A Dissertation

entitled

International Benchmarking of Integrated Product Development Practices in the Auto Industry Supply Chain: A Multigroup Invariance Analysis

by

Ahmad Syamil

Submitted as partial fulfillment of the requirements for the Doctor of Philosophy Degree in Manufacturing Management

William J. Doll
Advisor: William J. Doll
Professor of Management

Richard A. Hudson
Graduate School

The University of Toledo

December 2000

UMI Number: 9990664

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

Committee Members,

Date of Signature

Bhal Bhatt
Professor of Management

December 12, 2000

Ken I. Kim
Professor of Management

December 12, 2000

Nagi G. Naganathan
Professor of Mechanical, Industrial, and Manufacturing Engineering

December 12, 2000

S. Subba Rao
Professor of Information Systems and Operations Management

December 12, 2000

An Abstract of

INTERNATIONAL BENCHMARKING OF INTEGRATED PRODUCT DEVELOPMENT PRACTICES IN THE AUTO INDUSTRY SUPPLY CHAIN: A MULTIGROUP INVARIANCE ANALYSIS

Ahmad Syamil

Submitted as partial fulfillment of the requirements for the

Doctor of Philosophy Degree in

Manufacturing Management

The University of Toledo

December 2000

The purpose of this study is to examine the relationship between integrated product development (IPD) practices and product development performance in two groups of companies in the auto industry supply chain, i.e., auto manufacturers and auto parts suppliers, in two major auto producing countries, i.e., the U.S. and Germany. An extensive literature review finds six IPD practices and eleven performance variables. To develop a survey instrument, this literature review was followed by in depth interviews with practitioners and academicians and then pre testing with 8 product development professionals to gain brevity as well as to establish face and content validity. A pilot study was

later conducted with 33 U.S. respondents to achieve several objectives: purification, reliability, convergent and discriminant validity, as well predictive validity. Survey items were deleted, modified, and added as necessary.

A large-scale survey was then conducted in the U.S. and Germany. Using both mail and web responses, a total of 267 usable U.S. responses and 139 usable German response was received. The survey instrument later underwent a rigorous mutigroup invariance analysis using Linear Structural Relationship (LISREL) to develop measuring items that have equivalent true scores across groups to reduce type I and type II errors. After the invariant instrument was developed, the instrument was then tested for reliability as well as discriminant, convergent, and predictive validity.

A series of stepwise regression analyses later finds that each IPD practice affects a certain set of performance variables. Two-way factorial analyses of variance (ANOVA) uncovers the differences between the U.S. and Germany as well as between auto manufacturers and auto suppliers in IPD practices and performance. The differences in performance can be explained by the difference in IPD practices. Moreover, the results suggest that the industry has not been successful in integrating product development across the supply chain, i.e., from auto manufacturers to auto suppliers.

Recommendations for further study include exploring the structural relationship among possible variables, conducting a longitudinal study, studying antecedents of IPD, studying Tier 2 auto suppliers better, and validating the invariant instrument through studying companies in different industries and different countries.

ACKNOWLEDGEMENTS

Reflecting on the long and intense process of completing my dissertation, I am deeply grateful to many people for their contribution and support. I would like to especially acknowledge my dissertation committee. Dr. William J. Doll, who was the chairman of my dissertation, was demanding but extremely helpful in providing feedback and shaping my way of thinking. Other committee members were Drs. Bhal Bhatt, Ken I. Kim, Nagi G. Naganathan, and S. Subba Rao. Among other things, Dr. Bhatt always encouraged me to think outside of the box. Dr. Kim always provided me with wise counsel. He also guided me when I worked as his graduate assistant throughout my Ph.D. studies. Dr. Naganathan gave excellent comments because of his engineering perspective. Finally, Dr. Rao helped me with his statistical knowledge. Moreover, he was the one who recruited me into the Ph.D. program. Without their support, guidance, patience, and understanding, this dissertation would not have been completed.

I am very fortunate to be part of the high quality graduate program at the University of Toledo, Toledo, Ohio, U.S. Among the many professors, there are a few I especially want to thank. Dr. Mark Vonderembse I want to thank for his encouragement and guidance throughout the program. Dr. Joseph Scazzero gave me excellent guidance in data analysis. Dr. Heinz Buhlman, professor of German literature, helped to check the German translation of my English survey. I also would like to express a great appreciation for the funding received from the Academic Challenge Grants both from the Department of Management and the Department of Information Systems and Operations Management.

Special thanks are also given to Dr. Muhammad Nurhuda who helped me collect surveys in Germany. Many thanks are also due to numerous engineers, product development managers, and executives in the auto industry who gave me excellent feedback throughout the various stages of my dissertation. I also would like to thank Mr. Herman Z. Latif, President of ASEAN Automotive Federation, who was largely responsible for developing my interest in the auto industry.

My family deserves special attention. I thank my wife, Siti Mardiana, and my daughter, Jasmine Iman Amalia, for their love and companionship during this struggle. Special gratitude goes to my parents who supported me with their prayers and whatever support I needed. I will remember them forever with my love and respect.

Finally, I wish to express my thanks to my undergraduate school, Bandung Institute of Technology and my country, Indonesia, which gave me a strong basic education.

TABLE OF CONTENTS

ABSTRACT	iv
ACKNOWLEDGEMENTS	vii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF APPENDICES	xiv
CHAPTER 1. INTRODUCTION	1
1.1. Problem Identification	5
1.2. Research Questions	6
1.3. Research Contributions	7
CHAPTER 2. LITERATURE REVIEW AND HYPOTHESES	9
2.1. Literature Review in Product Development	14
2.2. Research Framework	30
2.3. The Relationship between Integrated Product Development Practices and Product Development Performance	32
2.3.1. Concurrent Engineering	32
2.3.2. Customer Involvement	35
2.3.3. Supplier Involvement	36
2.3.4. Heavyweight Product Development Managers	38
2.3.5. Platform Products	40
2.3.6. Information Technology Utilization	42
2.4. Integrated Product Development Practices: the U.S. vs. Germany	44
2.4.1. Concurrent Engineering	44
2.4.2. Customer Involvement	46
2.4.3. Supplier Involvement	47
2.4.4. Heavyweight Product Development Managers	49
2.4.5. Platform Products	50
2.4.6. Information Technology Utilization	51
2.5. Product Development Performance: the U.S. vs. Germany	52
2.5.1. Teamwork Performance	52
2.5.2. Engineering Change Time	54
2.5.3. Product Cost Reduction	55

2.5.4. Team Productivity 57
2.5.5. Manufacturing Cost Reduction 58
2.5.6. Product Integrity 60
2.5.7. Suppliers' On-Time Performance 61
2.5.8. Suppliers' Quality Performance 62
2.5.9. Suppliers' Cost Performance 63
2.5.10. Product Development Time 64
2.5.11. Customer Satisfaction 65
2.6. Integrated Product Development Practices and Performance: OEMs vs. Auto Suppliers 66

CHAPTER 3. RESEARCH METHODS 73

3.1. Measurement Properties 74
3.2. Pilot Study Method 75
3.3. Pilot Study Results 82
3.4. Large Sample Method 90
3.4.1. Respondent Bias Analysis 91
3.4.2. Sample Characteristics 95
3.4.3. Measurement Results 99
3.4.3.1. Invariance Analysis Procedures 99
3.4.3.2. Invariance Analysis across the U.S. and Germany 102
3.4.3.3. Invariance Analysis across OEMs and Auto Suppliers 109
3.4.4. Model Fit Indices, Discriminant, and Predictive Validity Analyses 115
3.5. Methods for Answering Research Questions 124

CHAPTER 4. RESEARCH QUESTIONS ANSWERED 129

4.1. Research Question No. 1: IPD and Performance Relationship 129
4.2. Research Question No. 2: the U.S. vs. Germany 132
4.2.1. Integrated Product Development Practices 134
4.2.2. Product Development Performance 138
4.3. Research Question No. 3: OEMs vs. Auto Suppliers 142
4.3.1. Integrated Product Development Practices 143
4.3.2. Product Development Performance 147
4.4. Research Question No. 4: Explaining Performance Difference 152
4.4.1. Performance Differences in the Two Countries 152
4.4.2. Performance Differences in the Two Levels of Supply Chain 157

CHAPTER 5. SUMMARY, DISCUSSION, AND RECOMMENDATIONS 162

5.1. Summary 162

5.2. Discussion 165
5.2.1. Substantive Contribution 165
5.2.2. Methodological Contribution 167
5.2.3. Practical Implication 168
5.3. Recommendation 169

CHAPTER 6. CONCLUSION 176

REFERENCES 178

LIST OF TABLES

Table

1.	Selected Survey-Based U.S. vs. German Product Development Studies	23
2.	Integrated Product Development (IPD) Practices: Definition, Rationale, and Reference	33
3.	Previous Studies in IPD and Product Development Performance: the US vs. Germany	45
4.	Data Set for Large Scale Study	73
5.	Item Correlation Matrix and Discriminant Analysis (Pilot Study)	84
6.	Descriptive Statistics, Reliability, Correlation, and Predictive Analyses (Pilot Study)	86
7.	Response Bias: Country and Supply Chain Analyses (Large Scale Study)	92
8.	Response Bias: Web vs. Mail Responses (Large Scale Study)	94
9.	Characteristics of Usable Responses	96
10.	Invariance Analysis: US and German Companies	103
11.	LISREL Pattern Analysis: Factor Loading for US and German Companies	105
12.	Invariance Analysis: OEMs and Auto Suppliers	110
13.	LISREL Pattern Analysis: Factor Loading for OEMs and Auto Suppliers	112
14.	Offending Items	116
15.	P-values from Universal Instrument vs. Unmodified Instrument for Evaluating the Differences between the US (n = 267) and Germany (n = 139)	117
16.	P-values from Universal Instrument vs. Unmodified Instrument for Evaluating the Differences between OEMs (n = 115) and Auto Suppliers (n = 291)	118
17.	Overall Model Fit of Measurement Instrument	119
18.	Discriminant Analysis (Large Scale Study)	122
19.	Descriptive Statistics, Correlation, and Reliability (Large Scale) Study	123
20.	Stepwise Regression Analysis - All Data: Universal Instrument (n = 406)	130
21.	P-values from Two-Factor Analysis of Variance of Integrated Product Development Practices and Performance Variables by Supply Chain and Country	133
22.	Interaction (Post-Hoc) Analysis of Customer Involvement Using Bonferroni Procedure	135
23.	Stepwise Regression Analysis with Dummy Variables - All Data: Universal Instrument (n = 406)	153

LIST OF FIGURES

Figure

1. Research Framework for International Benchmarking of Integrated Product Development Practices in the Auto Industry Supply Chain 31
2. Model Generating Process for Pilot Study Analysis 77
3. Invariance Analysis 101

LIST OF APPENDICES

Appendix

1.	Research Instrument for Pilot Study in the U.S.	193
2.	Assessment of Unidimensionality (and Convergent Validity) of Product Development Performance Dimensions: Description and Rationale of the Procedure	199
3.	Instrument for Large Scale Survey in the U.S.	203
4.	Research Instrument for Large-Scale Survey in Germany	209

CHAPTER 1

INTRODUCTION

The auto industry is entering a new paradigm. Three forces have shaped the auto industry. The first force is fierce international competition (Birou and Fawcett, 1994; Cusumano and Nobeoka, 1996; Abdalla, 1999). As a result, many companies will not exist with current ownership status (Kobe, 1994; Kerwin and Vlasic, 1996). Companies in the auto industry have to deal with merger, acquisition, and strategic alliance to survive and grow in this turbulent change (Pilkington, 1999; Alford, Sackett, and Nelder, 2000).

The second force is the development of supply chain management, i.e., an integrated approach to procuring, designing, producing, and delivering products from suppliers, manufacturers, and customers (Harland, 1996; Liker et al., 1996; Sako and Helper, 1998; Dröge et al., 2000). Rather than an arm's length relationship with auto suppliers, auto manufacturers/original equipment manufactures/OEMs have led the trend in developing a closer relationship with selected suppliers (Cusumano and Takeishi, 1991; Taylor, 1994; Curkovic et al., 2000). These trends have forced both auto manufacturers and auto suppliers to undergo radical changes in the way they do business, including how these two levels of supply chain develop vehicles together.

The third force is integrated product development (IPD). IPD is a process that systematically employs cross-functional disciplines to integrate product development activities across the value chain from suppliers, OEMs, and customers (Fleming and Koppleman, 1997; Ettlie, 1997; Usher, Roy, and Parsaei, 1998; Moffat, 1998; Paashuis, 1998; Rezayat, 2000a). Customers have become more discerning, sophisticated, and demanding (Clark and Fujimoto, 1991; Gilmore and Pine, 2000).

Accordingly, the development of world-class products is imperative to the survival and growth of companies in the auto industry. Not only is product development becoming more central to meeting the increasingly specialized demands of customers, but also it can have a powerful impact on manufacturing productivity and quality. For example, the machine setup time is determined not only by process design, but also by product design. The same is true for product quality. Poor product design causes many defects on the production floor (van Dierdonck, 1990). Product designs drives 70-80% of the final product cost and 70% of the total product life cycle cost. A recent J.D. Power Initial Quality Survey of new vehicles indicates that two-third of quality problems come from design and engineering faults, not simply assembly plant mistakes (White, 2000). Thus, the ability to reduce cost and improve quality on the factory floor is not enough in today's competitive environment. Many auto firms realize that excellence in manufacturing is useful only if firms are able to develop superior products (Gersbach et al., 1994; Corso, Muffatto, and Verganti, 1999).

Unfortunately, developing new products in the auto industry is not an easy task. The development of a new car involves thousands of auto components (e.g.. up to 20.000 components), hundreds of design engineers. and absorbs enormous amounts of money (Monden, 1993; Muffato, 1999). For example, the development of the Ford Escort in the 1980s and the Dodge Neon in 1990s is reported to have cost their companies $5 billion and $1.3 billion respectively. Auto companies also face huge risks from the lengthy product development process, i.e. auto companies must be able to predict customer demand for the next 3 to 5 years.

Consequently, involving dominant parties in the supply chain is necessary to IPD. For instance, bringing suppliers early in the product development process leads to dramatic reduction in product development cost (Jacobs and Herbig, 1998) and in product development time (Clark, 1989; Droge, Jayaram, and Vickery, 1999). Another example is that the early involvement of the customer in product development adds to the understanding of product usage and characteristics representative of the target market (Pitta and Franzak, 1996; Fynch, 1999). By bringing supplier and customer into the product development, auto companies can expect to better meet the challenges of the global auto industry.

Although the auto industry is becoming global, the national environment in which the industry is born and grow can determine the competitive advantage of the industry. For example, Porter (1990) argues that one determinant is related and supporting industries such as world-class suppliers. Some also argue that cultural differences may make a difference in certain practices. For instance, European nations appear to have better multi-functional cooperation than do North American nations (Gerpott and Domsch, 1985; Edgett, Shipley, and Forbes, 1992; Song and Parry, 1996). This difference in turn makes the difference in practices that require cross-functional cooperation such as concurrent engineering.

Although international studies are abundant, only some of them specifically deal with product development in U.S. and German auto industries. The most prominent international product development studies in the auto industry published in the late 1980s or early 1990s were primarily conducted during the later 1980s by researchers at Harvard University (e.g., Clark and Fujimoto, 1991) and Massachusetts Institute of Technology's International Motor Vehicle Programs (e.g., Womack, Jones, and Ross, 1990) in the U.S., Europe, and Japan. There is a need for follow-up because a decade has passed since these researches were conducted. Additionally, the researches used only a small sample (i.e., 29) and were conducted at OEM (auto manufacturer) facilities. Suppliers have been researched mainly from the auto manufacturer's point of view.

Current trends in the auto industry call for a new and integrated approach to studying product development. Unfortunately, very little is known about the transferability of product development practices from OEMs to supplier firms and how the practices relate with performance.

This dissertation focuses on product development practices and performance, i.e., a practice framework. The study was conducted at two dominant players in the auto industry of supply chains, i.e., auto manufacturers or Original Equipment Manufacturers (OEMs) and auto parts suppliers, in two major car-producing countries, i.e., U.S. and Germany. Unlike previous MIT and Harvard's studies that use objective measures such as product development time in months, this dissertation used subjective measures collected from survey to collect data.

A review of international product development studies that compares the U.S. and Germany using subjective survey measures indicates that many researchers lack the rigor in developing measures. For instance, only some of them (e.g., Balachandra, 1996) use forward and backward translation. In another instance, only few researchers (e.g., Hegarty and Hoffman, 1990) report the results of reliability analysis. Moreover, none of the studies use discriminant analysis for developing measuring instrument. Furthermore, none of them use a multi-country invariance analysis when developing measures. Without an invariant measure, no researcher can determine if the mean differences found in the groups (e.g., U.S. vs. Germany) are caused by substantive differences among the groups or by measurement artifacts.

1.1. Problem Identification

From an initial literature review, several major problems are identified:

a. Previous prominent international product development studies in the auto industry studies need to be updated because they are more than a decade old. The auto industry has been shaped in the last decade. Do differences in integrated product development practices and performance still exist between U.S. and German auto industries? The lack of answer and update may be due to the difficulty in collecting international data because international study is time consuming and costly.

b. The previous prominent studies focused on an OEM perspective. Except for aspects of supplier involvement, product development in the auto suppliers has not been studied extensively. Although OEMs have pushed auto suppliers to do more design work, with limited supplier resources are IPD practices transferable from OEMs to suppliers? Large-scale study that compares product development in OEM with that of auto suppliers is practically non-existent.

c. International product development in the auto industry that uses multi-group invariance analysis has not been found. Without an invariance instrument, the assurance that respondents of different group associate survey items with similar constructs cannot be made.

1.2. Research Questions

Since the late 1980s, firms in the auto industry world wide have made substantial efforts to implement integrated product development practices in their own firms and across their supply chain. This dissertation answered the following four major research questions:

1. What is the relationship between integrated product development (IPD) practices (independent variables) and product development performance (dependent) variables?
2. Are there differences between U.S. and Germany in IPD practices? Are there differences in product development performance between these two countries?
3. Are there differences between OEMs and suppliers in IPD practices? Are there differences in product development performance between these stages in the supply chain?
4. Are the differences in product development performance between countries and between stages of the supply chain due to differences in IPD practices?

1.3. Research Contributions

Realizing the importance of an invariant instrument in international study and subgroup analysis, this dissertation gives two methodological contributions:

a. Developing a step-by-step invariance analysis that can be replicated.
b. Developing a universal product development instrument that can be used by other researchers.

Moreover, this dissertation provides two substantive contributions:

a. Updating previous studies related with the differences between U.S. and German auto industries.

b. Giving the progress of transferring product development practices from auto manufacturers to auto suppliers.

The next few chapters of this dissertation are organized as follows. A product development literature review, research framework, and hypotheses are provided in Chapter 2. The research methodology for generating an invariant instrument appears in Chapter 3. This methodology includes interview, pilot study, and large-scale study. Chapter 4 answers the research questions. Chapter 5 provides summary, discussion, and recommendation. Finally, a conclusion is provided in Chapter 6.

CHAPTER 2

LITERATURE REVIEW AND HYPOTHESES

Companies in the auto industry have been blessed by the contributions of forward thinking individuals. One such individual was Henry Ford. He combined product standardization with the quasi-assembly lines found in the meatpacking and mail order industries. The result was a revolutionary assembly line to mass-produce vehicles at a much lower cost than its competitors (Heizer and Render, 1999).

Another individual was Alfred P. Sloan of General Motors. Among other things, he structured the sprawling and disorganized GM's product lines into five divisions, i.e., Chevrolet, Pontiac, Oldsmobile, Buick, and Cadillac. Each division serves a different price and market category. This strategy propelled GM to become the world's largest auto company (Sloan, 1963; Thompson and Strickland, 1992).

The third notable individual was Taiichi Ohno, who was the Vice President of Toyota Corporation. Borrowing from the reorder-point system commonly found in the U.S. supermarkets' inventory management, he invented Just-in-Time Production System. He defined JIT as a production of necessary product at necessary quantity and necessary time (Suzaki, 1985; Monden, 1993; Russell and Taylor, 2000). His JIT invention then metamorphosed into several new management principles such as time-based competition (Stalk, 1988; Stalk and Hout, 1990; Blackburn, 1991), lean manufacturing (Krafcik, 1988; Womack et al., 1990), and, most recently, agile manufacturing (Gunasekaran, 1999).

These individuals not only shaped the way their companies do business but they also shaped the whole auto industry as competitors scramble to copy their invention or try to find a better invention. In the last decade, however, three much-larger-than-individual driving forces have shaped the world's auto industry.

The first force is the increased competition resulting from fierce international competition (Birou and Fawcett, 1994; Cusumano and Nobeoka, 1996; Abdalla, 1999). Until the 1950s only a handful of auto companies could sell their products globally. Today, more than 30 companies compete on a global scale. Few and strong regional companies have been replaced by many companies that compete globally. Direct rivalry among products from different countries of origin is observed more frequently (Clark and Fujimoto, 1991). Many companies cannot survive with previous ownership status (Kobe, 1994; Kerwin and Vlasic, 1996). Merger, acquisition, and strategic alliance are ways to survive and grow in this turbulent change (Pilkington, 1999; Alford, Sackett, and Nelder, 2000).

The second force is the development of supply chain management, i.e., an integrated approach to procuring, designing, producing, and delivering products from suppliers, manufacturers, and customers (Harland, 1996; Liker et al., 1996; Sako and Helper, 1998; Dröge et al., 2000). Previously, the relationship between auto manufacturers and auto suppliers was characterized by an arm-length relationship and mutual suspicion. Since a decade ago, auto manufacturers have led the trend to develop a closer relationship with selected suppliers (Cusumano and Takeishi, 1991), to reduce the number of suppliers they deal directly with (Kobe, 1994; Kerwin and Vlasic, 1996), and to order more modules/sub assemblies than individual parts (Taylor, 1994). Also, suppliers have been invited to play an increasing role as product designers (Kamath and Liker, 1994). These trends have forced both auto manufacturers and auto suppliers to undergo radical changes in the way they do business, including how these companies collaborate in developing new vehicles (Cusumano and Nobeoka, 1996; Curkovic, Vickery, and Dröge, 2000).

The third force is integrated product development. The competitive battleground for auto firms has shifted from a narrow focus on the factory floor and internal product development activities without involving external parties to the broader integrated product development (IPD) (Fleming and Koppleman, 1997; Ettlie, 1997; Usher, Roy, and Parsaei, 1998; Moffat, 1998; Paashuis, 1998; Rezayat, 2000a). IPD is a process that systematically employs cross-functional disciplines to integrate product development activities across the value chain from suppliers, OEMs, and customers. By bringing supplier and customer in product development, auto companies can expect to better meet the challenges of the global auto industry.

In spite of the fact that the auto industry is becoming global, the national environment in which the firm is born and grows still play a significant role in determining the competitive advantage of the firm. Porter (1990) offers a

"National Diamond" that consists of six determinants of a nation's industry competitiveness. The first determinant is the factor conditions of a nation such as skilled labor. Demand conditions such as demanding customers that do not accept inferior or outmoded products are the second determinant. The third determinant comes from related and supporting industries such as world-class suppliers. Evidence in the auto industry clearly supports his argument. The fourth determinant is firm strategy, structure, and rivalry. Porter also argues that government, the fifth determinant, should play a role as a catalyst and challenger. Chance that cannot be planned for but creates an atmosphere for competitive advantage is the sixth determinant. Those six determinants create a specific combination that can explain why a nation achieves success in a particular industry.

Although Porter does not mention that culture is a determinant of a nation's competitiveness, many scholars argue that culture is still relevant in international studies. For example, some experts suggest that the high degree of supplier involvement in the Japanese auto industry is cultural. They argue that Japanese auto manufacturers have a particular way of treating their suppliers as children that does not exist in other cultures. Governance by trust is also more prevalent in Japan because of the existence of a suppliers association (kyoryokukai). The association enhances communication among suppliers and prohibits automakers' opportunism. The association creates business norms that are determined by cultural values (Sako, 1996; Sako and Helper, 1998).

In another example, Souder and Jenssen (1999) argue that the differences between U.S. and Scandinavian product development practices are due to cultural differences. For instance, they find that U.S. companies have a higher level of project manager competency than do Scandinavian companies. They argue that Scandinavians value project managers less because in Scandinavia collaboration among individuals is more spontaneous, informal, and internally motivated. Scandinavian national culture rate "feminine" values higher. This includes work humanization and mutual assistance among individuals. A high degree of project manager competency such as authority is simply not needed in Scandinavia. In contrast, U.S. national culture stresses "masculine" values such as assertiveness, results, and competition that support the need for a higher degree of project manager competency. Cultural differences have also proven invaluable in explaining supply chain relationship differences in U.K. and Spain (Harland, 1996), managerial practices and attitudes (Peterson and Smith, 1997), consumer purchase patterns (Jarvenpaa, Tractinsky, Saarinen, and Vitale, 1999) and various factors that can affect the practices and performance of a nation's companies and industries.

The three driving forces that were mentioned earlier (i.e., global competition, supply chain management, and integrated product development) and the fact that a national culture can make a difference are what motivated this international product development dissertation. A review of literature in product development follows.

2.1. Literature Review in Product Development

Product development is a process by which an organization transforms data on market opportunities and technical possibilities into information assets for commercial production (Clark and Fujimoto, 1991). Brown and Eisenhardt (1995) classify the empirical research on product development into three main streams: rational plan, communication web, and disciplined problem solving. Compared with the two other product development research streams, the disciplined problem-solving stream has a deeper focus on the actual product development such as concurrent engineering and the activities of product development managers. Although this dissertation is build primarily upon the disciplined problem-solving stream, the two other steams will also be discussed in brief.

Myers and Marquis (1969) and SHAPPO studies (Rothwell, 1972; Rothwell et al., 1974) build the foundation of the rational stream of product development literature. The rational stream suggests that rational and proper planning leads to financial performance (e.g., profits, sales, and market share) of the product. Most rational plan research uses explanatory methods. This stream of research concludes that careful planning, well-coordinated execution and top management support are the keys to successful product development.

Allen (1971, 1977) at MIT starts the communication stream. The communication researchers work on the basis that the more effective the communication among product development team members and between team members and outsiders, the better the product development performance. Strong theoretical foundation and more sophisticated statistical methodology compared with the rational stream are the characteristics of the communication stream.

The disciplined problem-solving stream of product development research begins with case studies in Japanese companies (e.g., Imai et al., 1985; Quinn, 1985; Takeuchi and Nonaka, 1986). Among other things, they find that a problem-solving strategy using concurrent engineering (CE) that involves cross-functional development teams increase product development performance, particularly the speed of product development.

Several researchers (e.g., Fleming and Koppleman, 1995; Moffat, 1998) argue that integrated product development is no more than concurrent engineering. The researcher disagrees with this opinion. Concurrent engineering focuses on integrating internal product and process activities within a company (Ponticel. 1996; Izuchukwu, 1996). In contrast to CE, IPD encompasses not only internal integration but also external integration across a supply chain that includes suppliers and customers. In today's competitive environment, it is important to use suppliers' capability in product development and to incorporate the inputs of customers (Karlsson, Nallore, and Soderquist, 1998; Gilmore and Pine, 2000). For example, the involvement of suppliers that have very high-technical skills in a specialized area reduce product development time significantly (Clark and Fujimoto, 1989; Clark, 1989; Clark and Fujimoto, 1991). Regarding customer involvement, Durgee, O'Connor, and Veryzer (1998) and

LaBahn and Krapfel (1999) find that in many organizations, integrated product development relies on not only the creativity of the product development team, but also the ability to study what customers want. Therefore, involving customers earlier and more deeply help the product development teams to understand the customer needs and wants better.

Other researchers also find additional practices. For example, Muffato (1999), Tatikonda (1999), and Sundgren (1999) find that the work of most product development teams and suppliers are organized around platform products that facilitate incremental product innovation, lower product cost, and learning spillover among all parties involved in integrated product development. Furthermore, Balakhrisnan, Kumara, and Sudaresan (1999) and Huang and Mak (1999) argue that information technology is a key enabler in integrated product development by reducing barriers to collaboration, compressing product development time, and enriching the quality of problem solving.

