

# Sharing Knowledge in Integrated Product Development

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## ABSTRACT:

Although product development is recognized as knowledge intensive work, we have a limited understanding of its impact on product development process performance. The mechanisms by which knowledge sharing contributes to strategic imperatives such as time-to-market and value to customers is not well understood. Despite increased interest in knowledge sharing in cross-functional teams, there have been few large-scale empirical studies of its efficacy. This paper develops a model that explains how shared knowledge enhances process performance as well as downstream strategic imperatives. In this paper shared knowledge is identified as three types: shared knowledge of customers, shared knowledge of suppliers, and shared knowledge of internal capabilities. This model is tested using a sample of 205 product development projects.

Key Word: Innovation; Knowledge Sharing; Integrated Product Development

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## 1. INTRODUCTION

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

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

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

Hoopes and Postrel (1999) propose that this correlation results from integration leading to patterns of shared knowledge among firm members, with the shared knowledge constituting a resource underlying product development efforts of a scientific software company. They aim primarily at measuring the importance of the relationship between shared knowledge and performance and focus on project failures and a lack of shared knowledge. Their study confirms that shared knowledge is an important resource underlying product development capabilities. They define the 'glitches' as a costly error resulting from knowledge not being shared, and measure the influence of glitches on firm performance. They also identify a set of 'syndromes' that can lead to glitches, and measure the relative importance of these syndromes. The glitch concept may offer a general tool for practical measurement of the marginal benefits of shared knowledge.

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

Shared knowledge is one of the unique, valuable and critical resources that is central to having a competitive advantage (Nonaka and Takeuchi, 1994, 1995; Prahalad and Hamel, 1990). Firms increasingly rely on building and creating a shared knowledge base as an important resource capability (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 regarded as a synergy between team members (Bostrom, 1989; Hoopes and Postrel, 1999).

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

Figure 1 shows the causal relationships of how shared knowledge (of customers, of internal capabilities and of suppliers) affect product development design processes and as a consequence impact product development performances. Each construct and hypotheses will be further discussed in the subsequent section. All the items of each construct are aggregated to test the nature of relationships.

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## **2. Shared knowledge**

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

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

Knowledge sharing attracts much attention in recent years. There is no doubt that knowledge sharing plays an important role for sustainable advantages. Firms increasingly rely on building and creating a shared knowledge of individuals in order to solve problems and find innovative solutions (Davenport, Jarvenpaa and Beers, 1996; Drucker, 1991; Kogut and Zander, 1992; Winter, 1987). Dyer and Nobeoka (2000) explored the 'black box' of knowledge sharing within Toyota's network and demonstrate that "Toyota's ability to effectively create and management network-level knowledge sharing processes at least partially explains the relative productivity advantages enjoyed by Toyota and its suppliers." Nonaka and Takeuchi (1995) explored the importance of shared knowledge for the success of a firm's product development efforts. In that sense, shared knowledge is central to enhancing a firm's competitive advantage.

However, studies of shared knowledge are limited in a particular industry: information systems (Nelson and Coopriider, 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.

## **2.1. Shared knowledge of customer**

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

## **2.2. Shared Knowledge of Suppliers**

Shared knowledge of suppliers refers to the extent of the shared understanding (i.e., know-why) of suppliers' design, process, and manufacturing capabilities among product development team members (Maas, 1988; Hahn, et al., 1990; Slade, 1993). Since suppliers are actively involved in key processes of IPD, the knowledge of suppliers' capabilities is critical for timely and cost-effective decision making in IPD (Evans and Lindsay, 1996). Shared knowledge of



suppliers allows product development members to improve their product processes (e.g., communication and collaboration among design and manufacturing engineers) and enhance customer values (e.g., fairly assessing costs of raw materials of the product supplied by the suppliers) because a substantial portion or part of their final product depends on suppliers' work.

### **2.3. Shared Knowledge of Internal Capabilities**

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

### **3. Product development Performance Outcomes**

Product development has evolved from sequential, functional specific product development to concurrent, cross-functional 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).

Loch, Stein, Terwiesch (1996) defined the product development performance as “measures the quality of development performance.” Product 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. In this study, these IPD performance measures are classified into two components: (1) process outcomes look at the effectiveness of the IPD process in terms of teamwork and productivity; (2) product outcomes concern the characteristics associated with how the products are delivered in terms of value to customer and time to market. Process outcomes measure the efficiency of the product development process itself. The efficiency of the IPD process is measured in terms of teamwork, developmental productivity and finally time to market. In this study, time to market (i.e., product development cycle time) is regarded as one of product outcomes because it measures the critical aspect of product development performance.

