 3 4 5
h. The project goals were well understood by the entire team.	1 2 3 4 5
i. An integrated set of project targets was clearly defined.	1 2 3 4 5
j. Project targets were consistent with our firm's overall business strategy.	1 2 3 4 5
k. Project targets were clearly communicated to all team members.	1 2 3 4 5
l. Technical risks were considered in setting project targets.	1 2 3 4 5
m. The project mission was well defined for all team members.	1 2 3 4 5
n. Project targets were clear.	1 2 3 4 5
o. Project targets were based on customer requirements.	1 2 3 4 5
p. This product development team had a well defined mission.	1 2 3 4 5
q. Project targets reflected the competitive situation.	1 2 3 4 5
r. The relative priority of each project target was clear.	1 2 3 4 5
s. Project targets were consistent with our manufacturing capabilities.	1 2 3 4 5
t. Project targets clearly specified tradeoffs between time and cost.	1 2 3 4 5
u. The project work plan was well understood by the entire team.	1 2 3 4 5
v. Project targets clearly specified tradeoffs between quality and cost.	1 2 3 4 5
w. The product concept was well understood by the entire team.	1 2 3 4 5
x. Project targets clearly defined customer requirements.	1 2 3 4 5
y. Our firm's overall product strategy guided the setting of project targets.	1 2 3 4 5
z. The project mission was well understood by the entire team.	1 2 3 4 5

C. **The following statements describe Process Outcomes (*i.e., Time to Market, Teamwork, Development Productivity*) and Product Outcomes (*i.e., Manufacturability, Value to Customer, Product Performance, and Manufacturing Cost*) of Shared Knowledge. They are randomly grouped together.**
For each statement please circle the number which best describes the project you identified on the first page.

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. Allocated personnel realistically.	1	2	3	4	5
b. Met its deadline for market introduction.	1	2	3	4	5
c. Worked well together.	1	2	3	4	5
d. Was productive.	1	2	3	4	5
E Developed products on schedule.	1	2	3	4	5
f. Resolved conflicts quickly.	1	2	3	4	5
g. Used financial resources sensibly.	1	2	3	4	5
h. Coordinated activities well.	1	2	3	4	5
i. Reduced the product development time.	1	2	3	4	5
j. Used all product development resources rationally.	1	2	3	4	5
k. Met the target date for our project.	1	2	3	4	5
l. Used product engineering hours efficiently.	1	2	3	4	5
m. Implemented decisions effectively.	1	2	3	4	5
n. Communicated clearly.	1	2	3	4	5

2. Product Outcomes					
a. This product had a high quality.	1	2	3	4	5
b. The manufacturing processes were simplified.	1	2	3	4	5
c. This product exceeded customer expectations.	1	2	3	4	5
d. The components worked well together.	1	2	3	4	5
e. The material cost of this product is considerably lower than the industry average.	1	2	3	4	5
f. Manufacturing problems were minimized.	1	2	3	4	5
g. The overhead cost of this product is considerably lower than the	1	2	3	4	5
industry average.	1	2	3	4	5
h. The system performance of this product was excellent.	1	2	3	4	5
i. The labor cost of this product is considerably lower than the industry average.	1	2	3	4	5
j. The number of parts was reduced.	1	2	3	4	5
k. This product created a high customer value.	1	2	3	4	5
l. The technical performance of this product was excellent.	1	2	3	4	5
m. This product was successful in the marketplace.	1	2	3	4	5
n. The product is easy to assemble.	1	2	3	4	5
o. The overall manufacturing cost of this product is lower than the industry average.	1	2	3	4	5
p. Customers highly valued this product.	1	2	3	4	5
q. The overall performance of this product was excellent.	1	2	3	4	5

D. Role Changes

Cross-functional product development often creates changes in job responsibilities, nature of work and work relationships. For each statement, please circle the number which best describes your perception about changes that have taken place in your firm over the past 3 years.