Some researchers from the disciplined problem-solving stream focus specifically on the product development projects in the auto industry. They include some researchers from MIT's International Motor Vehicle Program (e.g., Womack et al., 1990) and Harvard University (e.g., Clark and Fujimoto, 1991). They measure the performance of the product development process using three dimensions: total product quality, lead-time, and productivity. They find that Japanese auto companies perform better than their counterparts in the U.S. and Europe because of the extensive use of supplier involvement, concurrent engineering, and heavyweight product development managers. Heavyweight product development managers are powerful managers who are highly effective in obtaining resources such as personnel and budget for product development teams.

An initial review of the disciplined problem-solving literature mentioned above identify six practices that focus on integrated product development:

a. Concurrent engineering: The practice of using cross-functional product development teams to simultaneously plan product and process activities.
b. Customer involvement: The practice of developing on-going interaction with customers to better understand their needs and wants in product development.
c. Supplier involvement: The practice of developing on-going interaction with suppliers to enhance their participation in product development efforts.
d. Heavyweight product development managers: The practice of using senior executives with substantial expertise and decision making authority to champion and direct product development efforts.
e. Platform products: The practice of planning multiple generations of products based on a core product and process design.
f. Information technology utilization: The practice of employing computer and communication technologies to plan and coordinate product development activities.

These six IPD practices have been postulated by many researchers (e.g., Meyer and Lehnerd, 1997; Schmidt, 1997; Moffat, 1998; Huang and Mak, 1999) to have a positive relationship with product development performance. Therefore, it is theoretically sound to justify relevant product development performance variables that will be used in this dissertation.

Two characteristics of IPD are the use of the cross-functional product development team (Browning, 1998; Hauptman and Hirji, 1999) and product development activities across the value chain from suppliers, original equipment manufacturers (OEMs), and customers (Asanuma, 1989; Liker et al., 1996; Neale and Corkindale, 1998; Dröge, Jayaram, and Vickery, 2000). Therefore, it is important to develop measures on teamwork performance, customer satisfaction, and supplier performance especially time, cost, and quality performance. These three supplier performance criteria were not chosen arbitrarily. A recent multiple-response survey indicates that 76% OEM engineers consider suppliers' quality performance as the most desired performance (Fitzgerald, 1997). Suppliers' cost performance finished at a distant second, at 28%. The OEM engineers were also asked about their dissatisfaction with suppliers. They indicated that suppliers' on-time performance is their number one concern in product development. Similar findings from Birou and Fawcett (1994) indicate that suppliers' quality, time, and product cost performances are the three most important criteria for supplier selection in both the U.S. and Germany. Surprisingly, the order of importance, i.e., quality, time, and cost is the same in both countries.

Many parties within and outside the organization develop products together. Therefore it is important to measure the integrity of the resultant products. On the other hand, speed and productivity traditionally measure product development performance (Wheelwright and Clark, 1995; Bowen, et al., 1994; Cusumano and Nobeoka, 1996; Terwiesch and Loch, 1999). In this dissertation, speed was measured in two ways, i.e., engineering change time that measures the effectiveness and efficiency of engineering activities (Balakrishnan and Chakravarty, 1996; Loch and Terwiesch, 1999) and overall product development time from start to finish (Karagozoglu and Brown, 1993; Abdalla, 1999). Furthermore, to remain competitive, firms in the auto industry are also under pressure to reduce product cost and manufacturing cost (Mercer, 1994; Ittner and MacDuffie; 1995; Milligan, 2000). Following all of the above considerations, the researcher has decided to develop instruments to measure product development performance constructs as laid out below.

a. Teamwork performance: The performance of individuals as a group when working together towards a common goal.

b. Engineering change time: The time required to modify some aspects of an existing product definition or documentation.

c. Product cost reduction: The success level of the process carried out by the product development team to reduce product costs.

d. Team productivity: The amount of work that can be done by the product development team considering the resources used.

e. Manufacturing cost reduction: The success level of the process carried out by the product development team to reduce manufacturing costs.

f. Product integrity: The consistency among a product's function, its structure, and its assembled components.

g. Suppliers' on-time performance: The success level of the process carried out by suppliers to reduce the time required to design, manufacture, and deliver products.

h. Suppliers' quality performance: The success level of the process carried out by suppliers to increase the quality of the products they design, manufacture, and deliver.

i. Supplier's cost performance: The success level of the process carried out by suppliers to reduce the cost of the products they design, manufacture, and deliver.

j. Product development time: The time required from product concept to product introduction.

k. Customer satisfaction: The satisfaction of the customer for the product designed for a certain target market.

In this international study, the researcher studied the six integrated product development practices identified above (e.g., concurrent engineering) with the eleven product development performances stated earlier. Although international studies are abundant, only some of them are specifically geared towards product development the U.S. and German auto industries. Most prominent international product development studies in the auto industry published in the late 1980s or early 1990s were primarily conducted during the later 1980s by researchers at Harvard University (e.g., Clark and Fujimoto, 1991) and Massachusetts Institute of Technology's International Motor Vehicle Programs (e.g., Womack, Jones, and Ross, 1990) in the U.S., Europe, and

Japan. There is a need for follow-up because a decade has passed since these researches were conducted. Furthermore, they only used a small sample (i.e., 29) and were conducted at OEMs' facilities. Suppliers have been researched mainly from the auto manufacturer's point of view.

Current trends in the auto industry call for a new and integrated approach to studying product development. Unfortunately, very little is known about the transferability of product development practices from OEMs to supplier firms and how the practices relate with performance at different levels of the supply chain in different countries.

This dissertation focuses on product development practices and performance in two major car-producing countries, i.e., U.S. and Germany, and also in two dominant players in the auto industry, i.e., OEMs and auto suppliers. Unlike previous MIT and Harvard studies that use objective measures such as product development time in months, this study uses subjective measures collected from a large-scale survey. From a statistical point of view, the use of a large sample size resulting from a large-scale survey means increasing the power and validity of the statistical analysis. Thus, a large sample size increases the probability of rejecting the null hypothesis when it is false or, in the other words, increases the probability of making a correct decision (Stevens, 1996). A large sample size also allows the researchers to test the generalizability of the findings, e.g., are the results peculiar to one or two OEM firms or countries or are they generalized across countries and supply chain levels?

Because this dissertation uses subjective or perceptual measures such as the level of concurrent engineering from 1 (not at all) to 5 (a great deal), it is prudent to review existing literature on product development comparisons between the U.S. and Germany that uses subjective measures. One of the contributions of this dissertation is related with the rigor of developing measuring instruments. Thus, for each article reviewed, the researcher recorded whether or not the article reported the use of forward and backward translation, reliability analysis, discriminant analysis, or invariance analysis when developing instruments. A summary of the literature is given in Table 1 and a detailed discussion follows.

Bergen, Miyajima, and McLaughlin (1988) study the relationship between R&D and commercial performance of 54 scientific instrument-manufacturing companies in the U.K., West Germany, the U.S., and Japan. They find that in the U.K. and Germany there is a strong correlation between expenditure per R&D person and productivity. However, this correlation is not significant in the U.S. and Japan. Additionally, U.S. productivity is lower than that of Japan but higher than that of U.K. and Germany. Germany has the lowest productivity and is the slowest performance in product development time because of many subcontracted R&D activities. In addition, they suggest that U.S. companies should increase senior management and manufacturing involvement in innovation as well as increasing R&D personnel to improve innovation performance (e.g., productivity). In regards to research methods, the authors do

Table 1

Selected Survey-Based U.S. vs. German Product Development Studies

Author	Year	Journal	Sample	Forward and Backward Translation	Reliability Analysis	Discriminant Analysis	Invariance Analysis
Bergen et al	1988	R&D Management	54 instrument manufacturing companies in the U K West Germany, the U S and Japan	N	N	N	N
Summary		Productivity rank Japan (highest), U S UK and Germany (lowest)					
Hegarty and Hoffman	1990	Journal of Product Innovation Management	362 managers in 8 European countries and US	N	Y	N	N
Summary		Influence on innovations varies by the respondents' functional specialties (e g marketing vs manufacturing) rather than their cultural background (U S vs Europe)					
Gupta, et al	1992	Journal of Product Innovation Management	46 German managers and 37 US managers	N	N	N	N
Summary		US managers do not emphasize product development speed to the same extent as do German managers					
Cooper, Robert G	1994	International Marketing Review	1,000 new product launches in more than 350 firms in Europe and North America	N	N	N	N
Summary		This article reports part of NewProd Study Eight key success drivers in product development such as strong product definition are confirmed					
Birou and Fawcett	1994	Int Journal of Physical Dist & Log Mgmt	133 U S managers and 83 European managers	N	N	N	N
Summary		U S companies involve suppliers more extensively than that of European companies					

Table 1 (Cont.)

Selected Survey-Based Studies in U.S. and German Product Development

Author	Year	Journal	Sample	Forward and Backward Translation	Reliability Analysis	Discriminant Analysis	Invariance Analysis
Kleinschmidt E J	1994	European Journal of Marketing	35 German, 56 Danish, 27 Canadian 35 U S companies	Y	N	N	N
Summary	There are differences in NPD practices and performance between European and North American companies						
Balachandra and Brockhoff	1995	Research and Technology Management	114 U S projects and 156 German projects	Y	N	N	N
Summary	Many R&D project termination factors are common in both countries as long as the market and technological environments are similar						
Balachandra et al	1996	Journal of Product Innovation Management	245 R&D projects in the U S , Germany, and the U K	Y	N	N	N
Summary	U S firms employ more non R&D people to monitor the R&D projects Cost control is very important for German firms						
Balachandra	1996	IEEE Transactions on Engineering Mgmt	114 U S , 112 German, 43 U K 57 Japanese R&D projects	Y	N	N	N
Summary	He develops discriminant functions that discriminates between successful and terminated R&D projects (one function for each country) Almost all factors that make up the function in one country also appear in three other countries						

not report anything related to forward and backward translation, reliability analysis, discriminant analysis, nor invariance analysis.

Hegarty and Hoffman (1990) analyze top management involvement in product development, the results of which came from a survey of 362 managers from four cultures coming from 8 European countries and the U.S. They approximate cultures by using clusters of nations. They argue that the U.S. and U.K. managers belong to the Anglo culture; German and German speaking managers from Switzerland belong to the Germanic culture; Belgium, France, and France speaking managers from Switzerland belong to the Latin culture; and finally Denmark, Sweden, and Norway managers belong to the Nordic culture. They find that Germanic managers scan social trends and use more long-term planning procedures than do managers from the three other cultures. Although they find some other differences among the four cultures, they conclude that most differences in top management involvement are due to different functional specialties. For example, marketing and R&D managers have the most dominant influences in the type of innovation being investigated than any other functional areas. This pattern is consistent in all cultures. With respect to research methods, the authors do not report anything related with forward and backward translation, reliability analysis, discriminant analysis, nor invariance analysis.

Gupta, Brockhoff, and Weisenfeld (1992) use conjoint analysis to reveal how R&D, marketing, and manufacturing managers make trade-offs among three critical measures in new product development: development schedule, development cost and product performance. Their respondents consist of 37 U.S. managers and 46 German managers. They find that U.S. managers put the greatest emphasis on meeting the product development budget and then the product development performance, whereas German managers give the highest priority on meeting the product development schedule followed by improving product performance. R&D managers in both countries appear to have the same emphasis on development schedule. The authors do not report anything related with forward and backward translation, reliability analysis, discriminant analysis, nor invariance analysis.

Birou and Fawcett (1994) analyze surveys from 133 U.S. product development managers and 83 European product development managers from various industries such as auto, electric/electronic, and machinery. Unfortunately, they do not break down the European data by country. Among other things, they find that U.S. companies have a higher frequency and intensity of supplier involvement as well as earlier involvement in product development than do European companies. They argue that a higher competition in the U.S., especially from Japanese companies, force U.S. companies to involve suppliers so that U.S. companies can develop product innovation faster. In contrast, European companies enjoyed some degree of protection from global competition until the early 1990. For example, Japanese cars only represent 2% of the Italian car market segment. The European electronic industries also have received government subsidies. When looking at research methods, the researcher did not discover anything related to forward and backward translation, reliability analysis, discriminant analysis, nor invariance analysis.

Kleinschmidt (1994) reports product development programs from 154 firms from Europe (35 German and 56 Danish firms) and 62 firms from North America (27 Canadian and 35 U.S. firms). He defines program as the totality of all product development projects, i.e., not just a single project. The firms came from various industries such as chemicals and auto industry. Among other things, he finds several differences between U.S. and German companies. For example, he finds that German product development managers use more formal procedures and systems and plan more because they are more adverse to risk. German CEOs have more involvement in new product development programs than their U.S. counterparts. Moreover, U.S. managers look for a shorter pay-off horizon. He concludes that European firms are more successful in new product development programs than are North American firms. Regarding research methods, Kleinschmidt uses forward and backward translation, but he does not mention any reliability analysis, discriminant analysis, or invariance analysis.

Balachandra and Brockhoff (1995) conduct a study to determine if R&D project termination factors are universal. They compare the data from 114 projects from 40 U.S. firms with 156 projects from 80 German firms. They find that many factors are common to both countries, for examples, deviation in time schedules and change in availability of experts. A similar study in the U.K. reveals resembling factors (Brockhoff, 1994). They contribute this to the similarity of market and technological environment. As for research methods, the authors apparently use forward and backward translation but do not report anything related to reliability analysis, discriminant analysis, or invariance analysis.

Following Brockhoff (1994) and Balachandra and Brockhoff (1995), Balachandra, Brockhoff, and Pearson (1996) study the managerial decision making involved in deciding to continue or terminate R&D projects. They collect data from 21 U.S., 27 German and 30 U.K. companies covering 245 projects that indicate 111 terminated projects and 134 successfully completed projects. Most of their analysis is in aggregate form, i.e., they do not divide the analysis by country. Only some of their analyses are divided in this way. Among other things, they find that both German and U.K. firms typically involve fewer people to monitor the R&D projects than do U.S. firms. In spite of that, U.S. firms employ more non-R&D people to monitor the projects. Cost control is more important for German firms than it is for the two other countries. In regard to research methods, the authors apparently use forward and backward translation but do not report anything related with reliability analysis, discriminant analysis, or invariance analysis.

Expanding on the work of Balachandra, Brockhoff, and Pearson (1996), Balachandra (1996) develops discriminant functions to discriminate between successful and terminated R&D projects in several countries. In addition to U.S., German, and U.K. data collected earlier, he now adds data collected from Japan. In total, he has data from 114 U.S. projects, 112 German projects, 43 U.K. projects, and 57 Japanese projects. He finds that almost all factors that make up the discriminant function in one country also appears in the three other countries, although some factors have different signs in different countries. For example, one factor namely "time for anticipated competition" has a negative sign in the U.S. and Japan meaning that if the value is low, the R&D project is most likely to succeed. However, the sign is positive in German and U.K. He argues that looming competing products can demoralize German and U.K. R&D staffs leading to termination of R&D projects. He also finds that a factor namely "adaptability of project leader" has a positive effect in Germany, U.K. and Japan but does not appear at all in the U.S. He argues that hierarchical organizations in the three countries require a higher degree of the adaptability of project leaders whereas U.S. organizations that promote a freer environment do not value such ability highly. With respect to instrument development, the author reports the use of forward and backward translation but nothing related with reliability analysis, discriminant analysis, or invariance analysis.

To sum up, most large scale survey-based studies that compare U.S. and German product development have provided excellent insights into the differences between the two countries. However, none of them are specifically geared towards the auto industry. Additionally, most of them have been poorly designed. For instance, some of them use forward and backward translation (e.g., Balachandra, 1996), only one of them reports the results of reliability analysis (i.e., Hegarty and Hoffman, 1990) and none of the studies use discriminant analysis when developing measures. Furthermore none of them use a multi-country invariance analysis. The importance of an invariant instrument for group analysis is paramount. Without an invariant instrument, no researcher can determine if the mean differences found in the groups (e.g., U.S. vs. Germany) are caused by substantive differences among the groups or by measurement artifacts. The lack of an invariant instrument can lead to type I and II errors. A type I error is the probability of rejecting the null hypothesis when it is true, e.g., saying two groups differ when in fact they don't. A type II error is the probability of accepting the null hypothesis when it is false, e.g., saying two groups don't differ when they do.

The next section will discuss a research framework that relates integrated product development practice and product development performance. A justification of this research framework and how IPD practices and performance differ in the U.S. and Germany then follow it.

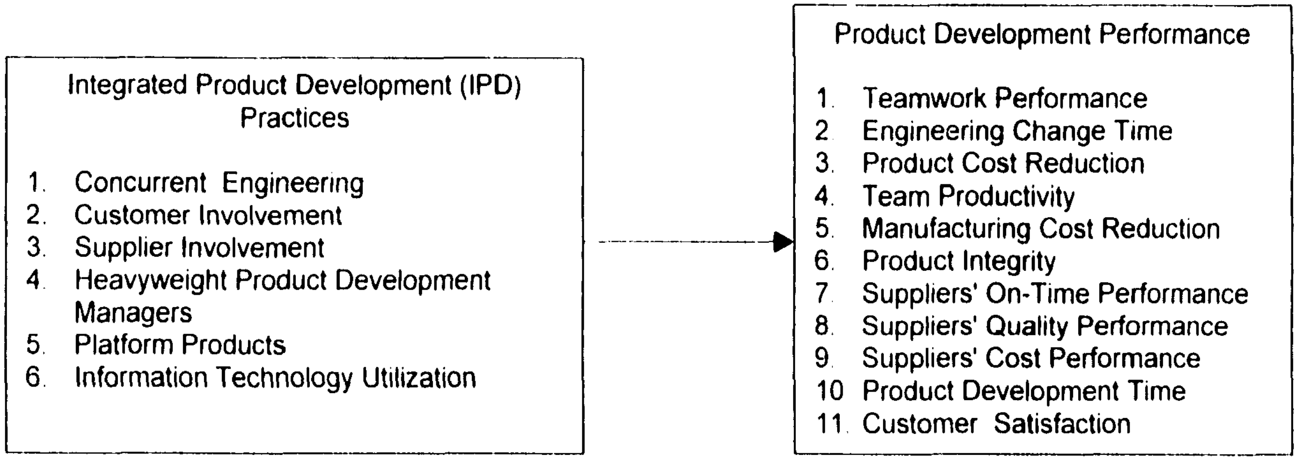
2.2. Research Framework

This study will provide information that will help answer the four research questions stated in Section 1.2. Figure 1 depicts the overall research framework. The researcher contends that there is a positive relationship between integrated product development practices and product development performance.

The relationship between product development practices and some aspect of product development performance has been widely studied in numerous research settings. Section 2.3 discusses this relationship in detail.

FIGURE 1

RESEARCH FRAMEWORK FOR INTERNATIONAL BENCHMARKING OF INTEGRATED PRODUCT DEVELOPMENT PRACTICES IN THE AUTO INDUSTRY SUPPLY CHAIN



2.3 The Relationship between Integrated Product Development Practices and Product Development Performance

This section discusses the logical rational of the research question no. 1, i.e., how each IPD practice leads to a higher product development performance. A summary of this discussion is given in Table 2.

2.3.1 Concurrent Engineering

A key practice of IPD is concurrent engineering (Ponticel, 1996; Izuchukwu, 1996). Concurrent engineering focuses on internal integration among product and process activities within a company. Koufteros (1995) argues that concurrent engineering consists of three subconstructs, i.e., cross-functional cooperation, early involvement of constituents, and overlapping development stages. The next paragraphs discuss each of the three subconstructs one-by-one.

The cross-functional nature of concurrent engineering improves the effectiveness of the product development teams when dealing with complex product development problems that required various different perspectives (Susman and Dean, 1992; Emmanuelides, 1993; Moffat, 1998). For example, customer requirements are understood and assimilated better throughout the product development process because the requirements are not filtered through gatekeepers in the marketing department, something that happens in sequential

Table 2

Integrated Product Development (IPD) Practices: Definition, Rationale, and Reference

Practice	Definition	Rationale: How It Improves Product Development Performance	Reference
Concurrent engineering	The practice of using cross-functional product development teams to simultaneously plan product and process activities.	Overlapping development stages reduce development time. Cross-functional product development enriches problem solving. Early involvement of constituents (e.g., manufacturing) allows the identification of manufacturing problems earlier.	Koufteros (1995); Izuchukwu (1996); Ettlie (1997); Swink (1998); Moffat (1998); Terwiesch and Loch (1999); Abdalla (1999); Hauptman and Hirji (1999)
Customer involvement	The practice of developing on-going interaction with customers to better understand their needs and wants in product development efforts	Understanding customer requirements better. Preventing late and costly design changes. Benchmarking a company's products with its competitors through customer inputs.	Evans and Lindsay (1996); Schmidt (1997); Fynch (1999); Balakrishnan et al. (1999); Gilmore and Pine (2000)
Supplier involvement	The practice of developing on-going interaction with suppliers to enhance their participation in product development efforts.	Using suppliers' engineering capability. Debugging manufacturing problems earlier. Reducing product development time by shifting part of the time to suppliers.	Clark (1991); Fujimoto (1994); Liker et al. (1996); Wasti and Liker (1997); Karlsson, Nallore, and Soderquist (1998).
Heavyweight product development managers	The practice of using senior executives with substantial expertise and decision making authority to champion and direct product development efforts.	The managers have significant experience, clout, and seniority to make things happen. They also have enough power to get people from different functions and resources from the organization	Clark and Fujimoto (1991); Wheelwright and Clark (1992); Fujimoto et al. (1996); Susman and Ray (1996); Kang and Young (2000).
Platform products	The practice of planning multiple generations of products based on a core product and process design.	Improving learning and problem solving speed. Reducing product development time and manufacturing investment.	Gersbergh et al. (1994); Meyer and Lehnerd (1997); Ikeda (1997); Muffato (1998); Muffato (1999); Sundgren (1999).
Information technology utilization	The practice of employing computer and communication technologies to plan and coordinate product development activities.	Analyzing and processing customer requirements better. Improving the speed of problem solving. Sharing information easier and faster.	Sanderson (1992); Gu and Chan (1995); Muller et al. (1996); Huang and Mak (1999); Giachetti (1999); Park and Baik (1999).

engineering. This, in turn, leads to potentially higher customer satisfaction (Ettlie, 1997).

Early involvement of constituents such as manufacturing personnel means manufacturing issues and complexities are brought up early. This can avoid costly redesign of products or production processes later if they do not fit or match each other. For instance, Cummins Engine Company develops manufacturing equipment before product design is finished. The company justifies the manufacturing investment because the up-front cost is more than offset by a smoother manufacturing process and lower manufacturing cost. It also leads to higher product integrity because manufacturing problems are debugged earlier (Swink, Christopher, and Mabert, 1996).

Numerous studies (e.g., Swink, 1998; Mofatt, 1998; Terwiesch and Loch, 1999; Abdalla, 1999; Hauptman and Hirji, 1999) indicate that the main benefit of the overlapping of development stages is to reduce product development time. Handfield (1994) in his study of 31 made-to-order-firms also found that concurrent engineered products are developed 40% faster than sequentially engineered products. In the auto industry, Clark and Fujimoto (1991) found that concurrent engineering increases product development productivity, reduces engineering change time, and cuts product development time.

2.3.2. Customer Involvement

Rather than simply delivering products to the customer, the auto industry has brought the customer closer to upstream process in the vehicle delivery process, i.e., product development. Several methods for involving the customer by capturing their input are available. This includes formal surveys, focus groups, visiting customers personally, field intelligence through repair technicians, study complaints, and Quality Function Deployment/QFD (Evans and Lindsay, 1996).

Companies use QFD to translate customer needs into design requirements, parts characteristics, manufacturing process, and finally quality plans (Evans and Lindsay, 1996). QFD improves product development in several ways. For example, the use of QFD can lead to understanding customer requirements better and prevent design errors, which, in turn, avoid costly late engineering changes (Schmidt, 1997). American Supplier Institute (1989), which is very active in promoting QFD, claims that QFD can reduce engineering changes up to 50%.

Another example is the fact that translating customer requirements into design requires cross-functional cooperation between marketing, design engineers, and manufacturing. Consequently, the use of QFD technique improves cross-functional communication and has a positive association with team performance, i.e., decision-making effectiveness (Moffat, 1998). QFD can also be used to find customer dissatisfaction and benchmark a company's products with their competitors. Thus, incorporating customer inputs in product development can lead to customer satisfaction (Gilmore and Pine, 2000).

The development of the Internet also offers a powerful way to involve customers in product development. For example, Fynch (1999) monitored the entire network of usenet groups that discuss a toolmaker's products for a full year and collected 1641 messages. He finds that the messages can be used to improve existing products and to benchmark customer satisfaction of the toolmaker's products with its competitor.

The next step in customer involvement is to customize each vehicle for each individual customer. Some companies in different industries (e.g., bicycle) have reengineered their entire supply chain to create made-to-order products whose physical dimensions fit that of each individual customer (Murakoshi, 1994). Not only do the companies satisfy the customer demand better, they also can charge a higher price for their individualized products (Balakrishnan, Kumara, and Sundaresan, 1999; Gilmore and Pine, 2000).

2.3.3. Supplier Involvement

An important aspect of supplier involvement in product development is black box engineering (Karlsson, Nallore, and Soderquist, 1998). In black box engineering, auto manufacturers give rough product specifications for product function and performance, cost target, and development time to suppliers. The suppliers then create a detailed design and deliver the product to the auto manufacturers. Fujimoto (1994), in his study of suppler relationship between Nippondenso and Toyota, argues that the ability of Nippondenso in black box engineering is an important part of the relationship.

Using data from 122 Japanese auto suppliers, Wasti and Liker (1997) generalized Fujimoto's finding that suppliers' engineering capability is an antecedent of supplier involvement. They find that suppliers' engineering capabilities have a positive association with the extent of supplier involvement. These engineering capabilities also have a positive relationship with the extent of supplier's influence on design decisions.

Involvement in black box engineering, such as in the case of Toyota and Nippondenso, should not be viewed as the only form of supplier involvement. Lesser engineering capabilities may mean a lesser role in product development. For example, Mazda provides CAD data for the surface of its door panels to Hirotec, which then designs the internal beams, manufacturers the panels, and send them to Mazda. However, higher suppliers' engineering capabilities lead to a better and more stable relationship between suppliers and auto manufacturers and a higher level of product development performance (Kamath and Liker, 1994).

Supplier involvement can benefit OEMs by, among other things, shifting part of the development time to the suppliers. This leads to a reduction of the total product development time. Most supplier involvement activities also include intense communication and problem solving activities early on in the product development activities (Liker et al., 1996). This early involvement leads to the early debugging of manufacturing problems, which, in turn, increase product integrity and reduce manufacturing costs.

Cusumano and Takeishi (1991) find that the ability of the supplier to reduce product cost correlates with supplier involvement. Product cost reduction is especially true with Japanese suppliers because they are well trained in value engineering that focuses on functional specifications in an optimal way. Value engineering can reduce 15-70% of part costs without sacrificing quality. Heizer and Render (1999) indicate that for every dollar spent on value engineering, $10 to $25 in savings can be realized.

2.3.4. Heavyweight Product Development Managers

Heavyweight product development managers are senior and powerful product development managers who can make things happen. Heavyweight product development managers improve product development performance in two ways (Wheelwright and Clark, 1995). First, because of their seniority, they have significant experience and clout to make things happen. In some cases their seniority often outranks functional managers. They also have enough power to get the people they need from different functions and to get other resources such as new equipment and funding. Second, because of their significant influence on product development teams and stages, they can direct and supervise working-level people and the entire stages of the product development project. They can create stronger identification, ownership, and commitment to the project.

In contrast to heavyweight product development managers, lightweight product development managers' main job is to coordinate product development, to collect information on the work status, and to help the functional groups solve their problem. Lightweight product development managers have no direct access to working-level people and have little power in an organization as a whole. Lightweight product development managers occur in organizations with strong functional divisions and coordinate product development activities through liaisons from each function (Clark and Fujimoto, 1991; Fujimoto, Iansiti, and Clark, 1996).