### **3.1. 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 customers' requirements can unite team members for their common interest. 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.

### **3.2. Developmental Productivity**

Developmental productivity refers to effectiveness of developing new products from product concept to manufacturing. Developmental 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). Developmental 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).

The development productivity was measured with four items. The respondents were asked to indicate, "Was productive", "Used financial resources sensibly", "Used all product development resources rationally", and "Used product engineering hours efficiently". A five-point Likert-type scale ranging from "Strongly disagree" (1) to "Strongly agree" (5) was used to measure the four items.

Teamwork and developmental productivity are regarded as process outcomes in that they reflect product development process characteristics rather than the product itself.

### **3.3. 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), develop products on schedule (Cohen, 1996; Zirger, 1996) and keep improving on the previous time to market (Mabert, et al., 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, et al., 1995; Ali, et al., 1995).

### **3.4. 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 commonalities in what customers value (Kim and Mauborgne, 1997). Value to customers is enhanced through shared knowledge of customers (Koen and Kohli, 1998).

Table 1 contains a definition of the constructs discussed above and the literature base.

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#### **4. A CONCEPTUAL MODEL**

In this section, the rationale underlying the proposed relationships is depicted. Figure 1 shows the causal relationships of how shared knowledge (shared knowledge of customers, shared knowledge of suppliers and shared knowledge of internal capabilities) affect product development process performance (mainly measured by teamwork) and the relationship of how process performance influence the downstream strategic imperatives such as time to market. Four hypotheses will be discussed in the subsequent section.

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## **5.1. HYPOTHESES**

A key to product development success is how much other product development 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 capability of meeting changing customer needs, 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).

**Hypothesis 1:** The greater the extent of shared knowledge of customers, the greater the extent of teamwork and development productivity.

Since suppliers are actively involved in key processes of IPD, shared knowledge of suppliers allows product development team members to improve product development process performance (e.g. its technical and overall performance). 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.

**Hypothesis 2:** The greater the extent of shared knowledge of suppliers, the greater the extent of teamwork and development productivity.

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 decision 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 affect 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.



Shared knowledge of internal capabilities refers to as the extent of a shared understanding (i.e., know-why) of the firm's internal design, process and manufacturing capabilities among product development members (Clark and Wheelwright, 1993; 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, market managers) are aware of the strengths and weakness of various aspects of design capabilities and manufacturing process. Shared knowledge of internal capabilities might affect almost all process performance.

**Hypothesis 3:** The greater the extent of shared knowledge of internal capabilities, the greater the extent of teamwork and development productivity.

The degree of teamwork among product development teams can resolve conflicts and complex issues quickly and constructively. In that sense, the quality of teamwork will positively affect to reduce the time to market. In many cases, the poor teamwork is the delaying factor for time to market. Effective decision-making is critical for speeding up the product development process.

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).

**Hypothesis 4:** The greater the extent of teamwork and development productivity, the greater the extent of time-to-market.

Stalk and Webber (1993) argue that firms often pursue speed without considering how faster product development or increased product turnover contribute to the fulfillment of their customer requirements. The high degree of teamwork among product development teams helps to consider another important strategic imperative (i.e., value to customer) in that marketing or quality manager consistently insist the value to customer as an important product development outcome. Development productivity does not merely concerns time element or financial elements. Rather, it considers the development efficiency in view of the ultimate value of the product to the customers (i.e., the important customer value requirements).

**Hypothesis 5:** The greater the extent of teamwork and development productivity, the greater the extent of value to customer.

## **6. Test of Hypotheses**

The test of hypotheses was conducted based on the reliable and valid instruments developed. Because of space limitation, only the final results are presented here omitting all the details of the research design and data analyses.

The first hypothesis predicted that shared knowledge of customers would be directly related to process performance outcomes. As seen in Fig. 2, the maximum-likelihood estimate for the path from shared knowledge of customers to process performance was significant and positive (standardized coefficient = 0.48 and  $t = 5.71$ ). This indicates that project teams working with high level of shared knowledge of customers were significantly higher of the process performance outcomes than those team with low level of shared knowledge of customers.