The 5 point scale is as follows:

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

a.	Qualifications required for design engineers have been upgraded.	1	2	3	4	5
b.	Training required for design engineers has been more extensive.	1	2	3	4	5
c.	Power of design engineers in product development team has increased.	1	2	3	4	5
d.	Influence of design engineers in product development team has	1	2	3	4	5
	increased.	1	2	3	4	5
e.	Technical skills required for design engineers have been more rigorous.	1	2	3	4	5
f.	Behavioral skills (e.g.. team work. inter-communication) required for design engineers have been more important.	1	2	3	4	5
g.	Design engineers' jobs have become more complex.	1	2	3	4	5
h.	Design engineers' jobs have been enlarged.	1	2	3	4	5
i.	Design engineers' jobs have been enriched	1	2	3	4	5
j.	Overall. design engineers feel more satisfied with their work.					
k.	Qualifications required for manufacturing engineers have been	1	2	3	4	5
	upgraded.	1	2	3	4	5
l.	Training required for manufacturing engineers has been more extensive.	1	2	3	4	5
m.	Power of manufacturing engineers in product development team has increased.	1	2	3	4	5
n.	Influence of manufacturing engineers in product development team has increased.	1	2	3	4	5
o.	Technical skills required for manufacturing engineers have become more rigorous.	1	2	3	4	5
p.	Behavioral skills (e.g.. team work. inter-communication) required for manufacturing engineers have been more important.	1	2	3	4	5
q.	Manufacturing engineers' jobs have become more complex.	1	2	3	4	5
r.	Manufacturing engineers' jobs have been enlarged.	1	2	3	4	5
s.	Manufacturing engineers' jobs have been enriched	1	2	3	4	5
t.	Overall. design engineers feel more satisfied with their work.					

This section is for statistical purpose. For items 1 through 8 and 14, please check the appropriate response. For items 9 through 13, please circle the appropriate response.

1. Your title : a_____ CEO/President b _____ Director /Senior Manager of Product Development
   c_____ Project Manager d ______Other: (please indicate)______________________

2. Do you work in the area of engineering? a _____ Yes b ______ No

3. If yes, what is your primary area?
   a.___Design Engineering b___Manufacturing Engineering c. ___Other: (please indicate___________

4. How desirable would it be to further enlarge the design engineer's job at your firm?

a______	b______	c________	d_________	e ________
very undesirable	somewhat undesirable	neutral	somewhat desirable	very desirable

5. How desirable would it be to further enlarge the manufacturing engineer's job at your firm?

a ______	b______	c________	d_________	e ________
very undesirable	somewhat undesirable	neutral	somewhat desirable	very desirable

6. **SIC Code**
   a _____ Fabricated Metal Products (34)
   b _____ Industrial & Commercial Machinery (35)
   c _____ Electronic, Electrical Equipment and Machinery (36)
   d _____ Transportation Equipment and Miscellaneous (37)

7. **Number of Employees**
   a _____ up to 499 b ______ 500 - 999
   c _____ 1,000 to 4,999 d ______ 5,000-9,999
   e_____ Over 10,000

8. **How would your firm be classified within the automotive industry structure?**
   a_______OEMs (e.g., Chrysler, GM, Ford) b ______First Tier Supplier owned by an OEM
   c_______ Independent First Tier Supplier d ______ Second Tier Supplier
   e_______Third Tier Supplier f ______ other: (please describe)_____________

9. **Your firm's product complexity is:**

a____________	b_____________	c________________	d________________	e
very low	low	moderate	high	very high

10. **Knowledge intensity of your product development process is:**

a____________	b_____________	c________________	d________________	e
very low	low	moderate	high	very high

11 **Your firm's process complexity is:**

a____________	b_____________	c________________	d________________	e
very low	low	moderate	high	very high

12. **The rate of technology change that your firm currently experiences is:**

a____________	b_____________	c________________	d________________	e
very slow	slow	moderate	rapid	very rapid

13. **The intensity of competition that your firm currently experiences is:**

a____________	b_____________	c________________	d________________	e
very low	low	moderate	high	very high

14. **The nature of competitive environment is:**
   a ___Primarily on low cost b____Primarily on innovativeness
   c ___Primarily on timely delivery of quality products d ___All of the above

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