The benefits of organizing product development with heavyweight product managers instead of lightweight product development mangers are enormous. Clark and Fujimoto (1990) find that the key to product integrity is leadership from heavyweight product development managers who focus on devising processes to create powerful product concepts, and making sure that the concepts are translated into design and manufacturing process details. Clark, Chew, and Fujimoto (1987) indicate that heavyweight product development manager's lead to fewer engineering hours and shorter development lead times. Moreover, Clark and Fujimoto (1991) found that the two highest design quality auto manufacturers also have the heaviest product managers. They also found that product development activities organized by function, i.e., no product manager, tend to have more engineering hours and longer lead times. Susman and Ray (1996), in a study of 45 project teams, report positive contributions from team leader strength to teamwork performance, i.e., group process effectiveness.

2.3.5. Platform Products

In a narrow definition, a platform in the auto industry is a basic chassis of a vehicle that includes suspensions with axles and underbody such as front floor, under floor, and engine compartment. A complete chassis includes not only the basic chassis but also engine, power train, fuel tank and exhaust system (Muffato, 1998; Muffato, 1999).

The platform or chassis represents a major part of the total car cost. Gersbach et al. from McKinsey and Company (1994) provide cost data for a medium size passenger car such as the Ford Taurus and Honda Accord. From their data, the researcher calculates that a complete chassis can consume 31% of the total car cost.

The development of a totally new platform also represents a major cost in the auto industry. The development cost can be anywhere between 60% (Sundgren, 1999) to 80% (Muffato, 1999) of the total product development cost. Therefore, sharing a platform among different vehicle models lead to a substantial reduction in product cost and product development cost. For example, Ford F-150 trucks share the same platform with the Ford Expedition and Lincoln Navigator Sport Utility Vehicles (SUVs). Another illustration is that the Honda Civic sedans share the same platform with the Honda CRV SUVs.

Sharing a platform among models may result in a 50% reduction in manufacturing cost especially in welding equipment investments (Muffato, 1999).

Developing different models from common platforms is now a common practice not only in the auto industry but also in other industries. A recent interview by the researcher with an IBM chief product developer indicated that IBM learned from the auto industry how to develop platform products efficiently. Another case is found in the consumer electronics industry. Sony created almost 250 models of Sony Walkmans from only 4 platforms (Sanderson and Uzumeri, 1995). NCR's ATM (Automated Teller Machine) Division (McDermott and Stock, 1994) and Black & Decker (Meyer and Lehnerd, 1997) also use platform products. Because of the broad application of platform products that encompasses various industries, in this dissertation platform products are defined broadly as the practice of planning multiple generations of products based on a core product and process design (Koufteros, 1995).

In addition to cost benefits described earlier, platform products also offer several other advantages. By reusing similar platforms, components, and manufacturing processes instead of completely redesign them all over again, companies can reduce product development time. In the auto industry, time reduction can be as high as 30% by using the same chassis for a period of time and modifying other modules of the vehicles. Thus, product development teams do not have to deal with much higher complexity when developing new products based on the same platform because they are already familiar with this platform.

This improves team productivity (Meyer and Lehnerd, 1997; Muffato, 1999; Sundgren, 1999).

2.3.6. Information Technology Utilization

There are a wide variety of integration tools to support product development teams. One important tool is information technology. This includes Computer Aided Design (CAD), CAM (Computer Aided Manufacturing), CAE (Computer Aided Design), PDM (Product Data Management), STEP (Standard for Exchange of Product Data), simulation, and the Internet that increase the speed of information processing and problem solving (Huang and Mak, 1999; Giachetti, 1999; Park and Baik, 1999). Some of these information technology tools will be discussed below.

Moffat (1998) found that the use of simulation software has a positive association with team decision-making effectiveness and project task performance. CAE and CAD allow product development teams to cope with late engineering changes quickly and share data with other parties, which, in turn, reduces overall product development time and satisfy customer demand better by producing the product faster (Gupta and Willemon, 1990; Liker et al., 1995; and Abdalla, 1999). For example, the use of CAD/CAM systems for product development in the auto industry can reduce the time required for designing and manufacturing body die up to 25% (Sanderson, 1992).

The ISO 10303 (STEP) standard allows product data exchange to various CAD/CAM systems through a neutral file, standard application protocols, and a common database (Gu and Chan, 1996). From visiting numerous companies, the researcher finds that STEP is supported by various CAD systems such as EDS Unigraphics used by General Motors and Delphi Automotive, France's Dassault Systemes CATIA used by DaimlerChrysler and Honda, and SDRC I-DEAS used by Ford and Visteon Automotive. The U.S. auto industry advocates STEP through the Auto industry Action Group (AIAG). The benefits of STEP include the easier exchange of CAD data among different geographic location within a company and between OEM and suppliers, regardless of different CAD systems. Although STEP offers many benefits, it is not finalized yet and needs further enhancement.

The development of the Internet and the World Wide Web also brings new opportunities in product development. As an illustration of this, Philips Advanced Development Center uses the Internet to involve lead users in the development of its products. The World Wide Web can also be used to gather and analyze customer requirements. Companies that better analyze their customer inputs and incorporate them in their product design may expect to better satisfy their customers (Fynch, 1999).

2.4. Integrated Product Development Practices: the U.S. vs. Germany

Section 2.4 presents previous studies related with the differences between the U.S. and Germany in each of the IPD practices (independent variables). A similar discussion for product development performance (dependent variables) is given in Section 2.5. A summary of Sections 2.4 and 2.5 is given in Table 3. The hypotheses presented in Sections 2.4 and 2.5 are the formalization of research question no. 2 for each of IPD practice and performance variables.

2.4.1. Concurrent Engineering

Concurrent engineering is the practice of involving teams of functional specialists to simultaneously plan product and process activities. As discussed earlier. Koufteros (1995) argues that concurrent engineering consists of three subconstructs, i.e., overlapping development stages, cross-functional cooperation, and early involvement of constituents. Several researchers discussed below have studied the difference between U.S. and Germany in each of those subconstructs with varying results.

For example, Clark, Chew, and Fujimoto (1987) find that U.S. companies have a higher degree of overlapping development stages than their European counterparts. However, information transfer between the stages is more intense in Europe. They make this conclusion after studying die development for outer body panels in the auto industry.

Table 3

Previous Studies in IPD and Product Development Performance:
the U.S. vs. Germany

IPD Practices (Independent Variables)	Previous Studies	Expected Result
Concurrent Engineering	Not conclusive	No difference
Customer Involvement	U S new product managers have less involvement in concept development and interaction with customers (Clark and Fujimoto, 1991, Souder, Buisson, and Garrett, 1997, Souder and Jenssen, 1999)	Germany > U.S.
Supplier Involvement	Supplier involvement is higher in Europe (Clark and Fujimoto, 1991, Sako, Lamming, and Helper, 1994)	Germany > U.S
Heavyweight Product Dev. Mgr.	U S new product managers have more influence with engineering coordination than their European counterparts (Clark and Fujimoto, 1991)	U S > Germany
Platform Products	Not conclusive	No difference
Information Technology	No previous study	No difference
Product Development Performance (Dependent Variables)	**Previous Studies**	**Expected Result**
Teamwork Performance	Teamwork performance is better in German companies (Sorge and Warner, 1989, Gerpott and Domsch, 1985, Johne and Snelson, 1988, Souder and Jenssen, 1999)	Germany > U S.
Engineering Change Time	U.S auto manufacturers are slower in engineering change time (Clark, Fujimoto, and Chew, 1987, Fujimoto, 1989, Clark and Fujimoto, 1991)	Germany > U S
Product Cost Reduction	U.S auto manufacturers are better in product cost reduction (Sheriff, 1988, Ittner and MacDuffie, 1995)	U S > Germany
Team Productivity	Team productivity is roughly equal in the two countries (Clark, Fujimoto, and Chew, 1987, Clark and Fujimoto, 1991)	No difference
Manufacturing Cost Reduction	German manufacturing cost is higher (Gersbach et al 1994, Ittner and MacDuffie, 1995)	U S > Germany
Product Integrity	Product manufacturability that is part of product integrity is better for U.S companies (Ittner and MacDuffie, 1995)	U S > Germany
Suppliers' On Time Performance	Not conclusive	No difference
Suppliers' Quality Performance	Not conclusive	No difference
Suppliers' Cost Performance	U.S auto suppliers are better in cost performance (Birou and Fawcett, 1994)	U S > Germany
Product Development Time	Not conclusive	No difference
Customer Satisfaction	On average, European automakers satisfy their customers better (Fujimoto, Iansity, and Clark, 1996)	Germany > U S

Other researchers indicate that European companies appear to have better multi-functional cooperation than do North American companies (Gerpott and Domsch. 1985; Edgett, Shipley, and Forbes, 1992: Song and Parry, 1996). Moreover, product development teams in German firms have good cooperation across functions and with top management. This cooperation makes the development output more efficient (Campbell, Sorge, and Warner, 1989).

In respect to the early involvement of constituents, the researcher has not found any literature that compares U.S. practices with German practices. To sum up, no conclusion can be drawn to definitely determine which country is superior in all of the three concurrent engineering subconstructs.

The following hypothesis will be tested:

H.1.a. There is no difference between the mean score of the concurrent engineering level of U.S. companies and that of German companies.

2.4.2. Customer Involvement

Customer involvement is the practice of developing on-going interactions with customers to better understand their needs and wants. External communication with outsiders such as customers is important so that the product development team gains diverse opinions and inputs beyond those of the team (Katz and Tushman, 1981). In a cross-industry study described earlier, Kleinschmidts (1994) finds no differences between the degree of customer involvement between North American and European companies. However, the literature below suggests that the degree of customer involvement is lower in the U.S.

In an auto industry study, Clark and Fujimoto (1991) find that product development managers in the U.S. have less involvement in concept development with customers than their European counterparts. Other studies also indicate that U.S. product development managers have less intimacy with customers compared to product development managers from New Zealand (Souder, Buisson, and Garrett, 1997) and Scandinavia (Souder and Jenssen, 1999).

The following hypothesis will be tested:

H.1.b. There is no difference between the mean score of customer involvement level of U.S. companies and that of German companies.

2.4.3. Supplier Involvement

Supplier involvement is the practice of developing on-going interactions with suppliers to enhance their participation in product development activities. Imai, Nonaka, and Takeuchi (1985) found that extensive supplier involvement is important for product development. This involvement allows suppliers to acquire specialized skills necessary to fulfill sudden and unexpected demand quickly and effectively.

In a study mentioned earlier, Birou and Fawcett (1994) find that U.S. companies have a higher frequency and intensity of supplier involvement as well as earlier involvement in product development than do European companies. However, one must remember that their respondents are not only from the auto industry, but also from electronic and machinery industries. In contrast, two studies in the auto industry described below clearly show that the degree of supplier involvement is higher in Europe than that of in the U.S. Unfortunately, the studies below do not analyze European data by country.

Clark and Fujimoto (1991) find that on average, the auto suppliers' share of product engineering ratio for U.S. OEMs, Europe volume OEMs (e.g. VW), and European high-end specialists (e.g., BMW) are 14%, 36%, and 37% respectively. In black-box engineering described earlier, European supplier involvement is also consistently higher than with U.S. suppliers.

In a more recent study, Sako, Lamming, and Helper (1998) conducted a postal survey in Europe, Japan, and the U.S. in 1993 and 1994. They received detailed responses from over 1,400 auto suppliers. Among other things, they find that the proportions of suppliers involved in product development in Europe and in the U.S are 84% and 67%, respectively.

The following hypothesis will be tested:

H.1.c. There is no difference between the mean score of supplier involvement level of U.S. companies and that of German companies.

2.4.4. Heavyweight Product Development Manager

A heavyweight product development manager is a senior executive with substantial expertise and decision making authority to champion and direct product development efforts. Evidence in the auto industry at OEM level (Clark and Fujimoto 1991) suggests that U.S. New Product Development (NPD) managers have more influence with engineering coordination than their European counterparts. The heavyweight product development manager, who centralizes power in the NPD team, contributes to the reduced engineering hours during product development. Hout (1996) also found that the use of heavyweight product development managers by Toyota facilitated faster and higher quality product development. Heavyweight product development managers help organizations formulate product concepts and implement them coherently across organization functions such as marketing, engineering, purchasing, and manufacturing (Fujimoto, Iansiti, and Clark, 1996).

The following hypothesis will be tested:

H.1.d. There is no difference between the mean score of heavyweight product development managers level of U.S. companies and that of German companies.

2.4.5. Platform Products

Platform products designate the practice of planning multiple generations of products based on a core product and process design. This practice captures the ability of an organization to make an incremental innovation. Companies use platform products more extensively to increase the speed of the NPD process (Blackburn, 1991). Several researchers discussed below have studied the difference between U.S. and Germany in platform products using various operational constructs. The results are mixed.

For example, Clark and Fujimoto (1991) study the number of body types in a new car. They argue that the number is important and represents a fundamental variety because it requires major engineering efforts. Their findings indicate that the number of body types per new car for U.S. OEMs is 1.7, for European volume OEMs such as VW is 2.7, and for European high-end specialists OEMs such as the BMW is 1.3.

Using their data, the researcher calculated the weighted average for body types per new car for all European OEMs and found the number to be 2.2, which is higher than the number for U.S. OEMs, i.e., 1.7. Those numbers indicate the European OEMs are better in platform products.

Furthermore, Clark and Fujimoto calculate the average number of body-engine combinations per new car. They find that the average number for U.S. and European OEMs is 6 and 23, respectively. This number, again, indicates that European OEMs are better in platform products.

In addition, Clark and Fujimoto also calculate the average ratio of shared parts per vehicle. They find that that the average ratios for U.S. OEMs, European volume OEMs, and European specialist OEMs are 38%, 28%, and 30% respectively. This indicates that U.S. companies use more shared parts than those of European companies.

A newer study by Ealey, Robertson, and Sinclair of McKinsey and Co. (1996) indicate that the number of variants per light vehicle platform for the Big Three and European are 2.7 and 1.5, respectively. This indicates that U.S. companies are better. To sum up, this literature review cannot suggest which country has a higher degree of platform products because of the many different criteria used to measure platform products and no single country always excels in all of those criteria.

The following hypothesis will be tested:

H.1.e. There is no difference between the mean score of platform products level of U.S. companies and that of German companies.

2.4.6. Information Technology Utilization

Information technology utilization is the practice of employing computer and communication technologies to plan and coordinate product development activities. No literature that explicitly compares information technology utilization between U.S. and German auto industries has been found. However, some fragmented literature below indicated how information technology has been used in product development in U.S. and German companies compared with other countries.

Germany is significantly ahead in computer aided engineering tools when compared to the U.K. (Voss et al., 1996). Greenley and Bayus (1994) indicate that there is little difference in the use of computer software for product launch and elimination decisions between U.K. and U.S. companies. Compared to U.S. users. Japanese users have lower access to some high-end CAD features, less access to CAD terminals and less formal training (Liker et al., 1992). Surprisingly, unlike their U.S. counterparts, Japanese major corporations develop their own CAD software (Liker et al., 1992).

The following hypothesis will be tested:

H.1.f. There is no difference between the mean score of information technology utilization level of U.S. companies and that of German companies.

2.5. Product Development Performance: the U.S. vs. Germany

2.5.1 Teamwork Performance

Teamwork performance is the performance of individuals as a group when working together towards a common goal (Leonard-Barton, 1992; Pinto, Pinto, and Prescott, 1993). Some may argue that teamwork is an independent variable of the product development performance. However, in this dissertation, the extent of teamwork in a way is measured by concurrent engineering, which is an independent variable. Secondly, this section is discussing teamwork performance, not teamwork per se. Furthermore, teamwork performance has been used by other researchers as dependent variables of integrated product development practices. For example, Susman and Dean (1992) and Emmanuelides (1993) argue that the cross-functional nature of concurrent engineering improves the decision-making effectiveness of the product development team by considering a problem from various perspectives. The use of information technology tools also speeds up the problem solving cycles of the product development team (Huang and Mak, 1999; Giachetti, 1999; Park and Baik, 1999; Rezayat, 2000b). The literature review below suggests that teamwork performance is better in Germany than that found in the U.S.

Gerpott and Domsch (1985) indicate that teamwork performance is better in Germany than that found in the U.S. They find that the strong professionalism of R&D people in the U.S. separates this group from manufacturing or other functions in an organization. In contrast, in Germany, functional integration of all functional areas makes teamwork performance higher.

Comparison between U.S. and other culture also indicates that U.S. product development teams have low teamwork performance. As an illustration, Souder and Jenssen (1999) indicate that U.S. product development teams have less spontaneous collaboration, less mutual assistance, and less shared responsibilities than those of Scandinavia. On the contrary, several studies consistently indicate that German product development teams have a higher teamwork performance than that of other cultures. For instance, Johne and

Snelson (1988) and Campbell, Sorge, and Warner (1989) indicate that cross functional team cooperation and top management involvement in product development are better in Germany than in the U.K. All those studies confirm Gerpottt and Domsch's (1985) findings, i.e., U.S. has a low level of teamwork performance and Germany has a high level of teamwork performance.

The following hypothesis will be tested:

H.1.g. There is no difference between the mean score of teamwork performance level of U.S. companies and that of German companies.

2.5.2 Engineering Change Time

Engineering change of an existing product is the modification of some aspect of the product's definition or documentation (Blackburn, 1991). The time required to modify it is called engineering change time. Engineering change can occur through some medium such as an engineering drawing or a bill of material (Heizer and Render, 1999). Engineering changes are very common in manufacturing companies, not only in the auto industry. For example, Boeing faced 12,000 engineering changes on its first 767 aircraft (Garvin, 1991). Engineering may be attractive in some perspectives such as matching competitor's innovation. However, it may cause disruption in manufacturing such as obsolesce of certain components, inventory fluctuation, schedule changes, and production delay (Balakrishnan and Chakravarty, 1996). Therefore, successfully managing engineering changes is very critical in manufacturing companies. Several studies discussed below indicate that European companies are better in engineering change time than their U.S. counterparts.

Clark, Chew, and Fujimoto (1987), Fujimoto (1989), Clark and Fujimoto (1991) suggest that U.S. auto manufactures are slower in engineering change time than their German counterparts. They find that the U.S. companies spend less time to thoroughly refine design and debug problems at the initial stages of product development (e.g., product engineering) resulting in more complex problems at later stages (e.g., production start-up). Such late engineering changes by U.S. companies drive a higher engineering change cost. They estimate that the engineering change cost as the share of total die cost is 30-50% for U.S. OEMs and 10-30% for European OEMs.

The following hypothesis will be tested:

H.1.h. There is no difference between the mean score of engineering change time of U.S. companies and that of German companies.

2.5.3. Product Cost Reduction

Product cost reduction construct measures the success level of the process carried by the product development team to reduce product costs (Clark, 1989). In Germany, product cost reduction is fostered by R&D department, while in the U.S it is fostered by marketing (Gupta et al., 1992). There is no previous study that directly compares U.S. product development teams and German product development teams on product cost reduction. However, the researcher argues that project or parts complexity can be a proxy of product cost. Higher complexity leads to a potentially higher product cost. Two studies indicating that U.S. companies are better in product cost reduction will be discussed below.

Sheriff (1988) studies product development using publicly available data and surveys to all major auto manufacturers in the U.S., Japan, and Europe. Among other things, he studies project complexity that is measured at car level. He calculates the product development project complexity index for a new car from numerous subjective values of exterior changes, interior changes, and platform changes from a pervious model. For examples, he gives a value of 20 for changes in seats and door panels. He then adjusts upward the sum of the values for each additional body style and wheelbase. He concludes that European product development projects have the highest project complexity when compared to their Japanese and U.S. counterparts.

In another study, Ittner and MacDuffie (1995) measure parts complexity using various criteria such as component variation and assembly requirements. They used a scale ranging from 0 (not complex) to 100 (very complex). Their analysis indicates that the complexity in European vehicles and U.S.'s North American vehicles are 69.95 and 41.42, respectively. Therefore, it may be suggested that European companies have higher product cost than that of U.S. companies.

The following hypothesis will be tested:

H.1.i. There is no difference between the mean score of product cost reduction level of U.S. companies and that of German companies.

2.5.4. Team Productivity

Team productivity measures the amount of work that can be done considering the resources used (Sheriff, 1988). Clark and Fujimoto (1991) use two variables to measure productivity, i.e., engineering hours and lead time. Some may argue that those two variables only measure output regardless of the resources or input used. Therefore, it is reasonable to also consider the resources used such as the number of people in a product development team as an input variable. The findings discussed below indicate that those three variables (i.e., engineering hours, lead time, and the number of people in a product development team) are nearly equal in the U.S. and Europe. Thus, the findings suggest that team productivity in the two regions is at the same level.

Clark and Fujimoto (1991) find that the average engineering hours per new car for U.S. OEMs, European volume OEMs such as VW, and European specialist OEMs such as Mercedes-Benz are 3.5 millions, 3.4 millions, and 3.4 millions, respectively. Those numbers indicate that the average engineering hours are roughly equal. With respect to product development lead time, they find that the lead time for U.S. OEMs (6 projects), European volume OEMs (7 projects), and European specialist OEMs (4 projects) are 61.9 months, 57.6 months, and 71.5 months, respectively. From their data, the researcher calculates that the weighted average lead time for all eleven European projects is 62.65 months. This number roughly equals with seven U.S. projects, i.e., 61.9

months. Moreover, the average number of product development people involved in a car is roughly equal in the two regions, i.e., for U.S. OEMs is 903 people and for European OEMs is 904 people (Clark, Chew, and Fujimoto, 1987). All those numbers indicate that team productivity is roughly equal in the U.S. and Europe.

The following hypothesis will be tested:

H.1.j. There is no difference between the mean score of team productivity level of U.S. companies and that of German companies.

2.5.5. Manufacturing Cost Reduction

A typical auto manufacturing process consists of five operations, i.e., stamping, welding, painting, assembly, and finally final testing (Gersbach et al., 1994). The first three operations are mostly automated and may represent 20% of the total employees in a plant. The last two operations are usually labor intensive and may account for 80% of the total employees. Added together, those five manufacturing operations may take about 25% of the total car cost excluding development cost (Mercer, 1994). Because of such a high portion, manufacturing cost reduction is important to achieve a cost advantage in the auto industry. An interview with an auto industry veteran also indicates that the manufacturing cost is a primarily criteria for evaluating plant managers.

Unfortunately, it is not easy to collect data on manufacturing costs in each company because the company considers this a confidential data. Therefore, several researchers use other variables as a proxy of manufacturing costs. Their studies described below suggest that German manufacturing costs are higher than that of the U.S.

Ittner and MacDuffie (1995) use data from 62 automobile plants collected from MIT International Vehicle Program (IMVP) to examine the extent to which various cost drivers account for plant-level differences in manufacturing overhead. They use labor hours as a proxy of manufacturing cost. They find that European factories use 14.09 indirect labor hours and 25.76 direct labor hours to produce one vehicle. The numbers are lower for U.S. factories in North America, i.e., 9.66 indirect labor hours and 17.52 direct labor hours for one vehicle. Therefore, they suggest that the U.S.'s North American factories have lower costs than do their European counterparts.

Gersbach et al., (1994) estimated that the labor productivity index in the U.S., German, and Japanese auto industry is 100, 116, and 66, respectively. They use the U.S. as an anchor by giving 100 for its productivity index. Similar to Birou and Fawcett (1994), they also argue that U.S. productivity is higher than that found in Germany because the U.S. is more exposed to industry leaders from Japan. International competition is also more prevalent in the U.S. than in Germany. Those two factors force U.S. companies to increase labor productivity and to reduce manufacturing cost more effectively than their German counterparts.

The following hypothesis will be tested:

H.1.k. There is no difference between the mean score of manufacturing cost reduction level of U.S. companies and that of German companies.

2.5.6. Product Integrity

Product integrity measures the consistency among a product's function, its structure, and its assembled components (Womack et al., 1990). Product integrity can be achieved by cross-functional coordination of the company and it supplier. Manufacturability, or how ease a product can be manufactured or assembled, is part of product integrity. A study by Krafcik (1990) described below does not indicate which region has products with better manufacturability. However, the Ittner and MacDuffie's study (1995), which is also explained below, suggests that North American vehicles have a higher degree of manufacturability.

Krafcik (1990) finds some Japanese auto manufacturers such as Toyota and Honda are clearly superior in the manufacturability of their products. However, it is not clear if U.S. auto companies are better than German companies in this area. For example, Ford is ranked higher than Volkswagen. However, VW is ranked higher than GM. This may lead to the conclusion that product integrity depends more on company rather than regional characteristics.

Instead of ranking the companies, Ittner and MacDuffie (1995) analyze data from 62 automobile plants geographically. They argue that design age can be used as a crude proxy for manufacturability because current products are designed with better manufacturability than older products. They find that European auto companies and North American auto companies have 4.74 and

4.50 years of design age. Therefore, they conclude that North American vehicles have better manufacturability than their European counterparts.

The following hypothesis will be tested:

H.1.I. There is no difference between the mean score of product integrity level of U.S. companies and that of German companies.

2.5.7. Suppliers' On-Time Performance

The importance of suppliers' on-time performance cannot be underestimated in product development. OEM development engineers indicate that their number one concern is suppliers' on-time performance (Fitzgerald, 1997). Unfortunately, because of the conflicting findings among Ittner et al. (1999), Birou and Fawcett (1994), and Nishiguchi (1989) described below, one cannot make conclusive findings related with suppliers' on-time performance differences between the two countries.

For example, Ittner et al. (1999) conducted a survey for 249 automotive and computer manufacturing companies in Canada, Germany, Japan, and United States. They find that German companies put a higher emphasis on suppliers' on-time performance than their U.S. counterparts. Their findings do not support the findings from Birou and Fawcett (1994) and Nishiguchi (1989) stated below.

Birou and Fawcett (1994) analyze surveys from 133 U.S. product development managers and 83 European product development managers from various industries such as automotive, electric/electronic, and machinery. They find that U.S. companies rate their suppliers' due date performance and suppliers' concept-to-market performance higher than German companies do.

Nishiguchi (1989) conducts a survey in 44 auto suppliers around the world. He finds that the proportion of auto parts delivered just in time in the U.S., Europe, and Japan are 14.8%, 7.9%, and 35.4%. These numbers suggests that the U.S. is better than Europe. However, Nishiguchi only measures suppliers' product delivery time. He does not measure suppliers' product development time.

The following hypothesis will be tested:

H.1.m. There is no difference between the mean score of suppliers' on-time performance level of U.S. companies and that of German companies.

2.5.8. Suppliers' Quality Performance

Numerous studies (e.g., American Supplier Institute, 1989; Cusumano and Takeishi, 1991; Curkovic, Vickery, and Droge, 2000) indicate the importance of suppliers' quality performance in product development. Unfortunately, the literature reviewed below indicates conflicting evidence regarding the differences between the U.S. and Germany in suppliers' quality performance. Nishiguchi (1989) conducts a survey of 44 auto suppliers around the world. He finds that that component defects per 100 cars for the U.S., Europe, and Japan are 33, 62, and 24. Therefore, he suggest that U.S. suppliers are better than European suppliers in quality performance. He also finds that Japanese auto suppliers are significantly ahead in die change times, lead time for new dies, and number of machines per workers compared with those in the U.S. and Europe. In contrast to Nishiguchi (1989), Ittner et al. (1999) using a subjective measure find that German companies put more emphasis on the importance of suppliers' quality performance than their U.S. counterparts.

Birou and Fawcett (1994), in a study described earlier, analyze surveys from 133 U.S. product development managers and 83 European product development managers from various industries such as automotive, electric/electronic, and machinery. They find that suppliers' quality performance is higher in the U.S. However, this difference is not significant.

The following hypothesis will be tested:

H.1.n. There is no difference between the mean score of suppliers' quality performance level of U.S. companies and that of German companies.