The second hypothesis predicted that shared knowledge of suppliers would be directly related to process performance outcomes. As seen in Fig. 2, the maximum-likelihood estimate for the path from shared knowledge of suppliers to process performance was significant and positive (standardized coefficient = 0.17 and  $t = 2.50$ ). This indicates that project teams working with high level of shared knowledge of suppliers were significantly higher of the process performance outcomes than those team with low level of shared knowledge of suppliers.

The third hypothesis predicted that shared knowledge of internal capabilities would be directly related to process performance outcomes. As seen in Fig. 2, the maximum-likelihood estimate for the path from shared knowledge of internal capabilities to process performance was significant and positive (standardized coefficient = 0.32 and  $t = 3.79$ ). This indicates that project teams working with

high level of shared knowledge of internal capabilities were significantly higher of the process performance outcomes than those team with low level of shared knowledge of internal capabilities.

The fourth hypothesis stated that the extent of process performance outcomes would shorten time-to-market of the new products developed. The results, Fig. 2, demonstrate support for the hypothesis 2 (standardized coefficient = 0.69 and  $t = 10.45$ ). The amount of time spent on product development was shorter when the extent of process performance outcomes increased.

The fifth hypothesis suggested that the extent of process performance outcomes would increase the extent of Value to Customer. The results, Fig. 2, demonstrate support for the hypothesis (standardized coefficient = 0.80 and  $t = 9.01$ ).

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## **7. Implications/ Conclusion**

The purpose of this study was to develop and test a model of team-level constructs likely to explain how the shared knowledge of customers, suppliers, and internal capabilities are related to the overall product development performances. This research fills the gap and contributes to the understanding of the role of the shared knowledge in IPD in a number of ways.

First, a major contribution of this research has been the development of a reliable instrument to measure the degree of shared knowledge in new product development arena, which can be used to support future research. Increasingly, knowledge generation or knowledge management is regarded as a prerequisite for the successful, innovative organization (Shadbolt and Milton, 1999; Cardinal and Hatfield, 2000; Grover and Davenport, 2001;). This finding encourages the management researchers to apply the theory of knowledge management into applied fields such as new product development, e-commerce, or marketing. Therefore, the knowledge sharing should receive greater research attention from scholars in the areas of new product development.

Second, as hypothesized, three components of shared knowledge (i.e., shared knowledge of customers, shared knowledge of suppliers, and shared knowledge of international capabilities) were positively related to process performances of new product development. The impact of knowledge sharing has been discussed in other contexts such as for IS group performance (Nelson and Coopride, 1996), IS outsourcing success (Lee, 2001), and building product development capability (Hoopes and Postrel, 1999). This study shows how specific knowledge sharing components enhances the new product development processes (i.e., teamwork and development productivity) and strategic outcomes (i.e., time to market and value to customer). This research argues that when project teams operate in an environment that encourages shared knowledge of customers,

suppliers and internal capabilities, the process performance (teamwork and development productivity) mediates the impact of knowledge sharing on the strategic imperatives of time-to-market and value to customer. The research findings suggest that knowledge sharing should be adequately shared among team members in guiding product and process design efforts. For achieving process goals, the research findings help managers to focus on how to improve teamwork and development productivity through active knowledge sharing among team members.

Third, if time-to-market and value-to-customer are strategic imperatives, knowledge sharing is a key driver. Knowledge sharing may also be a key driver for other strategic imperatives such as manufacturability. The extent of knowledge sharing for any strategic imperative provides overall competitiveness for project managers. Improving overall product development may require strategic thinking on how critical components of knowledge should be shared among cross-functional team members.

Finally, for effective IPD implementation, integration has to occur primarily at the conceptual level because product development is knowledge intensive work. The results of this study lend support to the five hypotheses. This study provides better understanding of the underlying constructs of shared knowledge in integrated product development, and provides supporting evidence for the previously untested statements regarding knowledge integration constructs.