2.5.9. Suppliers' Cost Performance

Purchases from suppliers are a major part of the cost of vehicles. For example, Ford Motor Company purchases make up about half of its vehicles' cost, excluding suppliers' role in building and factory equipment (Gilmour, 1991). Therefore, the cost of incoming materials from suppliers is a critical element of an auto manufacturer' cost advantage over other auto manufacturers. Consequently, suppliers are under pressure by OEMs to cut their costs by 3 – 10% each year (Milligan, 2000). The pressure is not only felt by Tier 1 suppliers, but also by Tier 2 and 3 suppliers so that the higher level tier can pass the cost reduction to their customers

Among the Big Three automakers, Chrysler is the most aggressive company that seeks cost reduction from its suppliers through the Supplier Cost Reduction Efforts (SCORE) Program, which was introduced in 1992. Within the first three years after its introduction, a total of 5,300 cost reduction ideas were generated by the SCORE program and saved Chrysler $1.7 billion (Dyer, 1996).

Birou and Fawcett (1994), using the data described earlier, conclude that U.S. companies rate their suppliers' cost performance higher than do their German counterparts. This may indicate that U.S. companies are better in suppliers' cost performance.

The following hypothesis will be tested:

H.1.o. There is no difference between the mean score of suppliers' cost performance level of U.S. companies and that of German companies.

2.5.10. Product Development Time

Product development time is the time required from product concept to product introduction (Stalk, 1988; Gupta, Brockhoff, and Weisenfeld, 1992). Product development time is among the most important performance criteria in new product development activities. Clark, Chew, and Fujimoto (1987) indicate that each day of delay in introducing a new $10,000 car may reduce the profitability of a company by $1 million. It is not clear, however, that U.S. companies develop products faster than German auto companies.

From the data found in Clark and Fujimoto (1991) described earlier, the researcher calculates that the mean lead time for all eleven European projects in their study is 62.65 months. This number is roughly equal with all seven U.S. projects, i.e., 61.9 months. Additionally, the variability of the mean is high. The range of the lead time for U.S. auto companies is between 50.2 months to 77.0 months whereas for European auto companies it is between 46.0 months to 97.0 months. Therefore, there is not enough evidence to say which region has a better product development time performance.

The following hypothesis will be tested:

H.1.p. There is no difference between the mean score of product development time of U.S. companies and that of German companies.

2.5.11. Customer Satisfaction

Customer satisfaction measures the satisfaction of the customer for the product designed in a certain target market (Cooper and Kleinschmidt, 1987). Customer satisfaction is important for most companies for several reasons. First, attracting new customers is more expensive than retaining existing customers. Moreover, satisfied customers mean lower handling cost in managing customer complaints, lower warranty costs, and can help a company get new customers. Finally, the transaction cost can also be lowered if a company can take advantage of the economic scale of the current customer base (Sharma, Niedrich, and Dobbins, 1999).

In the auto industry, Fujimoto (1989), Clark and Fujimoto (1991), and Fujimoto, Iansitity, and Clark (1996) measure customer satisfaction using several variables including total quality design, repurchase intentions of customers, and a subjective evaluation by auto magazine experts. They find that U.S. OEMs satisfy customers at the same level as European volume OEMs such VW. However, European high-end specialists OEMs such as BMW and Mercedes Benz satisfy their customers better. This may suggest that on average European companies satisfy customers better than do their U.S. counterparts.

The following hypothesis will be tested:

H.1.q. There is no difference between the mean score of customer satisfaction level of U.S. companies and that of German companies.

2.6. Integrated Product Development Practices and Performance: OEMs vs. Auto Suppliers

The literature review in Sections 2.1 to 2.5 suggest that there were still significant differences among countries in the extent to which they have implemented integrated product development practices. Since a decade ago companies in each country have made efforts to integrate their product development activities and to facilitate the adoption of these practices across their supply chain. Surprisingly, no researcher has deeply conducted a large scale comparative study of IPD practices and performance between OEMs and auto suppliers. However, some fragmented studies below deserve attention.

Clark (1989) and Clark and Fujimoto (1991) estimate the percentage of off-the-shelf parts as opposed to newly designed parts. They find that the percentage for U.S., European, and Japanese auto projects are 38%, 30%, and 18%. The low percentage for the Japanese projects theoretically may increase product development time because the Japanese must do more designing. Strangely, the reverse is true. Japanese OEMs are able to reduce product development time by involving suppliers more extensively in product development. Clark also finds that Japanese supplier engineers work more efficiently than do OEM engineers when the suppliers are involved in product development.

As discussed earlier, one important part of supplier involvement is black-box engineering. In this kind of involvement, OEMs give rough product specifications for product function and performance, cost target, and development time to suppliers. The suppliers then create detailed design and deliver the product to OEMs (Karlsson, Nallore, and Soderquist, 1998). Fujimoto (1994) traced the history of supplier involvement particularly black-box engineering from World War II. He finds that Toyota was forced to rely on its suppliers, i.e., Nippondenso, because the American Occupational Authority had requested Toyota to split Nippondenso away from Toyota. The split reduced Toyota engineering capabilities. Therefore, Toyota had no way to survive except involving Nippondenso early on in the product development to borrow

Nippondenso's engineering and technical know how. Like earlier research (e.g., Clark and Fujimoto, 1991), Fujimoto (1994) indicate that supplier (i.e., Nippondenso) engineering capability is higher than that of OEM (i.e., Toyota).

Instead of studying the supplier relationship between only two companies like the one conducted by Fujimoto (1994), Nishiguchi (1989) surveys 44 matching auto suppliers consisting of 18 North American, 18 European, and 18 Japanese auto suppliers. Among other things, he studies die change times, machines per workers, inventory levels, and number of daily JIT deliveries. He concludes that regional differences exist, i.e., Japanese suppliers are better than North American and European suppliers. This result mirrors similar studies from MIT International Motor Vehicle Program for OEMs, such as the one reported by Lamming (1989). Those MIT studies also conclude that Japanese OEMs are better than their North American and European counterparts. Despite results from Nishiguchi (1989) and Lamming (1989), some cautionary notes must be taken. First, although regional differences exist, they do not compare OEMs versus auto suppliers using the same variables. Secondly, the variables that they use mostly are manufacturing variables, not product development variables.

With regards to German auto suppliers, Thompson and Strickland (1992) suggest that German auto suppliers are big suppliers that have high technical capabilities that produced well-engineered and high-quality components. They maintain high quality R&D teams and participated broadly in joint R&D with their customers. Their findings are supported by the researcher's interview with a product development veteran who has been working in both Germany and the

U.S. The veteran indicated that because of the high technical capabilities of German auto suppliers, some times the suppliers are able to dictate to German OEMs on how to accommodate the suppliers' products into a vehicle design due to inherent technical advantage of the products or components.

Although some findings discussed above (Clark and Fujimoto, 1991; Fujimoto, 1994) suggest that some Japanese and German auto suppliers have a higher engineering capability than OEMs, several considerations must be made before making any conclusion. First, supplier engineering capability per se is not studied in this dissertation. Several studies discussed earlier (e.g., Kamath and Liker, 1994; Wasti and Liker, 1997) indicate that the supplier engineering capability is an antecedent of supplier involvement, one of IPD practices. It is not the objective of this dissertation to collect data related with the antecedents of IPD practices.

Second, while it may be true that suppliers have more engineering capabilities to design certain components, it is not clear if OEM engineers as an overall group is less capable than are supplier engineers. Developing a vehicle involves not only components but also more complex products such as subassemblies, modules, and finally the whole vehicle, areas in which many auto suppliers may not be capable.

Third, OEMs have more resources than auto suppliers. Therefore, the lack of resources may hamper auto suppliers in carrying out certain product development practices such as information technology utilization, something that requires investment. A recent visit by the researcher to the Auto Industry Action

Group (AIAG) suggests that not all Tier 1 suppliers have 3-Dimension CAD systems nor design engineers who can do complex numerical analysis. This lack of resources may lower product development performance.

Fourth, with respects to product development at OEMs, customer involvement means involving auto customers whereas supplier involvement means involving Tier 1 suppliers. On the other hand, customer involvement for Tier 1 suppliers means involving OEMs whereas supplier involvement means involving Tier 2 suppliers. Those differences in external environments may result in different practices and performance. Consequently, some variables such as supplier involvement, customer involvement, and supplier performance that are critical in studying product development differences between OEMs and suppliers must be interpreted cautiously.

To assess the difference between auto manufacturers/original equipment manufacturers/OEMs and auto parts suppliers in IPD practices and performance as well as assessing the progress of the adoption of IPD practices across the auto industry supply chain, the researcher tested the following hypotheses:

H.2.a. There is no difference between the mean score of concurrent engineering level of auto manufacturers and that of auto parts suppliers.

H.2.b. There is no difference between the mean score of customer involvement level of auto manufacturers and that of auto parts suppliers.

H.2.c. There is no difference between the mean score of supplier involvement level of auto manufacturers and that of auto parts suppliers.

H.2.d. There is no difference between the mean score of heavyweight product development managers level of auto manufacturers and that of auto parts suppliers.

H.2.e. There is no difference between the mean score of platform products level of auto manufacturers and that of auto parts suppliers.

H.2.f. There is no difference between the mean score of information technology utilization level of auto manufacturers and that of auto parts suppliers.

H.2.g. There is no difference between the mean score of teamwork performance level of auto manufacturers and that of auto parts suppliers.

H.2.h. There is no difference between the mean score of engineering change time of auto manufacturers and that of auto parts suppliers.

H.2.i. There is no difference between the mean score of product cost reduction level of auto manufacturers and that of auto parts suppliers.

H.2.j. There is no difference between the mean score of product cost reduction level of auto manufacturers and that of auto parts suppliers.

H.2.k. There is no difference between the mean score of manufacturing cost reduction level of auto manufacturers and that of auto parts suppliers.

H.2.l. There is no difference between the mean score of product integrity level of auto manufacturers and that of auto parts suppliers.

H.2.m. There is no difference between the mean score of suppliers' on-time performance level of auto manufacturers and that of auto parts suppliers.

H.2.n. There is no difference between the mean score of suppliers' quality performance level of auto manufacturers and that of auto parts suppliers.

H.2.o. There is no difference between the mean score of suppliers' cost performance level of auto manufacturers and that of auto parts suppliers.

H.2.p. There is no difference between the mean score of product development time of auto manufacturers and that of auto parts suppliers.

H.2.q. There is no difference between the mean score of customer satisfaction level of auto manufacturers and that of auto parts suppliers.

The next chapter discusses the research methodologies that were used to develop measuring instruments and then test the hypotheses above.

CHAPTER 3

RESEARCH METHOD

The items that were used to measure integrated product development practices had been developed and tested for reliability and validity by Koufteros (1995). Therefore, in the first stages of this research (item generation and pilot study). the researcher developed instruments to measure product development performance only. The pilot study method described in Section 3.2. was conducted only in the U.S. After the pilot study, a large sample survey was conducted both in the U.S. and Germany. The data set from each country was then divided by the position in the auto industry supply chain, i.e.. OEM and auto parts supplier as seen in Table 4.

Table 4

Data Set for Large Scale Study

Position in the Supply Chain	Country	
	US	Germany
OEM	x	x
Auto Supplier	x	x

OEM = Original Equipment Manufacturer
= Auto Manufacturer

x = Data

3.1. Measurement Properties

Following Nunnally (1978), Churchill (1979), Cook and Campbell (1979) Venkatraman (1989), and Sethi and King (1994), reliability and validity were checked when developing the instrument. Reliability is measured by the degree of which the measuring instrument is free from error and therefore has a consistent result. Validity is the degree to which the instrument really measures what is intended. If an instrument is valid, then it is reliable, but not vice-versa.

The most popular indicator of reliability is Chronbach's alpha. The square root of alpha is the estimated correlation of the k-item test with errorless true scores. An alpha of more than 0.80 is sufficient. Venkatraman (1989) argues that reliability assessment is part of evaluating the internal consistency of construct operationalization. Another way to measure internal consistency is through testing the unidimensionality of the construct. Unidimensionality refers to the existence of one latent construct underlying a set of measuring items. Unidimensionality can be assessed through LISREL's Confirmatory Factor Analysis (CFA) fit indices that will be described later.

Validity can be evaluated in many ways: face validity, content validity, convergent validity, discriminant validity, and nomological validity. Face validity measures the match between operational and conceptual definitions. Content validity is very similar to face validity but the focus is on the items that measure a construct. Both face validity and content validity can be achieved by a thorough review of existing literature and a series of interviews with experts on the subject being studied.

Convergent validity measures the consistency of an instrument across multiple operationalizations. Both Venkatraman (1989) and Sethi and King (1994) use LISREL' CFA fit indices to measure both convergent validity and unidimensionality described earlier. Discriminant validity is demonstrated when a measure differs significantly from others. If the sample size is large like in the large-scale study, LISREL's discriminant analysis is used. However, LISREL software cannot work with a small sample size like the one in the pilot study. Therefore, an item correlation matrix was used. Both LISREL's discriminant analysis and item-correlation matrix will be discussed in detail later.

Finally, nomological validity checks the relation of a set of constructs with others. In this spirit, predictive validity using a construct correlation matrix was utilized to check if there is a correlation between one construct and other constructs that are judged to be related.

3.2. Pilot Study Method

Traditionally, exploratory techniques were only used in the pilot study (exploratory) stage of the instrument development and confirmatory techniques were only used in the confirmatory stage. Unlike traditional pilot study analyses that only use exploratory factor analysis, the researcher used both confirmatory and exploratory techniques. The following paragraphs describe the background information related with those two techniques

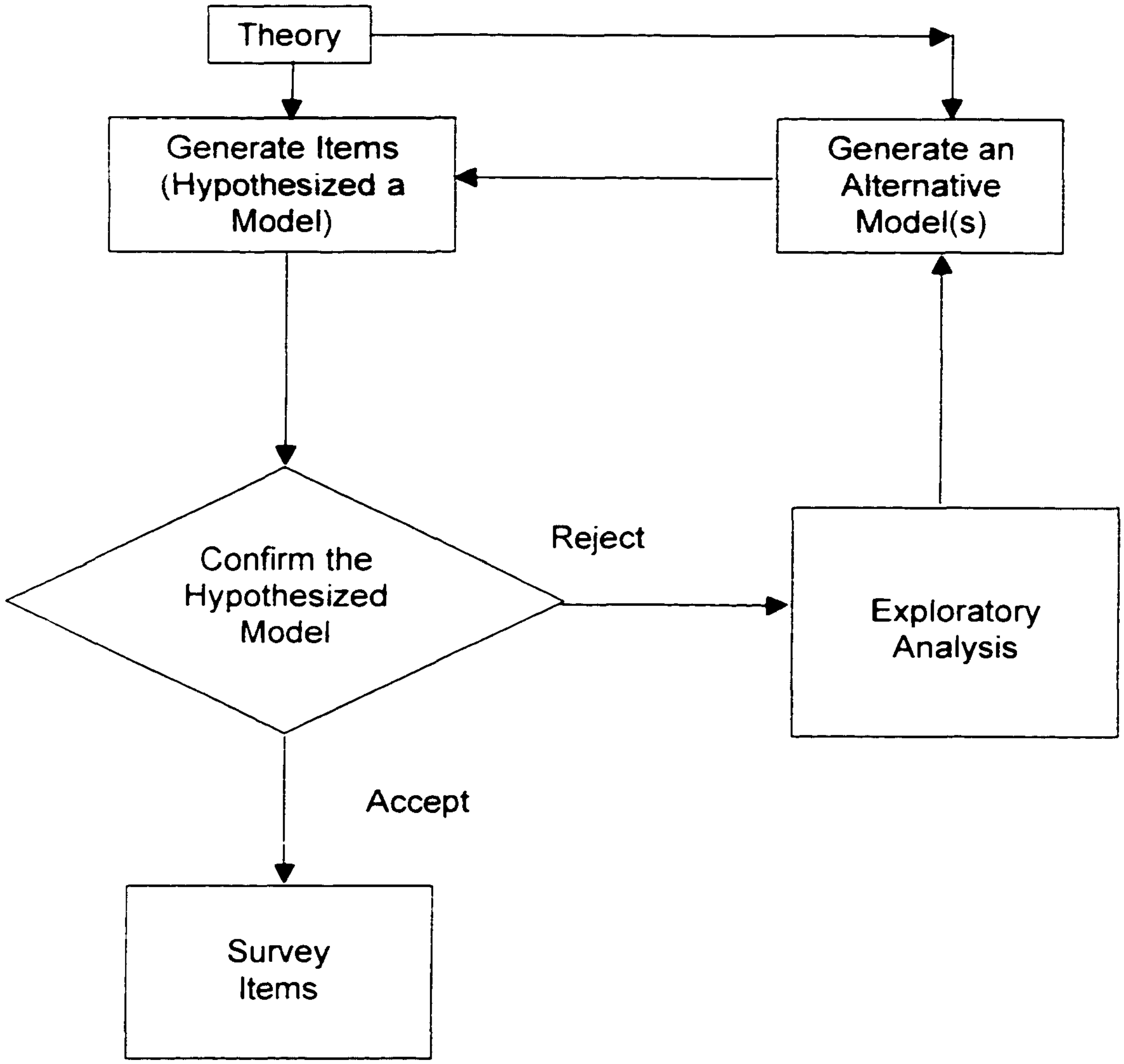
The traditional instrument development method relies on a domain sampling theory. i.e.. researchers should have items that capture each aspect of the construct that is being measured. A common tool for this traditional method is exploratory factor analysis (EFA). The key trait that must be achieved in EFA is a simple factor structure. i.e., having high loading on one factor or dimension while having low cross-loadings on other factors (Churchill, 1979). However, factor analysis has a limitation. Factor analysis does not estimate error terms because factor loadings contain both trait (true scores) and errors. Therefore, researchers do not know if error terms are correlated.

In contrast to EFA. Structural Equation Modeling (SEM) tools such as Linear Structural Relationship (LISREL) provides an estimate of both factor loadings and error terms (Joreskog and Sorbom, 1996). If the error terms are uncorrelated. adding the items together will cancel out the error terms. Correlated error terms mean that the terms share unidentified common factor(s). Items that have correlated error terms are modified or deleted as necessary. Figure 2 shows the research cycle used in this pilot study stage and the research cycle description is laid out below.

First, a theoretical foundation based on a review of available literature was used for generating items to match the eleven product development performance variables mentioned in Chapter 2. Possible items were drawn from major literature items related to product development including Cooper and Kleinschmidt (1987), Sheriff (1988), Womack et al. (1990), Krafcik (1990), Clark and Fujimoto (1991), Blackburn (1991), Cusumano and Takeishi (1991),

Figure 2

Model Generating Process for Pilot Study Analysis



Kleinschmidt (1994), Birou and Fawcett (1994), Khuri and Plevyak (1994), Brown and Eisenhardt (1995), Song and Parry (1996), Ponticel (1996), Cusumano and Nobeoka (1996), Fujimoto, Iansiti, and Clark (1996), Izuchukwu (1996), and Nishiguchi (1996). The researcher also conducted open-ended interviews with employees from auto related companies such as Ford Motor Company, 3M, Delphi Automotive, DaimlerChrysler, and TRW. A set of product development performance items was then generated using the five-point Likert scale where 1 = strongly disagree, 2 =disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

Five professors in the College of Business Administration and the College of Engineering at the University of Toledo then checked the items for product development performance variables. Six fellow Ph.D. students in Manufacturing Management and Mechanical Engineering also checked the items. After that, the items were pre-tested by eight product engineers and managers from Visteon Automotive (an enterprise of Ford Motor Company), Dana Corporation, Ford Motor Company, Alcoa, and Meritor Automotive (formerly Rockwell Automotive). The objectives of the rigorous procedure that was mentioned above are brevity, understandability, and content validity of items generated from the literature review (Kerlinger 1973). The items were modified, deleted, and added as necessary. Appendix I shows the pilot study items.

These items were hypothesized to measure product development performance variables (constructs). Using the pilot study data, the initial hypothesized measurement model for all items in each construct was tested using LISREL. A confirmatory factor analysis (CFA) method used by Bagozzi and Yi (1988) was utilized to assess the hypothesized model for each construct.

First, the hypothesized model should pass preliminary fit criteria such as the absence of negative error variances, correlation greater than one, and very large standard errors. If these problems arise, then model specification and input must be checked. Next, overall model fit indices were checked. No statistic is universally accepted as an overall model fit index. Therefore, several model fit indices were used. These included chi-square statistic, root mean square error of approximation (RMSEA), expected cross validation index (ECVI), Non-Normed Fit Index (NNFI), and Comparative Fit Index (CFI). The next paragraphs discuss each of the model fit indices that can be grouped into three classes (Hair, Anderson, Tatham, and Black, 1998).

The first class of model fit indices measure the absolute fit of the model to the data such as the likelihood-ratio chi square statistics and root mean square error of approximation (RMSEA). Chi-square measures the deviation between the sample covariance matrix and the fitted covariance matrix. An acceptable model is the one that has the p-value of greater than or equal to 0.05. However, it must be interpreted carefully because its dependence on sample and sensitivity to departures from multivariate normality (Bollen, 1989). For example, in large samples even a small deviation can lead to the rejection of any model size (Kline, 1998).

One way to overcome this problem is to use another fit index that takes particular account of the departure from multivariate normality such as by using

Root Mean Square Error of Approximation (RMSEA) as a measure of discrepancy per degree of freedom. A value of 0.05 indicates a close fit (Joreskog and Sorbom, 1996).

Another class of model fit indices is incremental fit indices in which a hypothesized model is compared with a baseline model, usually the independence model. One such index is the Tucker-Lewis' (1973) Comparative Fit Index (CFI) that is a normed relative non-centrality index and calculates each non-centrality parameter by the difference between its T statistics and the corresponding degree of freedom. CFI ranges from 0 (no fit at all) to 1.0 (perfect fit). A CFI of 0.9 is considered good (Hair et al., 1998). Bentler and Bonnet's (1980) non-normed fit index (NNFI) is an extension of Tucker-Lewis' CFI to all types of covariance structured models. An NNFI value of more than 0.90 indicates a good fit. NNFI is not affected by the sample size (Doll, Hendrickson, and Deng, 1998).

The last class of model fit indices is parsimonious fit indices that consider not only fit but also compare the models on the basis of some criteria that takes parsimony, i.e., number of parameters, into account. Expected Cross Validation Index (ECVI) belongs to this class. ECVI measures the deviance between the fitted covariance matrix in the analyzed model and the expected covariance matrix if one is able to obtain another sample with the same size. ECVI is a relative fit index. The lowest score indicates the best chance of cross validation (Joreskog and Sorbom, 1996).

In addition to LISREL model fit indices, Chronbach's alpha was used to measure the reliability of the hypothesized model. High reliability, i.e., more than 0.9, indicates that the model is repeatable, has a high component of true score, and low component of random error (Nunnaly, 1978). In addition, an item that has a low Corrected-Item Total Correlation (CITC) would be considered for deletion before submitting a model to SPSS's Exploratory Factor Analysis (EFA).

An EFA exploratory factor analysis (EFA) was conducted to check dimensionality and factor pattern. Because dimensions were assumed to be correlated, oblique rotation was used. Based on CFA and EFA, an alternative model (i.e., a model with fewer items) was generated. Items that had a low individual squared multiple correlation (SMR) but a high correlation and high Modification Index (MI) between the items were considered for elimination. An MI of 3.84 or higher indicates that a statistically significant reduction in the chi-square is obtained when the coefficient is estimated. This process was continued until the best fitting model that makes theoretical sense was found.

The next step after CFA and EFA described in Figure 2 above was to test for discriminant validity between each pair of product development performance constructs (variables). Discriminant validity measures the ability of measurement items to differentiate among constructs being measured. As suggested earlier, SEM could not be used at this pilot study stage because the sample size was too small. Therefore, the correlation matrix was used. Violations in the correlation matrix occur when an item is more correlated with items measuring another construct than with the items measuring its intended construct Campbell and Fiske (1959).

3.3. Pilot Study Results

The mailing list containing the names of the professionals was provided by a professional society that prefers to remain anonymous. The mailing list from the professional society identifies the respondents who work in the product development area, such as vice president of engineering, director of research and development, product development manager and product development engineers. A total of 300 professionals were selected. The pilot study questionnaires were mailed twice, three weeks between each mailing. Thirty-three usable responses were received resulting in a response rate of eleven percent. A ten percent response rate is typical for a long survey involving senior management.

A detailed step-by-step analysis for each construct using the method described in Section 3.1. is shown in Appendix II. In addition to suggesting a set of constructs with good fit indices, the analysis in Appendix II also suggests that two constructs must be split. First, product-cost reduction was initially thought of as a single construct. The analysis indicated that it should be split into two constructs, i.e., product cost reduction and manufacturing cost reduction. Second. suppliers' performance was conceptualized as a single construct. The analysis indicated that this construct consisted of several constructs. The modification of these constructs will be discussed after discussing the results of discriminant analysis and reliability analysis as shown in Table 5 and Table 6, respectively.

A series of discriminant validity tests was conducted for the remaining items after CFA and EFA from the pilot study analysis in Appendix II. Table 5 reports the item correlation matrix and discriminant validity test. Manufacturing cost reduction and supplier performance constructs were not included in the table because those two constructs were restructured for the large-scale study. The next paragraph describes an example on how to read the discriminant validity tests in Table 5.