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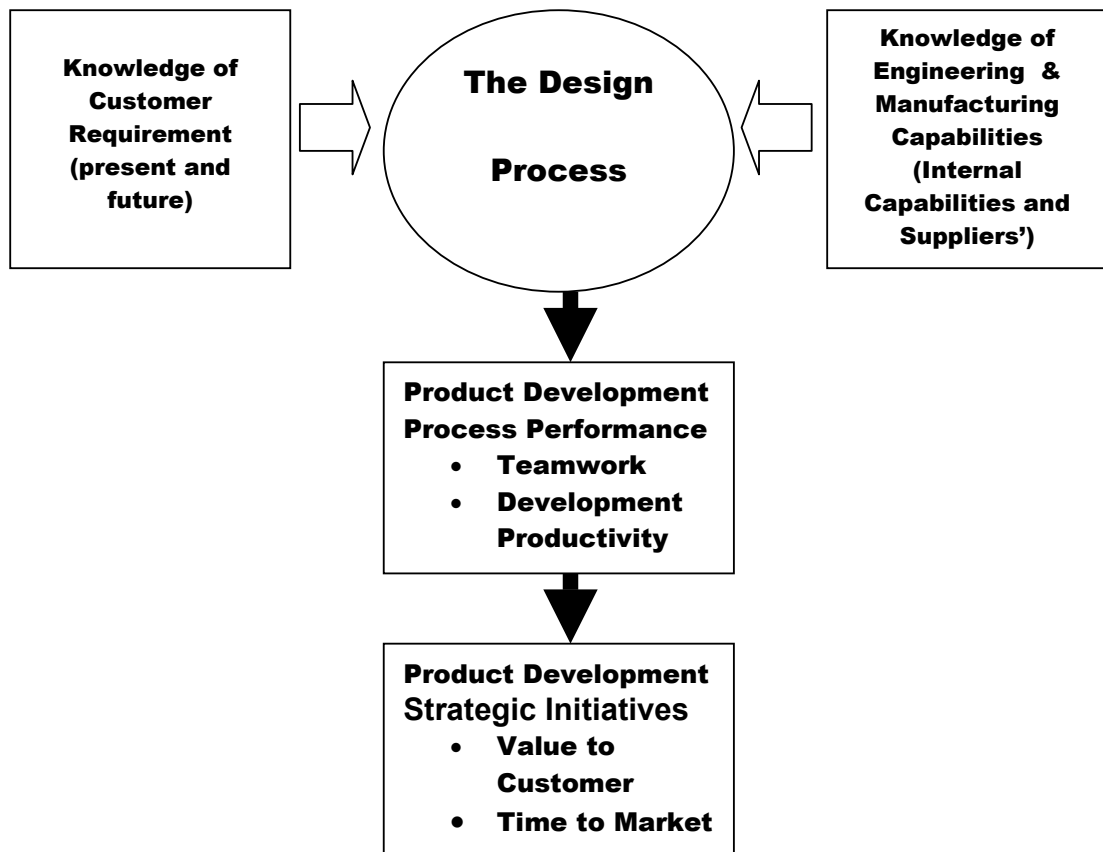
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APPENDIX



**Figure 1: Matching Customer Requirements with Engineering & Manufacturing Capabilities**

Table 1:

Variable	Definition	Literature
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Shared 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.
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.
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.
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.
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.