As can be seen in Table 5, the remaining engineering change time (EC) construct after CFA and EFA consists of four items, i.e., EC5, EC7, EC8, and EC10. The lowest correlation (r) happens between EC5 and EC8, which is 0.458. This lowest correlation should be higher than a correlation between any EC and any other items that does not belong to EC, otherwise a violation happens. In the first column, violation happens between EC5 and three items, i.e., TW2 (r = 0.506), IP8 (0.473), and PF11 (0.501). Thus, item EC5 has three counts of violation. The number of non-EC items, i.e., from TW1 to PF11, is 29. Half of this number is 14.5. Three counts of violation are less than 14.5. Therefore, item EC5 passes the discriminant validity test. The rest of the items follow the same method for assessing the discriminant validity. The violation counts in Table 5 indicates that none of the counts for each item exceed half the

Table 5

Item Correlation Matrix and Discriminant Analysis
(Pilot Study)

Construct	Engineering Change				Teamwork Performance					Team Productivity				Product-Cost Reduction				Product Integrity				
Item	**EC5**	**EC7**	**EC8**	**EC10**	**TW1**	**TW2**	**TW4**	**TW5**	**TW8**	**TP1**	**TP2**	**TP6**	**TP7**	**PC1**	**PC2**	**PC3**	**PC6**	**IP1**	**IP3**	**IP5**	**IP6**	**IP8**
EC5	1.000	0.621	0.458	0.508	0.293	0.506	0.282	0.334	0.259	0.262	0.414	0.403	0.211	0.118	0.329	0.298	0.345	0.291	0.343	0.413	0.386	0.473
EC7	0.621	1.000	0.775	0.589	0.267	0.497	0.457	0.296	0.307	0.127	0.289	0.294	-0.151	0.209	0.231	0.292	0.190	0.230	0.363	0.278	0.256	0.325
EC8	0.458	0.775	1.000	0.685	0.326	0.481	0.470	0.246	0.481	0.245	0.269	0.231	-0.075	0.189	0.185	0.203	0.247	0.274	0.257	0.253	0.266	0.332
EC10	0.508	0.589	0.685	1.000	0.449	0.503	0.362	0.492	0.534	0.285	0.452	0.512	0.126	0.041	0.115	0.100	0.081	0.159	0.218	0.106	0.190	0.386
TW1	0.293	0.267	0.326	0.449	1.000	0.573	0.605	0.618	0.623	0.650	0.631	0.678	0.425	0.396	0.463	0.400	0.216	0.424	0.370	0.251	0.389	0.333
TW2	0.506	0.497	0.481	0.503	0.573	1.000	0.489	0.450	0.542	0.499	0.557	0.537	0.439	0.090	0.107	0.017	0.093	0.394	0.401	0.260	0.427	0.468
TW4	0.282	0.457	0.470	0.362	0.605	0.489	1.000	0.586	0.534	0.360	0.648	0.651	0.142	0.246	0.419	0.454	0.195	0.394	0.434	0.307	0.290	0.290
TW5	0.334	0.296	0.246	0.492	0.618	0.450	0.586	1.000	0.537	0.650	0.700	0.723	0.238	0.208	0.439	0.413	0.170	0.339	0.301	0.044	0.251	0.180
TW8	0.259	0.307	0.481	0.534	0.623	0.542	0.534	0.537	1.000	0.499	0.557	0.635	0.439	0.255	0.239	0.336	0.177	0.577	0.513	0.415	0.455	0.422
TP1	0.262	0.127	0.245	0.285	0.650	0.499	0.360	0.650	0.499	1.000	0.567	0.613	0.487	0.336	0.457	0.471	0.166	0.535	0.369	0.220	0.486	0.238
TP2	0.414	0.289	0.269	0.452	0.631	0.557	0.648	0.700	0.557	0.567	1.000	0.684	0.484	0.345	0.420	0.370	0.214	0.468	0.319	0.210	0.251	0.254
TP6	0.403	0.294	0.231	0.512	0.678	0.537	0.651	0.723	0.635	0.613	0.684	1.000	0.459	0.340	0.455	0.570	0.253	0.573	0.544	0.390	0.528	0.528
TP7	0.211	-0.151	-0.075	0.126	0.425	0.439	0.142	0.238	0.439	0.487	0.484	0.459	1.000	0.196	0.306	0.202	0.068	0.615	0.422	0.420	0.510	0.412
PC1	0.118	0.209	0.189	0.041	0.396	0.090	0.246	0.208	0.255	0.336	0.345	0.340	0.196	1.000	0.672	0.685	0.567	0.487	0.307	0.267	0.278	0.211
PC2	0.329	0.231	0.185	0.115	0.463	0.107	0.419	0.439	0.239	0.457	0.420	0.455	0.306	0.672	1.000	0.758	0.691	0.456	0.341	0.380	0.317	0.293
PC3	0.298	0.292	0.203	0.100	0.400	0.017	0.454	0.413	0.336	0.471	0.370	0.570	0.202	0.685	0.758	1.000	0.569	0.527	0.470	0.366	0.372	0.221
PC6	0.345	0.190	0.247	0.081	0.216	-0.093	0.195	0.170	0.177	0.166	0.214	0.253	0.068	0.567	0.691	0.569	1.000	0.358	0.162	0.404	0.181	0.309
IP1	0.291	0.230	0.274	0.159	0.424	0.394	0.394	0.339	0.577	0.535	0.468	0.573	0.615	0.487	0.456	0.527	0.358	1.000	0.755	0.698	0.692	0.656
IP3	0.343	0.363	0.257	0.218	0.370	0.401	0.434	0.301	0.513	0.369	0.319	0.544	0.422	0.307	0.341	0.470	0.162	0.755	1.000	0.759	0.704	0.642
IP5	0.413	0.278	0.253	0.106	0.251	0.260	0.307	0.044	0.415	0.220	0.210	0.390	0.420	0.267	0.380	0.366	0.404	0.698	0.759	1.000	0.794	0.728
IP6	0.386	0.256	0.266	0.190	0.389	0.427	0.290	0.251	0.455	0.486	0.251	0.528	0.510	0.278	0.317	0.372	0.181	0.692	0.704	0.794	1.000	0.741
IP8	0.473	0.325	0.332	0.386	0.333	0.468	0.290	0.180	0.422	0.238	0.254	0.528	0.412	0.211	0.293	0.221	0.309	0.656	0.642	0.728	0.741	1.000
PT2	0.309	0.210	0.210	0.430	0.375	0.328	0.344	0.429	0.373	0.304	0.522	0.488	0.417	0.119	0.228	0.137	0.035	0.450	0.296	0.333	0.369	0.335
PT4	0.126	-0.003	0.000	0.093	0.144	0.121	0.209	0.171	0.164	0.152	0.289	0.410	0.405	0.135	0.198	0.214	0.023	0.431	0.149	0.237	0.415	0.322
PT5	0.357	0.412	0.221	0.340	0.284	0.359	0.434	0.277	0.320	0.061	0.502	0.489	0.244	0.272	0.251	0.314	0.152	0.381	0.399	0.249	0.172	0.246
PT6	0.189	0.321	0.202	0.287	0.320	0.103	0.331	0.267	0.359	0.075	0.263	0.470	0.234	0.270	0.436	0.406	0.319	0.409	0.386	0.372	0.364	0.330
PT7	0.313	0.229	0.134	0.385	0.225	-0.052	0.311	0.263	0.185	0.140	0.292	0.536	0.148	0.224	0.328	0.366	0.341	0.347	0.158	0.328	0.306	0.396
CS2	0.234	0.074	0.007	0.155	0.213	0.018	-0.019	0.130	0.210	0.099	0.109	0.304	0.234	0.434	0.352	0.394	0.351	0.265	0.207	0.167	0.173	0.209
CS4	0.199	0.121	0.144	0.155	0.190	0.053	0.123	0.050	0.295	0.063	0.122	0.247	0.265	0.258	0.232	0.309	0.274	0.273	0.219	0.235	0.181	0.066
CS5	0.366	0.203	0.359	0.470	0.314	0.286	0.193	0.181	0.220	0.279	0.219	0.337	0.362	0.146	0.316	0.292	0.226	0.288	0.196	0.168	0.195	0.311
CS6	0.358	0.322	0.341	0.251	0.280	0.170	0.303	0.192	0.249	0.087	0.226	0.285	0.179	0.399	0.395	0.329	0.515	0.340	0.237	0.235	0.161	0.176
CS9	0.432	0.201	0.273	0.377	0.157	0.179	0.231	0.150	0.250	0.017	0.330	0.336	0.249	0.098	0.296	0.221	0.510	0.269	0.086	0.315	0.135	0.292
CS11	0.501	0.385	0.324	0.462	0.270	0.220	0.362	0.370	0.202	0.121	0.256	0.421	0.108	0.161	0.500	0.366	0.269	0.022	0.112	0.150	0.097	0.079
# of violations	**3**	**1**	**3**	**6**	**4**	**8**	**5**	**4**	**8**	**3**	**3**	**9**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**

None of the counts for each item exceeds half of the potential comparisons
Total # of violations = 95
Note Manufacturing cost reduction and supplier performance constructs are not included in this calculation

Table 5 (Cont.)

Item Correlation Matrix and Discriminant Analysis
(Pilot Study)

Construct	Product Development Time					Customer Satisfaction					
Item	PT2	PT4	PT5	PT6	PT7	CS2	CS4	CS5	CS6	CS9	CS11
EC5	0.309	0.126	0.357	0.189	0.313	0.234	0.199	0.366	0.358	0.432	0.501
EC7	0.210	-0.003	0.412	0.321	0.229	0.074	0.121	0.203	0.322	0.201	0.385
EC8	0.210	0.000	0.221	0.202	0.134	0.007	0.144	0.359	0.341	0.273	0.324
EC10	0.430	0.093	0.340	0.287	0.385	0.155	0.155	0.470	0.251	0.377	0.462
TW1	0.375	0.144	0.284	0.320	0.225	0.213	0.190	0.314	0.280	0.157	0.270
TW2	0.328	0.121	0.359	0.103	-0.052	0.016	0.053	0.286	0.170	0.179	0.220
TW4	0.344	0.209	0.434	0.331	0.311	-0.019	0.123	0.193	0.303	0.231	0.382
TW5	0.429	0.171	0.277	0.267	0.263	0.130	0.050	0.181	0.192	0.150	0.370
TW8	0.373	0.164	0.320	0.359	0.185	0.210	0.295	0.220	0.249	0.250	0.202
TP1	0.304	0.152	0.061	0.075	0.140	0.099	0.063	0.279	0.087	0.017	0.121
TP2	0.522	0.269	0.502	0.263	0.292	0.109	0.122	0.219	0.226	0.330	0.256
TP6	0.488	0.410	0.489	0.470	0.536	0.304	0.247	0.337	0.285	0.336	0.421
TP7	0.417	0.405	0.244	0.234	0.148	0.234	0.265	0.362	0.179	0.249	0.108
PC1	0.119	0.135	0.272	0.270	0.224	0.434	0.258	0.146	0.399	0.098	0.161
PC2	0.228	0.198	0.251	0.436	0.328	0.352	0.232	0.316	0.395	0.296	0.500
PC3	0.137	0.214	0.314	0.406	0.366	0.394	0.309	0.292	0.329	0.221	0.366
PC6	0.035	0.023	0.152	0.319	0.341	0.351	0.274	0.226	0.515	0.510	0.269
IP1	0.450	0.431	0.381	0.409	0.347	0.265	0.273	0.288	0.340	0.269	0.022
IP3	0.296	0.149	0.399	0.386	0.158	0.207	0.219	0.196	0.237	0.086	0.112
IP5	0.333	0.237	0.249	0.372	0.328	0.167	0.235	0.168	0.235	0.315	0.150
IP6	0.369	0.415	0.172	0.364	0.306	0.173	0.181	0.195	0.161	0.135	0.097
IP8	0.335	0.322	0.246	0.330	0.396	0.209	0.066	0.311	0.176	0.292	0.079
PT2	1.000	0.665	0.553	0.405	0.503	-0.039	0.031	0.101	0.159	0.230	0.247
PT4	0.665	1.000	0.512	0.496	0.577	0.236	0.325	0.237	0.263	0.327	0.242
PT5	0.553	0.512	1.000	0.598	0.385	0.257	0.390	0.240	0.507	0.376	0.364
PT6	0.405	0.496	0.598	1.000	0.565	0.426	0.480	0.263	0.474	0.407	0.406
PT7	0.503	0.577	0.385	0.565	1.000	0.206	0.199	0.184	0.259	0.342	0.351
CS2	-0.039	0.236	0.257	0.426	0.206	1.000	0.718	0.615	0.642	0.505	0.474
CS4	0.031	0.325	0.390	0.480	0.199	0.718	1.000	0.660	0.810	0.680	0.593
CS5	0.101	0.237	0.240	0.263	0.184	0.615	0.660	1.000	0.613	0.695	0.604
CS6	0.159	0.263	0.507	0.474	0.259	0.642	0.810	0.613	1.000	0.662	0.623
CS9	0.230	0.327	0.376	0.407	0.342	0.505	0.680	0.695	0.662	1.000	0.596
CS11	0.247	0.242	0.364	0.406	0.351	0.474	0.593	0.604	0.623	0.596	1.000
# of violations	6	4	7	10	2	0	1	0	2	1	2

Table 6

Descriptive Statistics, Reliability, Correlation, and Predictive Analyses (Pilot Study)

Variables	Means	# of items	std dev	1 CE	2 CI	3 SI	4 PD	5 PP	6 IT	7 EC	8 TW	9 TP	10 PC	11 IP	12 PD	13 CS
1. Concurrent Engineering	22.00	7	5.18	[0.87][a]												
2. Customer Involvement	18.40	5	5.63	0.514**	[0.94]											
3. Supplier Involvement	18.80	6	5.24	0.587**	0.582**	[0.87]										
4. Heavyweight Prod. Dev. Mgr	18.90	6	4.49	0.532**	0.561**	0.380*	[0.79]									
5. Platform Products	9.36	3	3.42	0.478**	0.342	0.505**	0.233	[0.90]								
6. Information Technology	23.20	6	5.90	0.588**	0.589**	0.521**	0.396*	0.454**	[0.92]							
7. Engineering Change Time	11.40	4	4.14	0.056	0.122	-0.131	-0.013	-0.105	0.149	[0.86]						
8. Teamwork Performance	16.60	5	3.35	0.175	0.334	0.158	0.223	0.026	0.270	0.611**	[0.86]					
9. Team Productivity	13.30	4	2.78	0.170	0.267	0.108	0.309	0.065	0.275	0.351	0.802**	[0.82]				
10. Product-Cost Reduction	13.50	4	4.51	0.236	0.298	0.290	0.265	0.455*	0.337	0.266	0.399*	0.463**	[0.88]			
11. Product Integrity	15.40	5	6.08	-0.005	0.204	0.164	0.240	0.062	0.127	0.397*	0.526**	0.613**	0.447*	[0.92]		
12. Product Development Time	15.00	5	3.80	0.141	0.252	0.177	0.005	0.015	0.338	0.347	0.519**	0.583**	0.268	0.467*	[0.84]	
13. Customer Satisfaction	20.00	6	6.70	0.106	0.498**	0.233	0.131	0.300	0.379*	0.394*	0.314	0.314	0.461*	0.247	0.352	[0.90]

Note:

1. Variables 1-6: Independent variables (Koufteros, 1995)
2. Variables 7-13: Dependent variables ("manufacturing cost reduction" and "supplier performance" are not included)
3. * = Correlation is significant at the 0.05 level (2-tailed)
4. ** = Correlation is significant at the 0.01 level (2-tailed).
5. a = Reliabilities (Chronbach's alphas) are on the diagonal

potential comparisons. Therefore, it can be concluded that all items retained after EFA and CFA in Appendix II pass a discriminant validity test.

Table 6 reports the descriptive statistics and reliability analysis of both integrated product development practices (independent variables) and product development performance (dependent variables). The lowest reliability, i.e., Chronbach's alpha = 0.79, was found in the heavyweight product development manager construct. This construct was developed earlier by Koufteros (1995). The rest of the constructs have a Chronbach's alpha of more than 0.82. This value is acceptable (Nunnally, 1978).

As can be seen from Table 6, most of the independent variables have a positive correlation with dependent variables as an evidence of predictive validity. However, engineering change time has a negative but non-significant correlation with supplier involvement, heavyweight product development managers, and platform products. Product integrity also has a negative but non-significant correlation with concurrent engineering. All of those negative correlations should be interpreted carefully because the sample size used in this pilot study analysis was small, i.e., 33 responses. Moreover, all of the negative correlations are not significant at alpha = 0.05.

For the large-scale study, the researcher modified several constructs as follows. As a result of the EFA and CFA described before, product cost reduction construct was split into two constructs, i.e., product cost reduction and manufacturing cost reduction. All items from the product cost reduction are similar with the previous items used in the pilot study. However, the following items were modified for the manufacturing cost reduction:

a. "Our product development team reduces assembly cost successfully. The new sentence is "Our product development team successfully reduce assembly cost." Some respondents indicate that relocating the word "successfully" makes the new sentence more appealing to the survey participants.

b. "Our product development team reduces production tooling and equipment cost successfully" was divided into two items, i.e., "our product development team reduces production tooling successfully" and "our product development team reduces equipment cost successfully." This split is necessary to reduce confusion among respondents. They consider "production tooling cost" and "equipment cost" as two different production cost variables.

Initially, supplier performance was thought as a single construct. The EFA and CFA analyses described before also indicated that the initial items used to measure suppliers' performance consist of several constructs. Therefore, for the next large-scale study, the suppliers' performance construct was split into three constructs, i.e., suppliers' on-time performance, suppliers' cost performance, and suppliers' quality performance.

The following items were added for suppliers' on-time performance construct:

a. "Our suppliers meet engineering change deadlines on time."

b. "Our suppliers meet our product development schedules on-time."

In a similar manner, the following items were added for suppliers' quality performance construct:

a. "Our suppliers provide high quality parts."

b. "Our suppliers meet our quality specification."

c. "Our suppliers deliver high quality materials."

d. "Our suppliers improve their quality performance."

Likewise, "Our suppliers design high quality materials" was changed to "Our suppliers design high quality products," because the words "designing products" are more common than "designing materials."

Additionally, the following items were added for the suppliers' cost performance construct:

a. "Our suppliers help reduce our overall cost."

b. "Our suppliers improve their cost performance."

c. "Our suppliers design parts that reduce our manufacturing cost."

"Our suppliers meet our target price" was modified to " Our suppliers meet our target cost" because the words "target cost" are a much more common in the auto industry. The construct "Internal Product Integrity" was renamed "Product Integrity" to make it shorter. The construct "Product-Customer Fit" was renamed "Customer Satisfaction " because the later name was more common. The revised items were used in the large-scale survey method described in the next section.

3.4. Large Sample Method

The large-scale survey was conducted both in the U.S. and Germany. The U.S. survey (Appendix III) was in English whereas the German survey was in German (Appendix IV). A German native speaker, who has an MBA and worked in an auto company, translated the English survey into German. An American graduate student, who used to live in a German-speaking country, conducted the translation from German back to English. Revision was performed if necessary. Finally, a professor in German literature checked the translation.

The large-scale survey was mailed to 2912 product development professionals in the U.S. auto industry and 975 product development professionals in German auto industry. The mailing list used in this large-scale study was provided by the same professional society that gave the mailing list for the pilot study. The large-scale questionnaires were mailed twice in each country, three weeks between each mailing. The professionals had the option of either mailing back the survey or filling out the survey via a web site developed specifically for this dissertation.

A non-response bias analysis was then conducted to compare the characteristics of respondents and non-respondents. Additionally, a comparison between web and mail responses was also performed. This non response-bias analysis is explained in the next section.

3.4.1. Respondent Bias Analysis

For this respondent bias analysis, a non-auto manufacturer category was used to group companies such as auto suppliers, heavy-truck supplier, R&D companies, and other non-auto manufacturers. The reason for this is because the mailing list used in this study does not state the type of respondents' company. It was easy to identify the type of the company when the company was an auto manufacturer or a popular auto supplier. However it was very time consuming and practically impossible to identify the type of numerous non-popular companies if no response was received. Table 7 summarizes the calculation for respondent bias analysis and will be discussed in the next paragraphs.

The large scale survey was mailed to 2912 product development professionals in the U.S. auto industry made up of 958 professionals or 32.89 % [958 / 2912] in auto manufacturing (OEM) and 1954 professionals or 67.11% [1954 / 2912] not in auto manufacturing (not OEM such as auto supplier). A total of 296 responses were received consisting of 75 professionals in auto manufacturing and 221 professionals not in not in auto manufacturing. Therefore, the response rate was 10.16% [296 / 2912]. A ten-percent response rate is very common for a long survey.

The number of expected responses and the number of actual (observed) responses were greatly different for the U.S. survey. The number of expected responses from U.S. auto manufacturers was 97 [32.89% x 2912] and the

Table 7

**Response Bias:
Country and Supply Chain Analyses
(Large Scale Study)**

Respondent Category

	Auto Mfr	Non Auto Mfr	Total
US	958	1954	2912
Germany	233	742	975

US Survey
Observed and Expected Number of Responses

	Auto Mfr	Non Auto Mfr	Total	p
Observed	75	221	296	
Expected	97	199	296	0.005632

German Survey
Observed and Expected Number of Responses

	Auto Mfr	Non Auto Mfr	Total	p
Observed	40	105	145	
Expected	35	110	145	0.297609

Combined Data
US and Germany
Observed and Expected Number of Responses

	Auto Mfr	Non Auto Mfr	Total	p
Observed	115	326	441	
Expected	132	309	441	0.076608

number of expected responses from non-auto manufacturers was 199 [67.11% x 2912]. The previous paragraph indicates that the actual number of responses was 75 for auto manufacturers and 221 for non-auto manufacturers. The actual number for auto manufactures was lower than expected but for non-auto manufactures this was higher. A chi-square analysis indicated that the difference between the expected and the actual numbers of responses was significant with p-value = 0.0056. This means that there was a non-response bias in U.S. because the p-value was less than 0.05.

The professional society that supplied the mailing list explained this response bias. They indicated that some U.S. facilities of auto manufacturers do not allow the distribution of surveys to employees. The researcher also received the same message from an auto manufacturer's employee.

In Germany, the large-scale survey was mailed to a total of 975 professionals consisting of 233 professionals who work for auto manufacturers and 742 professionals who work for non-auto manufacturers. Using the same method previously described for U.S. respondents, a response bias analysis was conducted for German respondents.

A total of 145 responses were received consisting of 40 professionals (vs. 35 expected responses) who work for auto manufacturers and 105 professionals (vs. 110 expected responses) who work for non-auto manufacturers. The response rate in Germany was 14.87%. A chi-square analysis indicated that the difference between the expected and the actual numbers of responses was not significant with p-value = 0.2976. This means that there was no response bias in Germany.

Although all respondents received the survey by mail, they had a choice of either mailing the completed survey via regular postal services or filling out the survey at a web site developed for this dissertation. Therefore, another way to check for the evidence of response bias was to compare the mean of web responses and that of mailed responses. T-tests were conducted to compare the means for 6 dependent variables and 11 independent variables for a total of 17 variables per country, or 34 variables for the two countries. If the critical p-value for the mean difference was 0.05 then by pure chance the expected number of differences was 1.7 [0.05 x 34] or 2 (rounded). Table 8 indicates that the differences occur in 3 constructs: teamwork performance, concurrent engineering, and information technology utilization.

Table 8

Response Bias:
Web vs. Mail Responses
(Large Scale Study)

Country	Variable	Mean		p
		Web n = 317	Mail n = 89	
US	Teamwork Performance	16.40	17.98	0.003
Germany	Concurrent Engineering	28.58	25.61	0.006
Germany	Information Technology	27.89	25.35	0.006

However, it is a plausible explanation that respondents who answered the survey via the web indicated a higher extent of computer technology utilization than those who answered via mail. Therefore, it may be concluded that there was no response bias between web and mail respondents.

3.4.2. Sample Characteristics

Only responses from auto manufacturers and auto suppliers were analyzed in the next paragraphs. Heavy-truck supplier, R&D companies, and any companies other than auto manufacturers and auto suppliers were no longer used. Table 9 indicates the characteristics of usable responses.

As can be predicted, most respondents from auto manufacturers (96% in the U.S. and 87.50% in Germany) indicated that their firm has annual sales of more than $5 billion. They also indicated that the number of employees in their firms is more than 200,000 people.

Respondents from auto suppliers in both countries indicated that most of their companies have annual sales between $ 1 - $5 billion and less than 50,000 employees. In both of the countries, most respondents work in Tier 1 independent auto suppliers not owned by auto manufacturers. The highest percentage of U.S. respondents works with body exterior (42.19%) but most of their counterparts in Germany work with power train (26.26%). Most respondents in the U.S. work at integrated system (30.73%) and

Table 9

Characteristics of Usable Responses

Company Characteristics

	Auto Manufacturer	Auto Supplier	Sub Total
US	75	192	267
Germany	40	99	139
Sub Total	115	291	406

Characteristics of Usable Responses from Auto Manufacturers

Annual sales

	US Freq	US %	Germany Freq	Germany %
Less than $ 5 b	0	0 00%	3	7 50%
More than $5 b	72	96 00%	35	87 50%
No answer	3	4 00%	2	5 00%
Total	75	100 00%	40	100 00%

Number of individuals who developed the product

	US Freq	US %	Germany Freq	Germany %
1 - 10	15	20 00%	1	2 50%
11 - 20	7	9 33%	1	2.50%
21 - 50	5	6 67%	1	2 50%
51 - 100	4	5 33%	1	2.50%
101 - 500	15	20 00%	8	20 00%
> 500	9	12 00%	10	25 00%
No answer	20	26 67%	22	55 00%
Total	75	100 00%	40	100 00%

Number of employees in auto business

	US Freq	US %	Germany Freq	Germany %
1 - 50,000	16	21 33%	7	17 50%
50,001 - 200 000	11	14 67%	9	22.50%
> 200, 001	23	30 67%	13	32 50%
No answer	25	33 33%	21	52 50%
Total	75	100 00%	40	100 00%

Supplier involvement in product development

	US Freq	US %	Germany Freq	Germany %
1 The company provides concepts, suppliers do the rest	2	2 67%	2	5 00%
2 The company provides critical specifications, suppliers do the rest	10	13 33%	9	22 50%
3 The company works with suppliers to co-develop the design	42	56 00%	10	25 00%
4 Suppliers provide initial feedback to the company's design	8	10 67%	0	0 00%
5 The company provides complete specification	7	9 33%	10	25 00%
6 Other	4	5 33%	6	15 00%
7 No answer	2	2.67%	3	7 50%
Total	75	100 00%	40	100 00%

Table 9 (Cont.)

Characteristics of Usable Responses

Characteristics of Usable Responses from Auto Suppliers

Annual sales

		US		Germany	
		Freq.	%	Freq.	%
< $50 million		28	14.58%	10	10.10%
$ 50 - $500 million		43	22.40%	22	22.22%
$500 m - $1 billion		20	10.42%	15	15.15%
$ 1 - $5 billion		45	23.44%	27	27.27%
> $5 billion		43	22.40%	21	21.21%
No answer		13	6.77%	4	4.04%
	Total	192	100.00%	99	100.00%

Number of individuals who developed the product

		US		Germany	
		Freq.	%	Freq.	%
1 - 10		81	42.19%	27	27.27%
11 - 20		34	17.71%	19	19.19%
21 - 50		26	13.54%	17	17.17%
51 - 100		16	8.33%	7	7.07%
100 - 500		14	7.29%	7	7.07%
> 500		2	1.04%	1	1.01%
No answer		19	9.90%	21	21.21%
	Total	192	100.00%	99	100.00%

Number of employees in auto business

		US		Germany	
		Freq.	%	Freq.	%
1 - 50,000		151	78.65%	72	72.73%
50,001 - 200,000		21	10.94%	17	17.17%
> 200, 001		2	1.04%	3	3.03%
No answer		18	9.38%	7	7.07%
	Total	192	100.00%	99	100.00%

Ownership Status

		US		Germany	
		Freq.	%	Freq.	%
Owned by an auto manufacturer		22	11.46%	5	5.05%
Independent auto supplier		151	78.65%	93	93.94%
No answer		19	9.90%	1	1.01%
	Total	192	100.00%	99	100.00%

Table 9 (Cont.)

Characteristics of Usable Responses

Characteristics of Usable Responses from Auto Suppliers (Cont.)

Tier level

	US		Germany	
	Freq.	%	Freq.	%
Tier 1	138	71.88%	84	84.85%
Tier 2	26	13.54%	9	9.09%
Tier 3	9	4.69%	2	2.02%
Other	1	0.52%	1	1.01%
No answer	18	9.38%	3	3.03%
Total	192	100.00%	99	100.00%

Product Type

	US		Germany	
	Freq.	%	Freq	%
Body exterior	81	42.19%	5	5.05%
Body interior	34	17.71%	15	15.15%
Power train	26	13.54%	26	26.26%
Chassis	16	8.33%	14	14.14%
Electrical/Electronic eq	14	7.29%	23	23.23%
Other	2	1.04%	16	16.16%
No answer	19	9.90%	0	0.00%
Total	192	100.00%	99	100.00%

Product Complexity

	US		Germany	
	Freq.	%	Freq.	%
Integrated Systems	59	30.73%	39	39.39%
Subsystem/subasseml	61	31.77%	40	40.40%
Components/parts	48	25.00%	14	14.14%
Materials	4	2.08%	2	2.02%
Other	1	0.52%	2	2.02%
No answer	19	9.90%	2	2.02%
Total	192	100.00%	99	100.00%

Supplier involvement in product development

	US		Germany	
	Freq.	%	Freq.	%
1 The company provides concepts, suppliers do the rest.	6	3.13%	3	3.03%
2 The company provides critical specifications, suppliers do the rest	28	14.58%	24	24.24%
3 The company works with suppliers to co-develop the design	71	36.98%	36	36.36%
4. Suppliers provide initial feedback to the company's design	43	22.40%	11	11.11%
5 The company provides complete specification	36	18.75%	20	20.20%
6 Other	2	1.04%	2	2.02%
7. No answer	6	3.13%	3	3.03%
Total	192	100.00%	99	100.00%

subsystem/subassembly (31.77%) levels. The percentages for German respondents are 39.99% and 40.40% respectively.

3.4.3. Measurement Results

The measuring instrument used in this study was utilized to analyze various subgroups such as U.S. auto companies, German auto companies, U.S. auto suppliers, and German auto suppliers. Therefore, it was important to develop a measuring instrument that is invariant across the subgroups.

The importance of an invariant instrument for group analysis is paramount. Without an invariant instrument, no researcher can determine if the mean differences found in the groups are caused by substantive differences among the groups or by measurement artifacts. The lack of an invariant instrument can lead to type I and II errors. A type I error is the probability of rejecting the null hypothesis when it is true, e.g., saying two groups differ when in fact they don't. A type II error is the probability of accepting the null hypothesis when it is false, e.g., saying two groups don't differ when they do.

3.4.3.1. Invariance Analysis Procedure

To overcome type I and II errors, an invariant instrument was developed from the original (unmodified) instrument used in this large-scale study. To develop the invariant instrument, a hierarchical ordering of nested models was used. Two models are called nested if the parameter of the more restrictive model is a subset of the less restrictive model (Bentler, 1990; Bentler and Bonnett, 1980). A step-by-step invariance analysis procedure is given in Figure 3.

The first step is to test the congeneric or conceptual equivalence of a model. This is done by conducting equal factor pattern analyses across subgroups. The main objective is to test whether the items of a construct in fact measure the same construct in various subgroups.

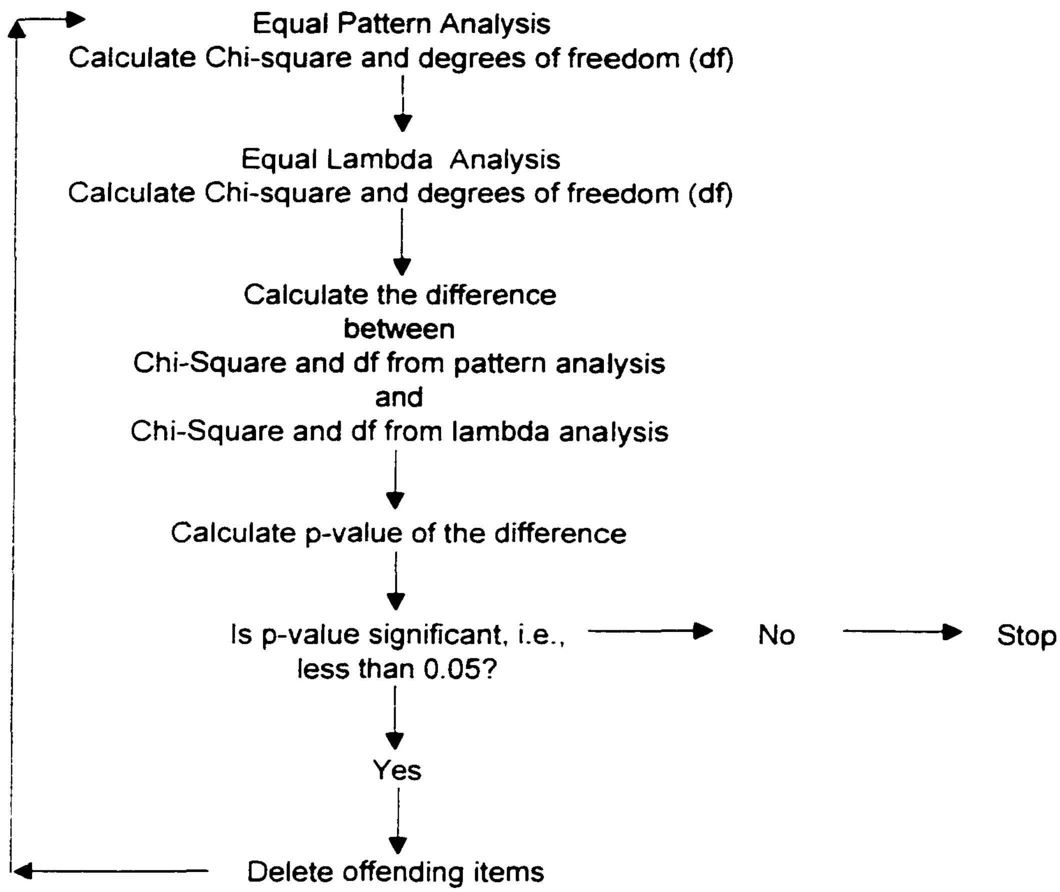
The second step is to test a model to check whether the items relate to a set of underlying constructs to the same extent in various subgroups, i.e., equivalent true scores of item-factor loading. The second step is called equal lambda analysis. Items with invariant factor loadings across subgroups are called robust or tau-equivalent.

As can be seen from the above explanation, the model used in the second step is more restrictive than the one used in the first step. The difference between the two models can be examined by subtracting the chi-square and the degrees of freedom of the second model (equal lambda analysis) and those of the first model (equal pattern analysis) (Bentler and Bonnett, 1980). The p-value of the difference is then tested against the critical p-value of 0.05.

If the hypothesis of equal variance is not rejected, i.e., $p > 0.05$, it provides strong evidence that the differences between parameters of subgroups are due to chance (Marsh, 1987). If the p-value is significant, i.e., $p < 0.05$, then offending items must be found. In most cases, offending items are items that

Figure 3

Invariance Analysis



have a large factor loading difference between two subgroups. After these offending items are found and deleted, the first step (equal lambda analysis) is repeated. This procedure was done for each of the original seventeen constructs across the U.S. and Germany and then repeated again across auto manufacturers and auto suppliers as discussed in Sections 3.4.3.2 and 3.4.3.3, respectively.

3.4.3.2. Invariance Analysis across the U.S. and Germany

Table 10 reports the results of the invariance analysis of the unmodified instrument across the two countries, i.e., the U.S. and Germany. As stated earlier, if the p-value of the difference was less than 0.05, then the next step was to find the offending items. Most offending items were items that had a large factor loading difference between U.S. and Germany as seen in Table 11. Two notable exceptions occurred in this analysis.

The first exception was item no. 4 of the customer involvement construct. Although its factor loading difference of 0.10 between the U.S. and Germany was among the smallest differences in the customer involvement construct, the deletion of item no. 4 resulted in a new model that had the largest p-value difference between equal pattern and equal lambda analyses. Therefore, item no. 4 was permanently deleted.

Table 10

Invariance Analysis:
U.S. and German Companies

Construct	Item	Analysis	X^2	df	Change in X^2	Change in df	p-value of the Changes	RMSEA	ECVI	NNFI	CFI	p-value of the Construct
Integrated Product Development Practices (Independent Variables)												
Concurrent Engineering	CE 1,2,3,4,5,6,7	Equal Pattern	188.18	28				0.168	0.600	0.83	0.89	0.00000
		Equal Lambda	193.83	34	5.65	6	0.46352	0.153	0.590	0.86	0.89	0.00000
Customer Involvement	CI 1,2,3,4,5	Equal Pattern	55.38	10				0.150	0.240	0.91	0.95	0.00000
		Equal Lambda	79.03	14	23.65	4	0.00009	0.152	0.270	0.91	0.93	0.00000
	CI 1,2,3,5	Equal Pattern	7.93	4				0.070	0.099	0.98	0.99	0.09420
		Equal Lambda	12.7	7	4.77	3	0.18943	0.063	0.096	0.99	0.99	0.07986
Supplier Involvement	SI 1,2,3,4,5,6	Equal Pattern	347.18	18				0.301	0.980	0.70	0.82	0.00000
		Equal Lambda	393.44	23	46.26	5	0.00000	0.282	1.070	0.75	0.81	0.00000
	SI 1,2,3,4	Equal Pattern	2.35	4				0.000	0.089	1.01	1.00	0.67122
		Equal Lambda	4.63	7	2.28	3	0.51636	0.000	0.082	1.01	1.00	0.70489
Heavyweight PDM	PD 1,2,3,4,5,6	Equal Pattern	53.08	18				0.098	0.250	0.94	0.96	0.00003
		Equal Lambda	62.11	23	9.03	5	0.10787	0.092	0.250	0.94	0.96	0.00002
Platform Products	PP 1,2,3	Equal Pattern	0.00	0				0.000	-	-	-	0.00000
		Equal Lambda	7.04	2	7.04	2	0.02960	0.000	-	-	-	0.00000
Information Technology	IT 1,2,3,4,5,6	Equal Pattern	112.37	18				0.161	0.400	0.90	0.94	0.00000
Utilization		Equal Lambda	130.4	23	18.03	5	0.00291	0.152	0.420	0.91	0.93	0.00000
	IT 1,2,3,4,5	Equal Pattern	241.71	12				0.308	0.690	0.59	0.75	0.00000
		Equal Lambda	245.81	15	4.1	3	0.25087	0.276	0.680	0.67	0.75	0.00000

Table 10 (Cont.)

Invariance Analysis:
U.S. and German Companies

Construct	Item	Analysis	X^2	df	Change in X^2	Change in df	p-value of the Changes	RMSEA	ECVI	NNFI	CFI	p-value of the Construct
Product Development Performance (Dependent Variables)												
Teamwork Performance	TW 1,2,3,4,5	Equal Pattern	117.53	10				0.231	0.390	0.85	0.82	0.00000
		Equal Lambda	118.71	14	1.18	4	0.88138	0.192	0.370	0.89	0.92	0.00000
Engineering Change Time	EC 1,2,3,4	Equal Pattern	18.80	4				0.135	0.130	0.96	0.99	0.00086
		Equal Lambda	20.18	7	1.38	3	0.71023	0.097	0.110	0.98	0.99	0.00518
Product Cost Reduction	PC 1,2,3,4	Equal Pattern	13.35	4				0.108	0.110	0.97	0.99	0.00969
		Equal Lambda	31.87	7	18.52	3	0.00034	0.133	0.140	0.95	0.97	0.00004
	PC 1,3,4	Equal Pattern	0.00	0				0.000	-	-	-	1.00000
		Equal Lambda	1.66	2	1.66	2	0.43605	0.000	-	-	-	1.00000
Team Productivity	TP 1,2,3,4	Equal Pattern	9.99	4				0.086	0.100	0.97	0.99	0.04062
		Equal Lambda	10.98	7	0.99	3	0.80367	0.053	0.092	0.99	0.99	0.13966
Manufacturing Cost Reduction	MC 1,2,3,4,5	Equal Pattern	26.07	10				0.089	0.160	0.97	0.98	0.00364
		Equal Lambda	31.05	14	4.98	4	0.28936	0.078	0.160	0.98	0.98	0.00546
Product Integrity	PI 1,2,3,4,5	Equal Pattern	141.18	10				0.255	0.450	0.77	0.89	0.00000
		Equal Lambda	151.41	14	10.23	4	0.03673	0.220	0.450	0.83	0.88	0.00000
	PI 2,3,4,5	Equal Pattern	56.65	4				0.196	0.170	0.88	0.96	0.00000
		Equal Lambda	61.04	7	4.39	3	0.22231	0.212	0.240	0.86	0.92	0.00000
Suppliers' On Time Performance	SO 1,2,3,4,5	Equal Pattern	79.02	10				0.185	0.290	0.88	0.94	0.00000
		Equal Lambda	94.74	14	15.72	4	0.00342	0.169	0.310	0.90	0.93	0.00000
	SO 1,2,3,4	Equal Pattern	14.18	4				0.112	0.110	0.96	0.99	0.00673
		Equal Lambda	17.41	7	3.23	3	0.35750	0.086	0.050	0.97	0.98	0.01496
Suppliers' Quality Performance	SQ 1,2,3,4,5	Equal Pattern	10.96	10				0.022	0.130	1.00	1.00	0.36051
		Equal Lambda	15.65	14	4.69	4	0.32061	0.024	0.120	1.00	1.00	0.33546
Suppliers' Cost Performance	SC 1,2,3,4,5	Equal Pattern	83.70	10				0.191	0.310	0.84	0.92	0.00000
		Equal Lambda	92.68	14	8.98	4	0.06160	0.167	0.310	0.89	0.92	0.00000
	SC 1,2,3,5	Equal Pattern	13.78	4				0.100	0.110	0.96	0.99	0.01699
		Equal Lambda	15.47	7	1.69	3	0.63916	0.079	0.100	0.98	0.99	0.02744
Product Development Time	PT 1,2,3,4,5	Equal Pattern	69.29	10				0.171	0.270	0.91	0.96	0.00000
		Equal Lambda	79.27	14	9.98	4	0.04077	0.152	0.280	0.93	0.95	0.00000
	PT 1,2,3,4	Equal Pattern	42.05	4				0.217	0.180	0.89	0.96	0.00000
		Equal Lambda	48.21	7	6.16	3	0.10408	0.171	0.180	0.93	0.96	0.00000
Customer Satisfaction	CS 1,2,3,4,5,6	Equal Pattern	47.85	18				0.091	0.240	0.97	0.98	0.00016
		Equal Lambda	53.72	23	5.87	5	0.31907	0.081	0.230	0.97	0.98	0.00029

Table 11

**Lisrel Pattern Analysis:
Factor Loading for U.S. and German Companies**

Contruct and Item	Factor Loading		|Difference|	Item Deleted?
	US	Germany		
Concurrent Engineering				
ce1	1.00	1.00	0.00	
ce2	1.17	1.09	0.08	
ce3	1.29	1.22	0.07	
ce4	1.37	1.45	0.08	
ce5	1.17	1.44	0.27	
ce6	1.36	1.36	0.00	
ce7	0.99	0.87	0.12	
Customer Involvement				
ci1	1.00	1.00	0.00	
ci2	1.98	3.23	1.25	
ci3	2.00	3.33	1.33	
ci4	1.39	1.29	0.10	Yes *
ci5	1.64	2.81	1.17	
Supplier Involvement				
si1	1.00	1.00	0.00	
si2	1.00	1.04	0.04	
si3	0.83	1.04	0.21	
si4	1.10	0.78	0.32	
si5	1.24	0.92	0.32	Yes
si6	1.30	0.81	0.49	Yes
Heavyweight Product Development Managers				
pd1	1.00	1.00	0.00	
pd2	0.96	1.62	0.66	
pd3	0.90	1.03	0.13	
pd4	1.04	1.30	0.26	
pd5	1.00	0.99	0.01	
pd6	0.71	0.79	0.08	
Platform Products				
pp1	1.00	1.00	0.00	
pp2	1.07	1.55	0.48	
pp3	1.13	1.26	0.13	
Information Technology Utilization				
it1	1.00	1.00	0.00	
it2	1.15	1.33	0.18	
it3	0.95	1.18	0.23	
it4	1.15	1.33	0.18	
i5	0.99	0.84	0.15	
it6	0.84	0.53	0.31	Yes

Table 11 (Cont.)

Lisrel Pattern Analysis:
Factor Loading for U.S. and German Companies

Contruct and Item	Factor Loading		IDifferenceI	Item Deleted?
	US	Germany		
Teamwork Performance				
tw1	1.00	1.00	0.00	
tw2	1.13	1.15	0.02	
tw3	1.14	1.25	0.11	
tw4	1.10	1.27	0.17	
tw5	1.12	1.36	0.24	
Engineering Change Time				
ec1	1.00	1.00	0.00	
ec2	1.21	1.13	0.08	
ec3	1.08	1.10	0.02	
ec4	1.13	1.01	0.12	
Product Cost Reduction				
pc1	1.00	1.00	0.00	
pc2	1.14	1.71	0.57	Yes
pc3	1.04	1.30	0.26	
pc4	1.12	1.08	0.04	
Team Productivity				
tp1	1.00	1.00	0.00	
tp2	1.08	1.16	0.08	
tp3	0.90	0.99	0.09	
tp4	0.62	0.54	0.08	
Manufacturing Cost Reduction				
mc1	1.00	1.00	0.00	
mc2	1.11	1.12	0.01	
mc3	1.16	1.03	0.13	
mc4	0.92	1.08	0.16	
mc5	1.12	1.08	0.04	
Product Integrity				
pi1	1.00	1.00	0.00	Yes**
pi2	1.12	0.99	0.13	
pi3	0.95	1.13	0.18	
pi4	0.93	1.14	0.21	
pi5	0.95	1.07	0.12	

Table 11 (Cont.)

Lisrel Pattern Analysis:
Factor Loading for U.S. and German Companies

Contruct and Item	Factor Loading		!Difference!	Item Deleted?
	US	Germany		
Suppliers' On Time Performance				
so1	1.00	1.00	0.00	
so2	1.10	1.18	0.08	
so3	0.95	1.15	0.20	
so4	1.04	0.94	0.10	
so5	1.23	0.91	0.32	Yes
Suppliers' Quality Performance				
sq1	1.00	1.00	0.00	
sq2	0.82	0.97	0.15	
sq3	0.99	1.09	0.10	
sq4	0.99	1.24	0.25	
sq5	0.75	0.93	0.18	
Suppliers' Cost Performance				
sc1	1.00	1.00	0.00	
sc2	1.33	1.23	0.10	
sc3	1.22	1.05	0.17	
sc4	1.52	1.06	0.46	Yes
sc5	1.47	1.13	0.34	
Product Development Time				
pt1	1.00	1.00	0.00	
pt2	0.95	0.85	0.10	
pt3	0.84	1.00	0.16	
pt4	0.97	0.97	0.00	
pt5	0.94	0.73	0.21	Yes
Customer Satisfaction				
cs1	1.00	1.00	0.00	
cs2	0.99	0.84	0.15	
cs3	1.07	1.03	0.04	
cs4	0.98	0.99	0.01	
cs5	1.00	1.12	0.12	
cs6	1.10	1.09	0.01	

* Deletion of item no. 4 creates the best new model

** An SPPS's factor analysis indicates that it has the largest factor loading difference

The second exception was item no. 1 of the product integrity construct. Item no. 1 in every construct is fixed in both LISREL's equal pattern and equal lambda analyses. Therefore, the factor loadings of item no. 1 were always 1 and the difference between two factor loadings in the two countries was 1 minus 1 or 0. However, a crosscheck with SPSS's factor analysis indicated that item no. 1 of the product integrity construct had the largest factor loading difference between the two countries. Therefore, item no. 1 was deleted from further hypothesis testing.

In addition to the two exceptions described above, the items for the platform product construct were not subjected to item deletion because the number of items was three. A minimum of three items is required for future research after this dissertation.

The invariance analysis across the two countries of the unmodified instrument resulted in the deletion of several items as follows:

1. Item number 1 of the customer involvement construct.
2. Item number 5 of the supplier involvement construct.
3. Item number 6 of the supplier involvement construct.
4. Item number 6 of the Information technology utilization construct.
5. Item number 2 of the product cost reduction construct.
6. Item number 1 of the product integrity construct.

3.4.3.3. Invariance Analysis across OEMs and Auto Suppliers

After conducting the invariance analysis of the unmodified (original) instrument across the U.S. and Germany as described above, the next step was to conduct the invariance analysis of the original instrument across the auto industry supply chain, i.e., auto manufacturers/original equipments manufacturers/OEMs and auto suppliers, which is recorded in Table 12.

If the p-value of the changes in Table 12 was less than 0.05, then the next step was to find the offending items. Most offending items were items that had a large factor loading difference between auto manufacturer and auto supplier as depicted in Table 13. One exception occurred in this study.

Although item no. 4 of the customer involvement construct had one of the lowest factor loading differences, this item was deleted from further analysis. This item had the highest modification indices in combination with other items. Another exclusion to note is that, like the previous invariance analysis across the two countries, the items for the platform product construct were not subjected to item deletion because the number of items was three.

The invariance analysis across the auto industry supply chain of the original instrument resulted in the deletion of several items as follows:

1. Item number 4 of the concurrent engineering construct.
2. Item number 4 of the customer involvement construct.
3. Item number 4 of the heavyweight product development managers construct.

Table 12

Invariance Analysis:
OEMs and Auto Suppliers

Construct	Item	Analysis	X^2	df	Change in X^2	Change in df	p-value of the Changes	RMSEA	ECVI	NNFI	CFI	p-value of the Construct
Integrated Product Development Practices (Independent Variables)												
Concurrent Engineering	CE 1,2,3,4,5,6,7	Equal Pattern	175.33	28				0.161	0.570	0.85	0.90	0.00000
		Equal Lambda	194.76	34	19.43	6	0.00350	0.153	0.590	0.86	0.89	0.00000
	CE 1,2,3,5,6,7	Equal Pattern	57.94	18				0.105	0.260	0.93	0.96	0.00000
		Equal Lambda	62.76	23	4.82	5	0.43824	0.093	0.250	0.94	0.96	0.00002
Customer Involvement	CI 1,2,3,4,5	Equal Pattern	48.35	10				0.138	0.220	0.92	0.96	0.00000
		Equal Lambda	58.01	14	9.66	4	0.04656	0.125	0.220	0.94	0.96	0.00000
	CI 1,2,3,5	Equal Pattern	12.69	4				0.104	0.110	0.96	0.99	0.01290
		Equal Lambda	15.4	7	2.71	3	0.43853	0.077	0.100	0.98	0.99	0.03116
Supplier Involvement	SI 1,2,3,4,5,6	Equal Pattern	286.37	18				0.272	0.830	0.71	0.82	0.00000
		Equal Lambda	288.85	23	2.48	5	0.77950	0.239	0.810	0.77	0.83	0.00000
Heavyweight PDM	PD 1,2,3,4,5,6	Equal Pattern	126.14	18				0.172	0.430	0.85	0.91	0.00000
		Equal Lambda	139.92	23	13.78	5	0.01707	0.159	0.440	0.87	0.90	0.00000
	PD 1,2,3,5,6	Equal Pattern	35.72	10				0.113	0.190	0.92	0.96	0.00009
		Equal Lambda	39.01	14	3.29	4	0.51052	0.094	0.180	0.95	0.96	0.00036
Platform Products	PP 1,2,3	Equal Pattern	0.00	0				0.000	-	-	-	1.00000
		Equal Lambda	5.47	2	5.47	2	0.06489	0.093	0.063	0.98	0.99	0.06489
Information Technology	IT 1,2,3,4,5,6	Equal Pattern	114.81	18				0.163	0.400	0.89	0.94	0.00000
Utilization		Equal Lambda	121.34	23	6.53	5	0.25801	0.145	0.390	0.91	0.93	0.00000

Table 12 (Cont.)

Invariance Analysis:
OEMs and Auto Suppliers

Construct	Item	Analysis	X^2	df	Change in X^2	Change in df	p-value of the Changes	RMSEA	ECVI	NNFI	CFI	p-value of the Construct
Product Development Performance (Dependent Variables)												
Teamwork Performance	TW 1,2,3,4,5	Equal Pattern	117.84	10				0.231	0.390	0.84	0.92	0.00000
		Equal Lambda	124.82	14	6.98	4	0.13695	0.198	0.390	0.89	0.92	0.00000
Engineering Change Time	EC 1,2,3,4	Equal Pattern	12.80	4				0.104	0.110	0.97	0.99	0.01228
		Equal Lambda	14.38	7	1.58	3	0.66393	0.072	0.100	0.99	0.99	0.04490
Product Cost Reduction	PC 1,2,3,4	Equal Pattern	17.40	4				0.129	0.120	0.95	0.98	0.00162
		Equal Lambda	19.85	7	2.45	3	0.48440	0.095	0.110	0.97	0.98	0.00590
Team Productivity	TP 1,2,3,4	Equal Pattern	14.88	4				0.116	0.120	0.95	0.98	0.00496
		Equal Lambda	17.53	7	2.65	3	0.44879	0.086	0.110	0.97	0.98	0.01427
Manufacturing Cost Reduction	MC 1,2,3,4,5	Equal Pattern	38.86	10				0.120	0.200	0.95	0.97	0.00003
		Equal Lambda	41.15	14	2.29	4	0.68259	0.098	0.180	0.97	0.98	0.00017
Product Integrity	PI 1,2,3,4,5	Equal Pattern	135.66	10				0.249	0.430	0.78	0.89	0.00000
		Equal Lambda	141.72	14	6.06	4	0.19471	0.213	0.430	0.84	0.89	0.00000
Suppliers' On Time Performance	SO 1,2,3,4,5	Equal Pattern	86.56	10				0.195	0.310	0.87	0.93	0.00000
		Equal Lambda	90.65	14	4.09	4	0.39396	0.165	0.300	0.90	0.93	0.00000
Suppliers' Quality Performance	SQ 1,2,3,4,5	Equal Pattern	19.03	10				0.067	0.150	0.98	0.99	0.03992
		Equal Lambda	24.90	14	5.87	4	0.20907	0.062	0.140	0.98	0.99	0.03557
Suppliers' Cost Performance	SC 1,2,3,4,5	Equal Pattern	92.21	10				0.202	0.330	0.81	0.91	0.00000
		Equal Lambda	94.39	14	2.18	4	0.70269	0.169	0.310	0.87	0.91	0.00000
Product Development Time	PT 1,2,3,4,5	Equal Pattern	69.27	10				0.171	0.270	0.91	0.96	0.00000
		Equal Lambda	69.72	14	0.45	4	0.97818	0.140	0.250	0.94	0.96	0.00000
Customer Satisfaction	CS 1,2,3,4,5,6	Equal Pattern	58.34	18				0.105	0.260	0.96	0.97	0.00000
		Equal Lambda	60.78	23	2.44	5	0.78550	0.090	0.240	0.97	0.98	0.00003

Table 13

Lisrel Pattern Analysis
Factor Loading for OEMs and Auto Suppliers

Contruct and Item	Factor Loading		|Difference|	Item Deleted?
	OEM	Supplier		
Concurrent Engineering				
ce1	1.00	1.00	0.00	
ce2	1.04	1.06	0.02	
ce3	1.14	1.31	0.17	
ce4	1.03	1.61	0.58	Yes
ce5	1.01	1.37	0.36	
ce6	1.23	1.36	0.13	
ce7	0.97	0.88	0.09	
Customer Involvement				
ci1	1.00	1.00	0.00	
ci2	2.19	1.55	0.64	
ci3	2.09	1.54	0.55	
ci4	1.23	1.16	0.07	Yes *
ci5	1.57	1.31	0.26	
Supplier Involvement				
si1	1.00	1.00	0.00	
si2	1.07	0.88	0.19	
si3	0.88	0.88	0.00	
si4	1.03	1.08	0.05	
si5	1.25	1.43	0.18	
si6	1.33	1.45	0.12	
Heavyweight Product Development Managers				
pd1	1.00	1.00	0.00	
pd2	1.00	1.02	0.02	
pd3	1.10	1.28	0.18	
pd4	1.10	1.66	0.56	Yes
pd5	1.06	1.39	0.33	
pd6	1.26	1.30	0.04	
Platform Products				
pp1	1.00	1.00	0.00	
pp2	1.67	1.18	0.49	
pp3	1.37	1.21	0.16	
Information Technology Utilization				
it1	1.00	1.00	0.00	
it2	1.21	1.12	0.09	
it3	0.86	1.03	0.17	
it4	1.15	1.19	0.04	
it5	0.96	0.99	0.03	
it6	0.87	0.73	0.14	

Table 13 (Cont.)

Lisrel Pattern Analysis
Factor Loading for OEMs and Auto Suppliers

Contruct and Item	Factor Loading		!Difference!	Item Deleted?
	OEM	Supplier		
Teamwork Performance				
tw1	1.00	1.00	0.00	
tw2	1.04	1.19	0.15	
tw3	1.04	1.24	0.20	
tw4	0.92	1.24	0.32	
tw5	1.07	1.22	0.15	
Engineering Change Time				
ec1	1.00	1.00	0.00	
ec2	1.10	1.22	0.12	
ec3	1.01	1.12	0.11	
ec4	1.05	1.12	0.07	
Product Cost Reduction				
pc1	1.00	1.00	0.00	
pc2	1.43	1.23	0.20	
pc3	1.24	1.06	0.18	
pc4	1.15	1.07	0.08	
Team Productivity				
tp1	1.00	1.00	0.00	
tp2	1.08	1.18	0.10	
tp3	0.98	0.95	0.03	
tp4	0.43	0.60	0.17	
Manufacturing Cost Reduction				
mc1	1.00	1.00	0.00	
mc2	1.08	1.11	0.03	
mc3	1.17	1.12	0.05	
mc4	1.05	0.92	0.13	
mc5	1.12	1.08	0.04	
Product Integrity				
pi1	1.00	1.00	0.00	
pi2	1.08	1.07	0.01	
pi3	1.06	0.99	0.07	
pi4	1.00	0.99	0.01	
pi5	0.81	1.09	0.28	

Table 13 (Cont.)