## APPENDIX

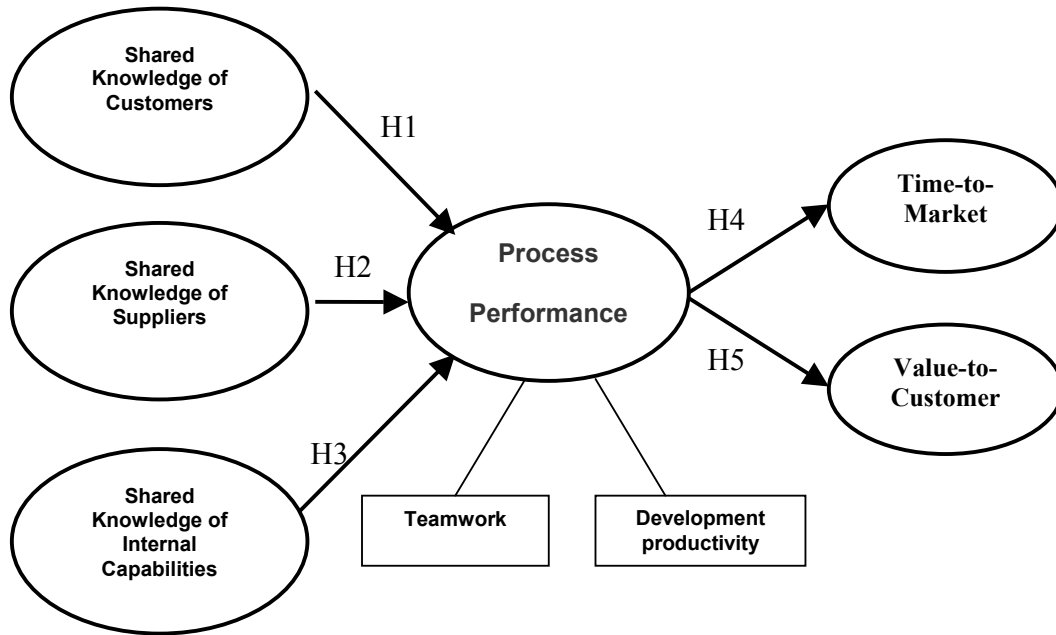
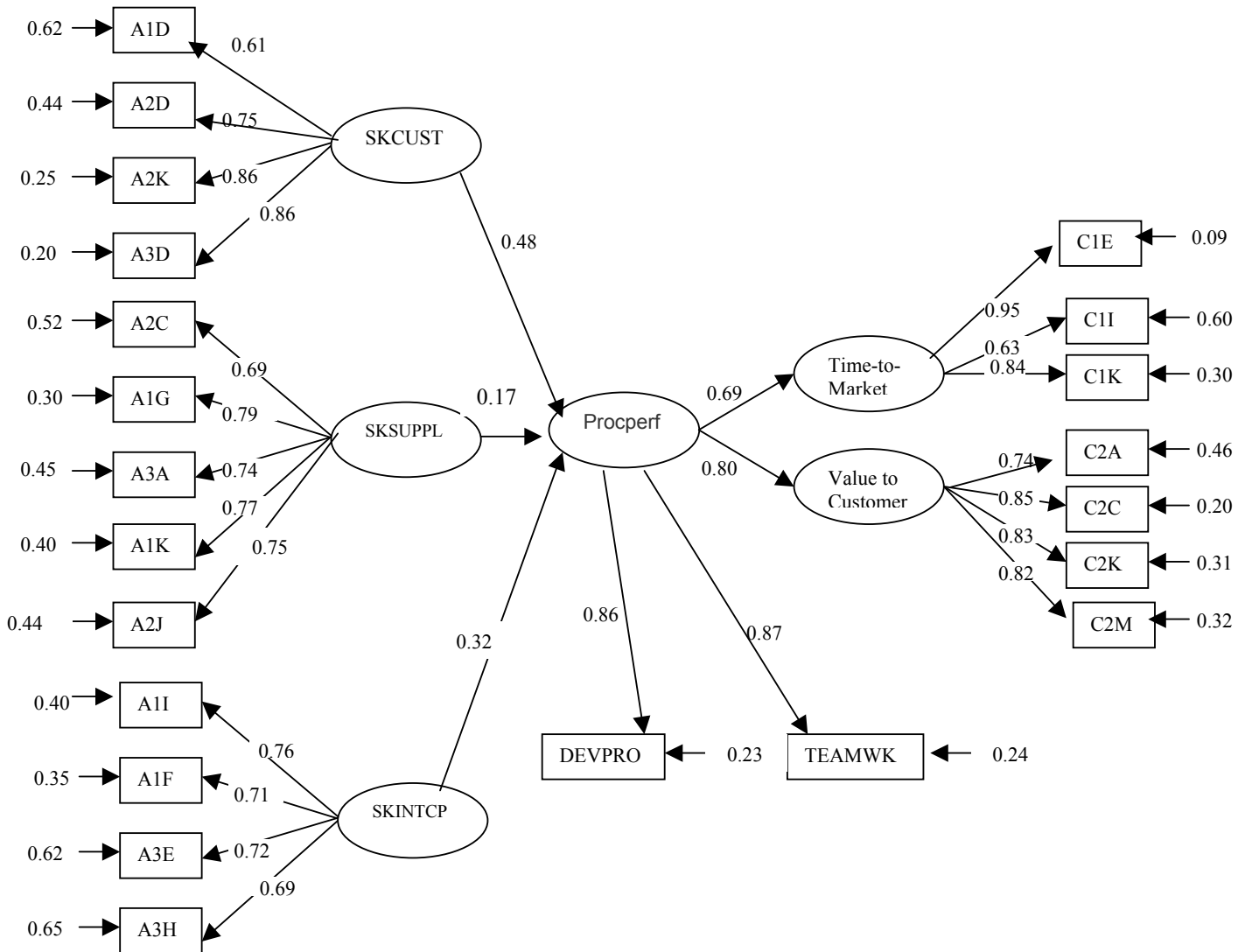


Fig. 2. Hypothesized model



**Fig. 3. Structural path estimates of hypothesized model**

Chi-Square=294.15, df=201, P-value=0.00002,  
 RMSEA=0.048, NNFI=0.96, CFI=0.96