Lisrel Pattern Analysis
Factor Loading for OEMs and Auto Suppliers

Contruct and Item	Factor Loading		IDifferenceI	Item Deleted?
	OEM	Supplier		
Suppliers' On Time Performance				
so1	1.00	1.00	0.00	
so2	1.05	1.18	0.13	
so3	0.88	1.08	0.20	
so4	1.00	0.98	0.02	
so5	0.96	1.20	0.24	
Suppliers' Quality Performance				
sq1	1.00	1.00	0.00	
sq2	0.89	0.83	0.06	
sq3	1.20	0.93	0.27	
sq4	1.16	1.04	0.12	
sq5	0.85	0.82	0.03	
Suppliers' Cost Performance				
sc1	1.00	1.00	0.00	
sc2	1.10	1.34	0.24	
sc3	0.99	1.14	0.15	
sc4	1.13	1.45	0.32	
sc5	1.26	1.34	0.08	
Product Development Time				
pt1	1.00	1.00	0.00	
pt2	0.91	0.93	0.02	
pt3	0.87	0.93	0.06	
pt4	1.00	0.98	0.02	
pt5	0.88	0.90	0.02	
Customer Satisfaction				
cs1	1.00	1.00	0.00	
cs2	0.91	0.96	0.05	
cs3	1.06	1.05	0.01	
cs4	0.94	1.02	0.08	
cs5	0.98	1.09	0.11	
cs6	1.04	1.15	0.11	

* Has the highest modification index

Table 14 lists all offending items that were deleted as the results of invariance analyses across the two countries and across the auto industry supply chain.

Table 15 and 16 indicate that the use unmodified/original instrument from the large scale survey that contains offending items (rather than universal/instrument instrument without offending items) may lead to type I and II errors.

3.4.4. Model Fit Indices, Discriminant, and Predictive Validity Analyses

Table 17 shows numerous fit indices of the measurement models. Because no statistic is universally accepted as an overall model fit index, several model fit indices were used. These fit indices were described in Section 3.2. For each construct, both fit indices of the original instrument used in the large-scale survey and those of the invariant instrument are presented. If the original instrument is similar with the invariant instrument because no items were deleted in the invariance analysis, then only one instrument labeled invariant instrument appears in each construct. In some constructs, ECVI, NNFI, and CFI are not provided because the indices cannot be computed if the construct consists of three items.

Table 14

Offending Items

Construct	Subgroup		Item	Lambda
IPD Practices (Independent Variable)				
Concurrent Engineering	Auto Mfr	CE 4	Process engineers are involved from the early stages of product development	1 03
	Auto Supplier		Process engineers are involved from the early stages of product development	1 61
Customer Involvement	Auto Mfr	CI 4	In developing the product concept, we listen to our customer needs	1 23
	Auto Supplier		In developing the product concept, we listen to our customer needs	1 16
	US	CI 4	In developing the product concept, we listen to our customer needs	1 39
	Germany		Um Produktkonzepte zu entwickeln berucksichtigen wir die Bedurfnisse unserer Kunden	1 29
Supplier Involvement	US	SI 5	We ask our suppliers for their input on the design of component parts	1 24
	Germany		Wir fragen unsere Zulieferer nach Vorschlagen zum Design von Komponententeilen	0 92
	US	SI 6	We make use of suppliers for their input on the design of component parts	1 30
	Germany		Wir berucksichtigen die Vorschlage unserer Zulieferer bei dem Design der Komponententeile	0 81
Heavyweight Prod Dev Mgr	Auto Mfr	PD 4	Product development managers have broad influence across the organization	1 10
	Auto Supplier		Produktentwicklungsmanager haben weitreichenden Einfluß in der gesamten Firma	1 66
Information Technology Utilization	US	IT 6	We use computers to coordinate product development activities	0 84
	Germany		Wir nutzen Computer um Produktentwicklungsaktivitaten zu koordinieren	0 53
Product Development Performance (Dependent Variable)				
Product Cost Reduction	US	PC 2	Our product development team reduces product costs successfully	1 14
	Germany		Unser Produktentwicklungsteam Reduziert Produktkosten erfolgreich	1 71
Product Integrity	US	PI 1	In our experience, all components fit together easily	1 00
	Germany		Unserer Erfahrung nach Passen alle Komponenten einfach zusammen	1 00
Suppliers' On Time Performance	US	SO 5	Our suppliers meet our product development schedules on time	1 23
	Germany		Unsere Zulieferer Halten unsere Produktionzeitplane punktlich ein	0 91
Suppliers' Cost Performance	US	SC 4	Our suppliers suggest ideas that reduce our product cost	1 52
	Germany		Unsere Zulieferer Machen Verbesserungsvorschlage die unsere Produktkosten senken	1 06
Product Development Time	US	PT 5	Compared to the average in the industry, our product development teams makes better progress in reducing total product development time	0 94
	Germany		Verglichen mit dem Industriedurchschnitt, unser Produktentwicklungsteam Macht besseren Fortschritt in der Reduzierung der Gesamtentwicklungszeit	0 73

Table 15

P-values from Universal Instrument vs. Unmodified Instrument for Evaluating the Differences between the U.S. (n = 267) and Germany (n = 139)

Construct	Universal Instrument						P-value from Unmodified Instrument	Note
	Item	Number of Items		U.S	Germany	P-value		
Integrated Product Development Practice (Independent Variable):								
Concurrent Engineering	CE 1,2,3,5,6,7	6	Mean SD	20.849 4.725	22.587 3.866	0.002	0.004	
Customer Involvement	CI 1,2,3,5	4	Mean SD	15.157 3.552	15.730 3.388	0.607	0.840	
Supplier Involvement	SI 1,2,3,4	4	Mean SD	11.917 3.912	12.920 3.819	0.006	0.111	Type II Error
Heavyweight Prod. Dev. Mgr.	PD 1,2,3,5,6	5	Mean SD	16.227 3.746	15.821 3.306	0.087	0.017	Type I Error
Platform Products	PP 1,2,3	3	Mean SD	10.060 2.893	9.183 2.798	0.001	0.001	(*)
Information Technology Utilization	CT 1,2,3,4,5	5	Mean SD	20.528 4.247	21.667 3.336	0.012	0.013	
Product Development Performance (Dependent Variable):								
Teamwork Performance	TW 1,2,3,4,5	5	Mean SD	17.569 3.8386	18.015 3.4556	0.447	0.447	(*)
Engineering Change Time	EC 1,2,3,4	4	Mean SD	13.616 3.5791	13.725 2.9885	0.670	0.670	(*)
Product Cost Reduction	PC 1,3,4	3	Mean SD	10.269 2.440	10.640 2.236	0.107	0.093	
Team Productivity	TP 1,2,3,4	4	Mean SD	13.798 2.823	14.348 2.613	0.157	0.157	(*)
Manufacturing Cost Reduction	MC 1,2,3,4,5	5	Mean SD	16.221 3.740	16.810 3.983	0.047	0.047	(*)
Product Integrity	PI 2,3,4,5	4	Mean SD	14.935 2.886	15.403 3.073	0.095	0.217	
Suppliers' On Time Performance	SO 1,2,3,4	4	Mean SD	12.988 2.806	13.333 2.824	0.310	0.053	
Suppliers' Quality Performance	SQ 1,2,3,4,5	5	Mean SD	17.669 3.309	18.928 3.395	0.000	0.000	(*)
Suppliers' Cost Performance	SC 1,2,3,5	4	Mean SD	12.984 2.711	12.828 3.018	0.699	0.229	
Product Development Time	PT 1,2,3,4	4	Mean SD	13.156 3.569	13.420 2.884	1.000	0.947	
Customer Satisfaction	CS 1,2,3,4,5,6	6	Mean SD	22.284 4.257	22.533 4.232	0.597	0.597	(*)

Note:

1. P-values are from two-factor invariance analyses. However, for this table, only p-values for the differences between the mean score of the U.S. and that of Germany are shown

2. (*) The items in the unmodified (original) instrument are similar to the items in the universal (invariant) instrument. No change happens after multigroup invariance analysis. Therefore, the p-value of the unmodified instrument is equal to the p-value of the universal instrument.

3. Type I and II errors are decided at alpha = 0.05

Table 16

P-values from Universal Instrument vs. Unmodified Instrument for Evaluating the Differences between OEMs (n = 115) and Auto Suppliers (n = 291)

Construct	Universal Instrument						P-value from Unmodified Instrument	Note
	Item	Number of Items		Auto Mfr. (OEM)	Auto Supplier	P-value		
Integrated Product Development Practice (Independent Variable):								
Concurrent Engineering	CE 1,2,3,5,6,7	6	Mean	22.2936	21.0725	0.029	0.057	Type II Error
			SD	5.3304	4.1335			
Customer Involvement	CI 1,2,3,5	4	Mean	13.7456	15.9828	0.000	0.000	
			SD	4.0040	3.0706			
Supplier Involvement	SI 1,2,3,4	4	Mean	15.3860	11.0243	0.000	0.000	
			SD	3.1497	3.4615			
Heavyweight Prod. Dev. Mgr.	PD 1,2,3,5,6	5	Mean	16.8018	15.8029	0.079	0.081	
			SD	3.1761	3.7254			
Platform Products	PP 1,2,3	3	Mean	10.2679	9.5655	0.093	0.093	(*)
			SD	2.9561	2.8414			
Information Technology Utilization	CT 1,2,3,4,5	5	Mean	21.7391	20.5897	0.012	0.008	
			SD	3.6421	4.0840			
Product Development Performance (Dependent Variable):								
Teamwork Performance	TW 1,2,3,4,5	5	Mean	17.9561	17.6289	0.575	0.575	(*)
			SD	4.2184	3.5007			
Engineering Change Time	EC 1,2,3,4	4	Mean	13.8246	13.5854	0.476	0.476	(*)
			SD	3.4468	3.3625			
Product Cost Reduction	PC 1,3,4	3	Mean	10.4957	10.3576	0.490	0.489	
			SD	2.6370	2.2664			
Team Productivity	TP 1,2,3,4	4	Mean	14.2807	13.8694	0.288	0.288	(*)
			SD	3.2356	2.5495			
Manufacturing Cost Reduction	MC 1,2,3,4,5	5	Mean	17.1250	16.1493	0.008	0.008	(*)
			SD	4.1376	3.6752			
Product Integrity	PI 2,3,4,5	4	Mean	15.3684	14.9823	0.176	0.142	
			SD	3.1742	2.8602			
Suppliers' On Time Performance	SO 1,2,3,4	4	Mean	13.7257	12.8617	0.009	0.004	
			SD	3.0858	2.6622			
Suppliers' Quality Performance	SQ 1,2,3,4,5	5	Mean	18.9107	17.7889	0.002	0.002	(*)
			SD	3.8122	3.1601			
Suppliers' Cost Performance	SC 1,2,3,5	4	Mean	14.0360	12.4910	0.000	0.000	
			SD	3.0746	2.5850			
Product Development Time	PT 1,2,3,4	4	Mean	13.8482	13.0138	0.095	0.100	
			SD	3.7204	3.1677			
Customer Satisfaction	CS 1,2,3,4,5,6	6	Mean	23.2252	22.0414	0.017	0.017	(*)
			SD	5.0375	3.8589			

Note:

1. P-values are from two-factor invariance analyses. However, for this table, only p-values for the differences between the mean score of the U.S. and that of Germany are shown.

2. (*) The items in the unmodified (original) instrument are similar to the items in the universal (invariant) instrument. No change happens after multigroup invariance analysis. Therefore, the p-value of the unmodified instrument is equal to the p-value of the universal instrument.

3. Type I and II errors are decided at alpha = 0.05

Table 17

Overall Model Fit of Measurement Instrument

Item		Fit Indices							
A. Concurrent Engineering		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	CE1,2,3,4,5,6,7	139.95	14	0.00000	0.149	0.410	0.87	0.91	0.8790
Invariant instrument	CE1,2,3,5,6,7	30.35	9	0.00038	0.077	0.130	0.96	0.98	0.8546
B. Customer Involvement		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	CI1,2,3,4,5	50.78	5	0.00000	0.150	0.170	0.91	0.95	0.8553
Invariant instrument	CI1,2,3,5	7.80	2	0.02025	0.085	0.059	0.97	0.99	0.8218
C. Supplier Involvement		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	SI1,2,3,4,5,6	382.55	9	0.00000	0.320	1.000	0.68	0.81	0.8908
Invariant instrument	SI1,2,3,4	1.17	2	0.55729	0.000	0.044	1.00	1.00	0.8572
D. Heavyweight Prod. Dev. Mgr.		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	PD1,2,3,4,5,6	42.77	9	0.00000	0.096	0.160	0.94	0.96	0.8227
Invariant instrument	PD1,2,3,5,6	27.01	5	0.00006	0.104	0.120	0.92	0.96	0.7708
E. Platform Product		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	PP1,2,3	0.00	0	1.00000	0.000	-	-	-	0.8603
F. Information Technology Utilization		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	IT1,2,3,4,5,6	109.59	9	0.00000	0.166	0.330	0.89	0.93	0.8964
Invariant instrument	IT1,2,3,4,5	71.01	5	0.00000	0.181	0.220	0.91	0.95	0.9027
G. Teamwork Performance		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	TW1 ... TW5	112.51	5	0.00000	0.230	0.330	0.84	0.92	0.9061
H. Engineering Change Time		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	EC1 ... EC4	12.77	2	0.00169	0.115	0.071	0.97	0.99	0.9131
I. Product Cost Reduction		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	PC1,2,3,4	13.52	2	0.00116	0.119	0.073	0.96	0.99	0.8839
Invariant instrument	PC1,3,4	0.00	0	1.00000	0.000	-	-	-	0.8163

Table 17 (Cont.)

Overall Model Fit of Measurement Instrument

Item		Fit Indices							
J. Team Productivity		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	TP 1,2,3,4	8.12	2	0.01725	0.087	0.060	0.97	0.99	0.7623
K. Manufacturing Cost Reduction		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	TP 1,2,3,4	24.53	5	0.00017	0.098	0.110	0.96	0.98	0.9000
L. Product Integrity		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	IP1, 2, 3,4,5	132.38	5	0.00000	0.251	0.380	0.78	0.89	0.8738
Invariant instrument	IP2,3,4,5	36.68	2	0.00000	0.207	0.130	0.87	0.96	0.8540
M. Suppliers' On Time Performance		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	SO1,2,3,4,5	78.54	5	0.00000	0.191	0.240	0.87	0.94	0.8869
Invariant instrument	SO1,2,3,4	11.85	2	0.00267	0.110	0.069	0.96	0.99	0.8580
N. Suppliers' Quality Performance		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	SQ1,2,3,4,5	7.79	5	0.16797	0.037	0.069	0.99	1.00	0.8840
O. Suppliers' Cost Performance		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	SC1,2,3,4,5	87.98	5	0.00000	0.202	0.270	0.83	0.91	0.8525
Invariant instrument	SC1,2,3,5	12.85	2	0.00162	0.116	0.071	0.95	0.98	0.8293
P. Product Development Time		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Unmodified instrument	PT1,2,3,4,5	65.91	5	0.00000	0.173	0.210	0.91	0.96	0.9102
Invariant instrument	PT1,2,3,4	42.18	2	0.00000	0.223	0.140	0.88	0.96	0.8922
Q. Customer Satisfaction		X^2	df	p	RMSEA	ECVI	NNFI	CFI	alpha
Invariant instrument	CS1,2,3,4,5,6	38.47	9	0.00010	0.090	0.150	0.97	0.98	0.9129

The invariant instrument should have both a lower RMSEA and a lower ECVI than those of the original instrument. This criteria is passed by all constructs except only two constructs, i.e., heavyweight product development managers and information technology utilization. NNFIs and CFIs are all above 0.90 except for teamwork performance, product integrity, and product development time that have a threshold NNFI of 0.84, 0.87, and 0.88, respectively. Chronbach's alpha is more than 0.80 except for heavyweight product development managers and team productivity that have an alpha of 0.7708 and 0.7623, respectively. Overall, each construct of the universal instrument has at least one good fit index.

Table 18 shows the result of discriminant validity analysis. Discriminant validity is achieved if the p-value difference between a constrained and unconstrained model is significant, i.e., less than 0.05. The table indicates that all pairwise tests among all eleven product development performance constructs provide strong support for discriminant validity.

The invariance (universal) instrument was then checked for predictive validity. Table 19 shows descriptive statistics, correlation and reliability of the invariance instrument.

Table 19 indicates that each and every correlation between IPD practice (independent variable) and product development performance (dependent variable) is positive as an evidence of predictive validity. The highest correlation is between concurrent engineering and teamwork performance, which is 0.547. All of the correlations are significant at least at alpha = 0.05 (two-tailed) except

Table 18

Discriminant Analysis
(Large Scale Study)

Variables	Constrained Model		Unconstrained Model		Difference		p-value
	Chi-square	df	Chi-square	df	Chi-square	df	
Team Work - Eng.Change	1169.37	27	230.19	26	939.18	1	0.00
Team Work - Prod. Cost	379.16	20	140.18	19	238.98	1	0.00
Team Work - Team Productivity	368.26	27	186.04	26	182.22	1	0.00
Team Work - Mfg. Cost	1571.17	35	205.88	34	1365.29	1	0.00
Team Work - Prod. Integ.	776.78	27	189.04	26	587.74	1	0.00
Team Work - Sup.'s On Time	958.88	27	164.78	26	794.10	1	0.00
Team Work - Sup.'s Quality	1491.00	35	172.15	34	1318.85	1	0.00
Team Work - Sup.'s Cost	798.65	27	155.73	26	642.92	1	0.00
Team Work - Prod. Dev. Time	1121.62	27	185.53	26	936.09	1	0.00
Team Work - Cust. Satisfaction	1675.99	44	206.17	43	1469.82	1	0.00
Eng.Change - Prod. Cost	281.71	14	23.45	13	258.26	1	0.00
Eng.Change - Team Productivity	455.28	20	46.54	19	408.74	1	0.00
Eng.Change - Mfg. Cost	1319.45	27	70.24	26	1249.21	1	0.00
Eng.Change - Prod. Integ.	713.13	20	84.11	19	629.02	1	0.00
Eng.Change - Sup.'s On Time	831.61	20	58.23	19	773.38	1	0.00
Eng.Change - Sup.'s Quality	1445.55	27	41.16	26	1404.39	1	0.00
Eng.Change - Sup.'s Cost	698.57	20	50.20	19	648.37	1	0.00
Eng.Change - Prod. Dev. Time	1061.31	31	64.68	30	996.63	1	0.00
Eng.Change - Cust. Satisfaction	1312.37	35	71.19	34	1241.18	1	0.00
Prod. Cost - Team Productivity	221.62	14	17.01	13	204.61	1	0.00
Prod. Cost - Mfg. Cost	258.76	20	55.20	19	203.56	1	0.00
Prod. Cost - Prod. Integ.	407.98	14	65.27	13	342.71	1	0.00
Prod. Cost - Sup.'s On Time	455.49	14	39.42	13	416.07	1	0.00
Prod. Cost - Sup.'s Quality	413.29	20	22.52	19	390.77	1	0.00
Prod. Cost - Sup.'s Cost	407.00	14	29.02	13	377.98	1	0.00
Prod. Cost - Prod. Dev. Time	407.52	14	53.25	13	354.27	1	0.00
Prod. Cost - Cust. Satisfaction	460.39	27	53.69	26	406.70	1	0.00
Team Productivity - Mfg. Cost	502.06	27	73.06	26	429.00	1	0.00
Team Productivity - Prod. Integ.	501.20	20	84.35	19	416.85	1	0.00
Team Productivity - Sup.'s On Time	650.81	20	42.05	19	608.76	1	0.00
Team Productivity - Sup.'s Quality	621.87	27	46.87	26	575.00	1	0.00
Team Productivity - Sup.'s Cost	674.15	20	49.30	19	624.85	1	0.00
Team Productivity - Prod. Dev. Time	576.37	20	65.57	19	510.80	1	0.00
Team Productivity - Cust. Satisfaction	618.02	35	98.26	34	519.76	1	0.00
Mfg. Cost - Prod. Integ.	712.70	27	111.18	26	601.52	1	0.00
Mfg. Cost - Sup.'s On Time	872.14	27	95.45	26	776.69	1	0.00
Mfg. Cost - Sup.'s Quality	1476.53	35	61.00	34	1415.53	1	0.00
Mfg. Cost - Sup.'s Cost	592.76	27	62.68	26	530.08	1	0.00
Mfg. Cost - Prod. Dev. Time	1043.76	27	90.75	26	953.01	1	0.00
Mfg. Cost - Cust. Satisfaction	1647.88	44	97.14	43	1550.74	1	0.00
Prod. Integ. - Sup.'s On Time	832.80	20	101.26	19	731.54	1	0.00
Prod. Integ. - Sup.'s Quality	646.45	27	81.54	26	564.91	1	0.00
Prod. Integ. - Sup.'s Cost	670.18	20	79.55	19	590.63	1	0.00
Prod. Integ. - Prod. Dev. Time	738.95	20	107.12	19	631.83	1	0.00
Prod. Integ. - Cust. Satisfaction	995.41	36	385.08	35	610.33	1	0.00
Sup.'s On Time - Sup.'s Quality	604.35	27	74.08	26	530.27	1	0.00
Sup.'s On Time - Sup.'s Cost	593.52	20	71.36	19	522.16	1	0.00
Sup.'s On Time - Prod. Dev. Time	889.87	20	85.64	19	804.23	1	0.00
Sup.'s On Time - Cust. Satisfaction	1165.81	36	361.70	35	804.11	1	0.00
Sup.'s Quality - Sup.'s Cost	655.08	27	94.68	26	560.40	1	0.00
Sup.'s Quality - Prod. Dev. Time	1091.12	27	79.97	26	1011.15	1	0.00
Sup.'s Quality - Cust. Satisfaction	1438.94	44	109.74	43	1329.20	1	0.00
Sup.'s Cost - Prod. Dev. Time	716.41	20	73.68	19	642.73	1	0.00
Sup.'s Cost - Cust. Satisfaction	775.62	35	139.44	34	636.18	1	0.00
Prod. Dev. Time - Cust. Satisfaction	920.66	35	114.02	34	806.64	1	0.00

Table 19

Descriptive Statistics, Correlation, and Reliability
Large Scale Survey

Variables	Means	# of items	std dev	1 CE	2 CI	3 SI	4 PD	5 PP	6 IT	7 TW	8 EC	9 PC	10 TP	11 MC	12 PI	13 SO	14 SQ	15 SC	16 PT	17 CS
1 Concurrent Engineering	21 42	6	4 53	8546(a)																
2 Customer Involvement	15 35	4	3 50	381(**)	8218															
3 Supplier Involvement	12 26	4	3 90	321(**)	-0310	8572														
4 Heavyweight Prod Dev Mgr	16 09	5	3 60	331(**)	243(**)	126(*)	7708													
5 Platform Products	9 76	3	2 89	275(**)	250(**)	161(**)	337(**)	8603												
6 Information Technology	20 92	5	3 99	363(**)	221(**)	245(**)	242(**)	246(**)	9027											
7 Teamwork Performance	17 72	5	3 71	547(**)	349(**)	111(*)	391(**)	194(**)	270(**)	9061										
8 Engineering Change Time	13 65	4	3 38	415(**)	229(**)	0630	279(**)	100(*)	211(**)	590(**)	9131									
9 Product Cost Reduction	10 40	3	2 38	428(**)	312(**)	114(*)	239(**)	221(**)	274(**)	540(**)	529(**)	8163								
10 Team Productivity	13 99	4	2 76	443(**)	286(**)	141(**)	318(**)	139(**)	263(**)	669(**)	555(**)	559(**)	7623							
11 Manufacturing Cost Reduction	16 42	5	3 83	459(**)	206(**)	193(**)	274(**)	250(**)	290(**)	479(**)	484(**)	573(**)	525(**)	9000						
12 Product Integrity	15 09	4	2 95	407(**)	257(**)	161(**)	288(**)	243(**)	371(**)	483(**)	461(**)	411(**)	498(**)	444(**)	8540					
13 Suppliers' On Time Performance	13 11	4	2 81	210(**)	171(**)	189(**)	177(**)	0780	208(**)	316(**)	352(**)	213(**)	266(**)	282(**)	340(**)	8580				
14 Suppliers' Quality Performance	18 10	5	3 39	283(**)	168(**)	232(**)	177(**)	171(**)	267(**)	360(**)	337(**)	306(**)	344(**)	326(**)	516(**)	549(**)	8840			
15 Suppliers' Cost Performance	12 93	4	2 82	344(**)	0790	329(**)	211(**)	234(**)	242(**)	255(**)	277(**)	335(**)	298(**)	418(**)	330(**)	460(**)	465(**)	8293		
16 Product Development Time	13 25	4	3 35	329(**)	291(**)	150(**)	359(**)	267(**)	229(**)	429(**)	318(**)	356(**)	462(**)	400(**)	424(**)	231(**)	290(**)	269(**)	8922	
17 Customer Satisfaction	22 37	6	4 24	333(**)	215(**)	142(**)	346(**)	271(**)	295(**)	433(**)	284(**)	279(**)	458(**)	336(**)	492(**)	258(**)	419(**)	294(**)	545(**)	9129

Note

1 Variables 1-6 Independent variables
2 Variables 7-17 Dependent variables
3 ** = Correlation is significant at 0 05 level (2-tailed)
4 * = Correlation is significant at 0 01 level (2-tailed)
5 a = Reliabilities (Chronbach's alphas) are on the diagonal

for the correlations between customer involvement and suppliers' cost performance, supplier involvement and engineering change time, platform products and suppliers' on-time performance that have correlations of 0.0790, 0.0630, and 0.0780, respectively. These three correlations are not significant at alpha = 0.05. After passing this predictive test, then the instrument was used to answer research questions that require the methodology described in Section 3.5.

3.5. Methods for Answering Research Questions

Methods for answering research questions are explained one-by-one below. The research question no.1 asks the relationship between integrated product development (IPD) practices and product development performance variables. The researcher used a series of stepwise regressions to answer the research question no.1. The objective of the stepwise regression is to find a set of independent variables whose values are known to predict the single dependent variable. The stepwise method might be the most popular method approach to pick the set of independent variables (Neter et al., 1996; Stevens, 1996). This method consists of several steps as described below.

First, each independent variable is considered for inclusion. The independent variable that has the highest correlation with the dependent variable enters the regression model first. At each of the successive steps, the independent variable not in the equation that has the lowest probability-of-F-to-enter and less than the SPPS' default value (i.e., 0.050) is entered. This means that the newest independent variable provides the greatest decrease in the unexplained variation in dependent variable. The independent variable already in the regression equation is removed if it has the highest probability-of-F-to-remove and it is higher than the SPPS' default value (i.e., 0.100) because the variable does not make a significant contribution (SPSS, 1998). The method terminates when no more independent variables are eligible for addition or deletion (Hair et al., 1998).

For stepwise regression, the researcher presents several estimates, i.e., standardized regression coefficient, t-value, R^2, and F-value (SPSS, 1998). The first estimate is the standardized regression coefficient or beta coefficient for each independent variable in the regression equation. These beta coefficients are the regression coefficients when all variables are expressed in standardized (z-score) form. Transforming the independent variables to standardized form is an attempt to make the regression coefficients more comparable since they are all in the same units of measure.

The significance of an estimated beta coefficient is established with the help of t-ratio or t-value, which is the ratio of beta coefficient to its standard error. The exact value of t depends on the degree of freedom and sample size. However, for almost any sample size, the approximated critical value for a 95 percent confidence interval level is 2. Therefore, as a rule of thumb, if the absolute t-value is greater than 2, the beta is almost certainly significant at the 95% level of confidence.

The sample coefficient of multiple determination is denoted by R^2 and equals the proportion of the total variation in the dependent variable that is explained by the regression equation. Clearly, R^2 is a measure of the closeness or fit of the regression line. The value of R^2 ranges from 0 (no fit) to 1 (perfect fit).

The last estimate is the F-statistic. A highly significant F-statistic indicates that the simultaneous test assessing beta coefficient is 0 is rejected. In other words, a high F-statistic indicates that the regression equation is helpful to explain the variation of the dependent variable.

Research questions 2 and 3 are dealing with testing the differences in IPD practices and performance between the U.S. and Germany as well as between OEMs and suppliers. The researcher used two-way factorial analysis of variance (ANOVA). The two-way ANOVA allows the researcher to see the joint effect of the independent variables (i.e., countries and stages of supply chain) on the dependent variable (e.g., teamwork performance). This interaction effect cannot be examined if the researcher runs two separate one-way analyses or t-tests. Moreover, factorial designs lead to reduction of type II error and thus increasing the power of the statistical analysis (Stevens, 1996).

If the p-value of the interaction effect is significant, i.e., less than 0.05, then a post-hoc analysis is conducted using Bonferroni procedure with a family level of confidence of 95%. In other words, the family error rate or alpha is 5%. The lower and upper bounds of the mean difference between two subgroups (e.g., U.S. OEMs and U.S. auto suppliers) is calculated as follows (Neter et al., 1996):

$$u_1 - u_2 = (y_1 - y_2) \pm B \sqrt{[MSE\ (1/n_1 + 1/n_2)]}$$

where:

u_1 = lower bound
u_2 = upper bound
y_1 = mean average of the first group (e.g., U.S. OEMs)
y_2 = mean average of the second group (e.g., U.S. auto suppliers)
n_1 = sample size in the first subgroup
n_2 = sample size in the second subgroup
MSE = mean square of errors
B = Bonferroni multiple = $t\ [1- \alpha / 2\ g;\ (n_T - a\ b)]$

where:

t = t value
α = error level (i.e., 5%)
g = number of subgroups in the family (i.e., 2)
n_T = total sample size
a = number of levels studied for factor A (i.e., 2 for country factor)
b = number of levels studied for factor B (i.e., 2 for supply chain factor)

If zero is not within the lower and upper bounds of a pairwise, i.e., two subgroups, then the researcher concluded with 95% confidence that a significant interaction effect occurs.

The last research question is concerned with whether or not the differences in product development performance between countries and stages of the supply chain are due to differences in IPD practices. Like the first research question, the last research question uses stepwise regression. However, the researcher added two dummy independent variables. For the country, 0 indicates the U.S. and 1 indicates Germany. For the level of supply chain, 0 and 1 indicates OEMs and supplier, respectively. If the country (or supply chain) as the dummy variable exists in the regression analysis, it means that there is a country effect (or supply chain effect) in predicting the dependent variable (e.g., teamwork performance). The next chapter answers the four research questions using the statistical analyses discussed in this section.

CHAPTER 4

RESEARCH QUESTIONS ANSWERED

This chapter discusses the answer to the four research questions listed in Section 1.2. The four research questions will be discussed one-by-one.

4.1 Research Question No. 1: IPD and Performance Relationship

The research question no. 1 asks if there is a positive relationship between each of the integrated product development practices and product development performance variables. Table 20 shows a series of stepwise regression analyses that was used to answer the research question. The researcher read the table vertically, i.e., column-by-column or by independent variable.

a. Concurrent Engineering

The first column of the independent variable list in Table 20 indicates that concurrent engineering has positive standardized coefficients with teamwork performance, engineering change time, product cost reduction, team productivity,

Table 20

Stepwise Regression
All Data: Universal Instrument (n = 406)

Product Development Performance (Dependent Variable)		**Integrated Product Development Practice (Independent Variable)**						R^2	F
		Concurrent Engineering	Customer Involvement	Supplier Involvement	Heavyweight PDM	Platform Products	Information Technology Utilization		
Teamwork	Std. Coef.*	0.411	0.122		0.223			0.343	62.660
	t	8.586	2.633		4.897				
Engineering Change Time	Std. Coef.	0.369			0.140			0.189	41.504
	t	7.323			2.772				
Product Cost Reduction	Std. Coef.	0.269	0.151				0.119	0.194	28.814
	t	5.471	2.929				2.302		
Team Productivity	Std. Coef.	0.338			0.171		0.102	0.226	34.945
	t	6.518			3.442		2.015		
Manufacturing Cost Reduction	Std. Coef.	0.380			0.109	0.147		0.243	37.936
	t	7.688			2.152	2.945			
Product Integrity	Std. Coef.	0.212	0.133		0.142		0.228	0.250	29.423
	t	3.961	2.654		2.873		4.511		
Suppliers' On Time Performance	Std. Coef.		0.112	0.147	0.109		0.116	0.089	8.616
	t		2.101	2.789	2.043		2.101		
Suppliers' Quality Performance	Std. Coef.	0.169		0.141			0.153	0.116	15.510
	t	3.043		2.644			2.796		
Suppliers' Cost Performance	Std. Coef.	0.228		0.221		0.154		0.184	26.283
	t	4.347		4.352		3.064			
Product Development Time	Std. Coef.	0.191			0.219	0.145		0.170	24.264
	t	3.684			4.131	2.773			
Customer Satisfaction	Std. Coef.	0.174			0.255		0.150	0.185	26.788
	t	3.261			4.984		2.876		

Note:

* = Std. Coef. = standardized regression coefficient = beta coefficient

manufacturing cost reduction, product integrity, suppliers' quality performance, suppliers' cost performance, product development time, and customer satisfaction.

b. Customer Involvement

The second column finds that customer involvement has a positive relationship with teamwork performance, product cost reduction, product integrity, and suppliers' on-time performance.

c. Supplier Involvement

The third column finds that supplier involvement has a positive relationship with suppliers' on-time performance, suppliers' quality performance, and suppliers' cost performance.

d. Heavyweight Product Development Managers

The fourth column finds that heavyweight product development managers construct has a positive relationship with teamwork performance, engineering change time, team productivity, manufacturing cost reduction, product integrity, suppliers' on-time performance, product development time, and customer satisfaction.

e. Platform Product

The fifth column finds that platform products construct has a positive relationship with manufacturing cost reduction, suppliers' cost performance, and product development time.

f. Information Technology Utilization

The sixth column finds that information technology construct has a positive relationship with product cost reduction, team productivity, product integrity, suppliers' on-time performance, suppliers' quality performance, and customer satisfaction.

4.2. Research Question No. 2: the U.S. versus Germany

The research question no. 2 asks if there are differences between the U.S. and Germany in both IPD practices and product development performance. This research question is formalized through a series of hypotheses in Section 2.4 for IPD practices and Section 2.5 for product development performance. Table 21 shows the p-values from two-factor analysis of variance of IPD practices and performance variables by country and supply chain. Supply chain differences will be discussed in Section 4.3. This section only discusses the

Table 21

P-values from Two-Factor Analysis of Variance of Integrated Product Development (IPD) Practices and Performance Variables by Supply Chain and Country

Integrated Product Development Practices (Independent Variables)	Number of items		Country				Supply Chain(***)			P-value of
			US	Germany	Current Study	Previous Study	OEM	Supplier	Current Study	Interaction (****)
Concurrent Engineering	6	Mean	20 849	22 587	Germany > US	Not Conclusive	22 294	21 073	OEM > Supplier	
		P-value	0 002 (*)				0 029 (**)			0 752
Customer Involvement	4	Mean	15 157	15 730	No difference	Germany > US	13 746	15 983	Supplier > OEM	
		P-value	0 607				0 000 (*)			0 000 (*)
Supplier Involvement	4	Mean	11 917	12 920	Germany > US	Germany > US	15 386	11 024	OEM > Supplier	
		P-value	0 006 (*)				0 000 (*)			0 507
Heavyweight Product Development Managers	5	Mean	16 227	15 821	No difference	US > Germany	16 802	15 803	No difference	
		P-value	0 087				0 079			0 073
Platform Products	3	Mean	10 060	9 183	US > Germany	Not Conclusive	10 268	9 566	No difference	
		P-value	0 001 (*)				0 093			0 140
Information Technology Utilization	5	Mean	20 528	21 667	Germany > US	No previous study	21 739	20 590	OEM > Supplier	
		P-value	0 012 (**)				0 012 (**)			0 906

Product Development Performance (Independent Variable)	Number of items		Country				Supply Chain			P-value of
			US	Germany	Current Study	Previous Study	OEM	Supplier	Current Study	Interaction
Teamwork Performance	5	Mean	17 569	18 015	No difference	Germany > US	17 956	17 629	No difference	
		P-value	0 447				0 575			0 544
Engineering Change Time	4	Mean	13 616	13 725	No difference	Germany > US	13 825	13 585	No difference	
		P-value	0 670				0 476			0 729
Product Cost Reduction	3	Mean	10 269	10 640	No difference	US > Germany	10 496	10 358	No difference	
		P-value	0 107				0 490			0 526
Team Productivity	4	Mean	13 798	14 348	No difference	No difference	14 281	13 869	No difference	
		P-value	0 157				0 288			0 496
Manufacturing Cost Reduction	5	Mean	16 221	16 810	Germany > US	US > Germany	17 125	16 149	OEM > Supplier	
		P-value	0 047 (**)				0 008 (*)			0 133
Product Integrity	4	Mean	14 935	15 403	No difference	US > Germany	15 368	14 982	No difference	
		P-value	0 095				0 176			0 442
Suppliers' On Time Performance	4	Mean	12 988	13 333	No difference	Not Conclusive	13 726	12 862	OEM > Supplier	
		P-value	0 310				0 009 (*)			0 946
Suppliers' Quality Performance	5	Mean	17 669	18 928	Germany > US	Not Conclusive	18 911	17 789	OEM > Supplier	
		P-value	0 000 (*)				0 002 (*)			0 335
Suppliers' Cost Performance	4	Mean	12 984	12 828	No difference	US > Germany	14 036	12 491	OEM > Supplier	
		P-value	0 699				0 000 (*)			0 736
Product Development Time	4	Mean	13 156	13 420	No difference	No difference	13 848	13 014	No difference	
		P-value	1 000				0 095			0 128
Customer Satisfaction	6	Mean	22 284	22 533	No difference	Germany > US	23 225	22 041	OEM > Supplier	
		P-value	0 597				0 017 (**)			0 945

Note

* = Significant at 0 01 level of significance
** = Significant at 0 05 level of significance
*** = No previous large scale study related with OEMs vs Auto Suppliers in IPD and product development performance has been found
**** = Interaction between country and supply chain

results for country differences. If the p-value was significant, i.e., $p < 0.05$, the hypothesis was rejected. The researcher also checked the interaction between country and supply chain. If the interaction was significant, then a post-hoc analysis using Bonferoni analysis discussed earlier in Chapter 3 was conducted. The next paragraphs describe each construct one-by-one and are grouped under either IPD practices or product development performance.

4.2.1. Integrated Product Development Practices

a. Concurrent Engineering

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their concurrent engineering, was rejected ($p = 0.002$). Germany has a higher mean score (mean = 22.587) of concurrent engineering than that of U.S. companies (mean = 20.849). As discussed before, the results of the previous studies related with concurrent engineering are mixed, i.e., it is not clear which country has a higher degree of concurrent engineering. This study indicates that German companies score higher in concurrent engineering. This result may be due to the fact that cross-functional cooperation is better in Germany as suggested by Gerpott and Domsch (1985), Edgett, Shipley, and Forbes (1992), and Song and Parry (1996).

b. Customer Involvement

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 15.157) and German companies (mean = 15.730) in the level of their customer involvement, was not rejected (p = 0.607). However, a significant interaction happens (p=0.000). Table 22 shows the interaction (post-hoc) analysis of customer involvement using Bonferroni procedure. As can be seen in the country analysis of Table 22, each pairwise interval indicates that at a 95% confidence interval, zero is not within lower and upper bounds. Therefore it can be concluded that a significant supply chain effect exists for each country.

Table 22

Interaction (Post-Hoc) Analysis of Customer Involvement
Using Bonferroni Procedure

Country Analysis

Country	Supply Chain		Mean	95% Confidence Interval for Mean Difference	
	OEM	Supplier			
	Mean	Mean	Difference	Lower bound	Upper bound
U.S.	14.4267	15.4427	-1.0160	-2.0169	-0.0151
Germany	12.4359	17.0408	-4.6049	-5.9965	-3.2133

Supply Chain Analysis

Supply Chain	Country		Mean	95% Confidence Interval for Mean Difference	
	U.S.	Germany			
	Mean	Mean	Difference	Lower bound	Upper bound
OEM	14.4267	12.4359	1.9908	0.5397	3.4419
Supplier	15.4427	17.0408	-1.5981	-2.5106	-0.6856

The country analysis in Table 22 also indicates an interesting result. The level of customer involvement for auto supplier is always higher compared to that of OEMs, regardless of the country. In other words, for U.S. companies, auto suppliers have a higher degree of customer involvement than that of OEMs. Similarly, for German companies, auto suppliers have a higher degree of customer involvement than that of OEMs. This may indicate that the strength of customer involvement in product development is stronger between industrial companies (i.e., between auto suppliers and OEMs) than that of between OEMs and their customers.

c. Supplier Involvement

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their supplier involvement, was rejected (p = 0.006). German companies (mean = 12.920) are better in supplier involvement than that of U.S. companies (mean = 11.917). This result confirms previous findings from Clark and Fujimoto (1991) and Sako, Lamming, and Helper (1998).

d. Heavyweight Product Development Managers

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 16.227) and German companies (mean = 15.821) in the level of their heavyweight product development managers, was not rejected (p = 0.087). However, a previous study indicates that U.S. product development managers are more powerful (Clark and Fujimoto, 1991). If the previous study was true, the finding of this dissertation may indicate that German companies have increased the power of product development managers in the last decade.

e. Platform Products

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their platform products, was rejected (p = 0.001). The U.S. has a higher mean score (mean =10.060) of concurrent engineering than that of German companies (mean = 9.183). As discussed before, previous studies indicate a mixed result because they use different operational constructs for measuring platform products.

f. Information Technology Utilization

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their information technology utilization, was rejected (p = 0.012). German companies have a higher mean score (mean = 21.667) of concurrent engineering than that of U.S. companies (mean = 20.528). This is one of the new findings resulting from this dissertation because there was no previous comparative study between the U.S. and Germany on information technology utilization. The higher level of information technology utilization in Germany may be due to the fact that technological orientation training occupies a prominent position in German companies (Dowling and Albrecht, 1991; Kern and Sabel, 1991; French, 1995).

4.2.2. Product Development Performance

a. Teamwork Performance

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 17.569) and German companies (mean = 18.015) in the level of their teamwork performance, was not rejected (p = 0.447). However, a previous study by Gerpottt and Domsch's (1985) indicates that Germany has a higher level of teamwork performance. If the previous study was true, the finding of this dissertation may indicate that U.S. companies have increased their teamwork performance in the last two decades.

b. Engineering Change Time

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 13.616) and German companies (mean = 13.725) in the level of their engineering change time, was not rejected (p = 0.670). However, a series of previous studies by Clark, Chew and Fujimoto (1987), Fujimoto (1989), and Clark and Fujimoto (1991) indicates that Germany is better in engineering change time. If the previous studies were true, the finding of this dissertation may indicate that U.S. companies have made some progress in reducing engineering change time in the last decade.

c. Product Cost Reduction

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 10.640) and German companies (mean = 10.269) in the level of their product cost reduction, was not rejected (p = 0.490). However, previous studies by Sheriff (1988) and Ittner and MacDuffie (1995) suggest that the U.S. has better performance in product cost reduction. If the previous study was true, the finding of this dissertation may indicate that German companies have increased their performance in product cost reduction.

d. Team Productivity

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 13.789) and German companies (mean = 14.348) in the level of their team productivity, was not rejected (p = 0.157). This supports previous studies.

e. Manufacturing Cost Reduction

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their manufacturing cost reduction, was rejected (p = 0.047). German companies have a higher mean score (mean = 16.810) of manufacturing cost reduction than that of U.S. companies (mean = 16.221). This result does not support the previous studies by Gersbach et al., (1994) and Ittner and MacDuffie (1995) suggesting that German companies had a higher manufacturing cost. One possible explanation is that German companies still have a higher manufacturing cost than that of U.S. companies. However, German companies are more satisfied with their progress in reducing manufacturing cost than that of U.S. companies.

f. Product Integrity

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 14.935) and German companies (mean = 15.403) in the level of their product integrity, was not rejected (p = 0.095). However, previous studies by Sheriff (1988) and Ittner and MacDuffie (1995) suggest that the U.S. has a better performance in product integrity. If the previous study was true, the finding of this dissertation may indicate that German companies have increased their product integrity.

g. Suppliers' On Time Performance

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 12.988) and German companies (mean = 13.333) in the level of their suppliers' on time performance, was not rejected (p = 0.310). The previous studies are not conclusive because of conflicting results.

h. Suppliers' Quality Performance

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 12.984) and German companies (mean = 12.828) in the level of their suppliers' quality performance, was rejected (p = 0.000). German companies have a higher score (mean = 18.928) of suppliers' quality performance than that of U.S. companies (mean = 17.669). The previous studies are not conclusive because of conflicting results.

i. Suppliers' Cost Performance

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 13.156) and German companies (mean = 13.420) in the level of their supplier's cost performance, was not rejected (p = 0.699). Previously, Birou and Fawcett (1994) indicate that U.S. companies rate their supplier's cost performance higher than that of German companies. However, one must remember that their respondents are from various industries, not only from the auto industry.

j. Product Development Time

The hypothesis, saying that there is no difference in the mean score of U.S. companies (mean = 22.284) and German companies (mean = 22.533) in the level of their product development time, was not rejected (p = 1.000). This result confirms the previous study by Clark and Fujimoto (1991).

k. Customer Satisfaction

The hypothesis, saying that there is no difference in the mean score of U.S. companies and German companies in the level of their customer satisfaction, was not rejected (p = 0.597). This result does not confirm previous studies by Fujimoto (1989), Clark and Fujimoto (1991), Fujimoto, Iansiti, and Clark (1996). They indicate that European OEMs satisfy customers better than their U.S. counterparts. If the previous studies were true, the finding of this dissertation may indicate that U.S. companies have increased their customer satisfaction level.

4.3. Research Question No. 3: OEMs vs. Suppliers

Research question no. 3 asks if there are differences between OEMs and suppliers in both IPD practices and product development performance. The question is formalized through a series of hypotheses in Section 2.6. To answer research question no. 3, Table 21 that was used to answer research question no. 2 was used again. The next paragraphs describe each construct one-by-one and grouped under either IPD practices or product development performance.

4.3.1 Integrated Product Development Practices

a. Concurrent Engineering

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their concurrent engineering, was rejected ($p = 0.029$). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 22.294) of concurrent engineering than that of auto suppliers (mean = 21.073). This may be due to the fact that product development in auto suppliers is less demanding so that it requires less concurrent workflow, less cross-functional cooperation, and less early involvement of constituents.

b. Customer Involvement

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their customer involvement, was rejected ($p = 0.000$). The finding of this dissertation indicates that auto suppliers have a higher mean score (mean = 15.983) of concurrent engineering than that of OEMs (mean = 13.746).

However, a significant interaction happens (p = 0.000). Table 22 discussed earlier shows the interaction (post-hoc) analysis of customer involvement using the Bonferroni procedure. As can bee seen in the supply chain analysis of Table 22, each pairwise interval indicates that at a 95% confidence interval, zero is not within lower and upper bounds. Therefore it can be concluded that a significant country effect exists for each level of the supply chain.

The country analysis in Table 22 also provides an interesting insight. The level of customer involvement for German auto suppliers is always higher compared to that of the other three subgroups, i.e., German OEMs, U.S. OEMs, and U.S. suppliers. This confirms the previous discussion indicating that auto suppliers in Germany have a high technical capability and are highly involved in the R&D activities of their customers (Thomson and Strickland, 1992). Technical capabilities are the main driver that builds the relationship between auto suppliers and their customers (Clark and Fujimoto, 1991; Fujimoto, 1994; Kamath and Liker, 1994; Wasti and Liker, 1997). A recent interview with a product development professional, who has been working in both Germany and the U.S., confirms this finding.

c. Supplier Involvement

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their supplier involvement, was rejected (p = 0.000). The finding of this dissertation indicates that OEMs have a substantially higher mean score (mean = 15.386) of supplier involvement than that of auto suppliers (mean = 11.024).

Looking from a customer relationship perspective, one must understand that auto suppliers' customers are OEMs whereas OEMs' customers are customers of automobiles. Looking differently from a supplier relationship perspective, Tier 1 suppliers are the suppliers for OEMs and Tier 2 suppliers are the suppliers of Tier 1 suppliers. Using data from the U.S. and Germany, this dissertation indicates that customer involvement is higher for auto suppliers whereas supplier involvement is higher for OEMs. This suggests that, in the U.S. and German auto industries, strong product development cooperation happens between OEMs and Tier 1 auto suppliers and vice versa but not between Tier 1 and Tier 2 suppliers. A recent interview by the researcher with a Japanese expert in the auto industry reveals a similar pattern, i.e., strong product development cooperation in the Japanese auto industry happens only between OEMs and Tier 1 auto suppliers but not between Tier 1 and Tier 2 suppliers. This may be due to the fact that most Tier 2 suppliers receive complete product specifications from Tier 1 suppliers.

d. Heavyweight Product Development Managers

The hypothesis, saying that there is no difference in the mean score of OEMs (mean = 16.802) and auto suppliers (mean = 15.803) in the level of their heavyweight product development managers, was not rejected (p = 0.079). This means that OEMs and auto suppliers have the same level of heavyweight product development managers

e. Platform Products

The hypothesis, saying that there is no difference in the mean score of OEMs (mean = 10.268) and auto suppliers (mean = 9.566) in the level of their platform products, was not rejected (p = 0.093). This means that OEMs and auto suppliers have the same level of platform products.

f. Information Technology Utilization

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in information technology utilization, was rejected (p = 0.012). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 21.739) of supplier involvement than that of auto suppliers (mean = 20.590). It is a plausible explanation that auto manufacturers have more resources to invest in information technology.

4.3.2. Product Development Performance

a. Teamwork Performance

The hypothesis, saying that there is no difference in the mean score of OEMs (mean =17.959) and auto suppliers (mean = 17.629) in the level of their teamwork performance, was not rejected (p = 0.575). This means that OEMs and auto suppliers have the same level of teamwork performance.

b. Engineering Change Time

The hypothesis, saying that there is no difference in the mean score of OEMs (mean =13.825) and auto suppliers (mean = 13.585) in the level of their engineering change time performance, was not rejected (p = 0.575). This means that OEMs and auto suppliers have the same level of engineering change time performance.

c. Product Cost Reduction

The hypothesis, saying that there is no difference in the mean score of OEMs (mean = 10.496) and auto suppliers (mean = 10.358) in the level of their product cost reduction, was not rejected (p = 0.490). This means that OEMs and auto suppliers have the same level of product cost reduction.

d. Team Productivity

The hypothesis, saying that there is no difference in the mean score of OEMs (mean =14.281) and auto suppliers (mean = 13.869) in the level of their team productivity, was not rejected (p = 0.288). This means that OEMs and auto suppliers have the same level of team productivity.

e. Manufacturing Cost Reduction

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their manufacturing cost reduction, was rejected (p = 0.008). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 17.125) of manufacturing cost reduction than that of auto suppliers (mean = 16.149). Thus, OEMs have better performance in manufacturing cost reduction than do auto suppliers.

f. Product Integrity

The hypothesis, saying that there is no difference in the mean score of OEMs (mean = 15.368) and auto suppliers (mean = 14.982) in the level of their product integrity, was not rejected (p = 0.176). This means that OEMs and auto suppliers have the same level of product integrity.

g. Suppliers' On Time Performance

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their suppliers' on-time performance, was rejected (p = 0.009). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 13.726) of suppliers' on-time performance than do auto suppliers (mean = 12.982).

As mentioned earlier, first-tier suppliers are the suppliers for OEM and second-tier suppliers are the suppliers for first-tier suppliers. The finding of this dissertation indicates that first-tier suppliers have a better on-time performance than that of second-tier suppliers.

h. Suppliers' Quality Performance

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their suppliers' quality performance, was rejected (p = 0.002). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 18.911) of suppliers' on-time performance than that of auto suppliers (mean = 17.789). Thus, the finding of this dissertation indicates that first-tier suppliers have a better on-time performance than that of second-tier suppliers.

i. Suppliers' Cost Performance

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their suppliers' cost performance, was rejected (p = 0.000). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 14.036) of suppliers' cost performance than that of auto suppliers (mean = 12.491). Therefore. the finding of this dissertation indicates that first-tier suppliers have a better cost performance than second-tier suppliers.

j. Product Development Time

The hypothesis, saying that there is no difference in the mean score of OEMs (mean =13.848) and auto suppliers (13.014) in the level of their product development time, was not rejected (p = 0.095). This means that OEMs and auto suppliers have the same level of product development time.

k. Customer Satisfaction

The hypothesis, saying that there is no difference in the mean score of OEMs and auto suppliers in the level of their customer satisfaction, was rejected (p = 0.017). The finding of this dissertation indicates that OEMs have a higher mean score (mean = 23.225) of customer satisfaction than that of auto suppliers (mean = 22.041). Consequently, the finding of this dissertation indicates that OEMs' customers are more satisfied than first-tier suppliers' customers (i.e., OEMs).

Before going to the next section, it is prudent to revisit all three supplier performance variables. If the respondents of the survey used in this dissertation are from OEMs and are asked to evaluate their suppliers' performance, it means that the survey asks about Tier 1 suppliers' performance. Similarly, if the respondents of the survey are Tier 1 suppliers and are asked to evaluate their suppliers' performance, it means that the survey asks about Tier 2 suppliers' performance. The findings of all three suppliers' performance measurements (on-time, quality, and cost performance) are very illuminating. In all three performance measurements, Tier 1 auto suppliers always have better performance than do Tier 2 auto suppliers. Moreover, in none of the other performance measures are auto suppliers better than auto manufacturers. This indicates that in the auto industry supply chain, product development performance is deteriorating as product development activities move upstream from OEMs to Tier 1 auto suppliers and then to Tier 2 auto suppliers. This suggests that the overall auto industry has not been successful in integrating product development across the supply chain.

4.4. Research Question No. 4: Explaining Performance Difference

The research question no. 4 asks if the differences in product development performance between countries and stages of the supply chain are due to differences in IPD practices. To answer this question, first the researcher attempted to find product development performance variables that differed in the two countries using Table 21. After that, the researcher used Table 23 to explain the difference. The same method was repeated for product development performance variable that differed in the two levels of supply chain. It is important to note that Table 23 uses two dummy variables. For country variable, 0 means the U.S. and 1 means Germany. For the supply chain variable, 0 and 1 mean OEMs and suppliers, respectively.

4.4.1. Performance Differences in the Two Countries

Table 21 indicates that Germany has higher performance in both manufacturing cost reduction and suppliers' quality performance than the U.S. These two performance measures will be discussed as follows.

a. Manufacturing Cost Reduction

The row containing manufacturing cost reduction in Table 23 can be explained in detail as follows:

Table 23

Stepwise Regression with Dummy Variables
All Data: Universal Instrument (n = 406)

Product Development Performance (Dependent Variable)		**Integrated Product Development Practice (Independent Variable)**									
		Country ** (U.S. vs Germany)	Supply Chain *** (OEM vs Supplier)	Concurrent Engineering	Customer Involvement	Supplier Involvement	Heavyweight PDM	Platform Products	Information Technology Utilization	R^2	F
Teamwork Performance	Std. Coef.*			0.411	0.122		0.223			0.343	62.657
	t			8.591	2.625		4.900				
Engineering Change Time	Std. Coef.			0.364			0.143			0.186	40.938
	t			7.237			2.839				
Product Cost Reduction	Std. Coef.			0.294	0.155				0.116	0.193	28.552
	t			5.417	2.993				2.254		
Team Productivity	Std. Coef.			0.339			0.168		0.100	0.223	34.427
	t			6.530			3.382		1.974		
Manufacturing Cost Reduction	Std. Coef.			0.372			0.107	0.132		0.227	34.941
	t			7.485			2.096	2.635			
Product Integrity	Std. Coef.			0.221	0.133		0.135		0.229	0.253	30.014
	t			4.137	2.652		2.755		4.555		
Suppliers' On Time Performance	Std. Coef.		-0.188		0.183				0.138	0.087	11.242
	t		-3.496		3.323				2.586		
Suppliers' Quality Performance	Std. Coef.	0.107		0.152		0.121			0.151	0.121	12.253
	t	2.105		2.734		2.292			2.785		
Suppliers' Cost Performance	Std. Coef.		-0.130	0.233		0.156		0.145		0.194	20.991
	t		-2.346	4.486		2.713		2.902			
Product Development Time	Std. Coef.			0.193			0.219	0.144		0.170	24.377
	t			3.723			4.128	2.758			
Customer Satisfaction	Std. Coef.			0.198			0.240		0.165	0.192	29.586
	t			3.755			4.736		3.203		

Note:

* = Std. Coef. = standardized regression coefficient = beta coefficient
** = Dummy variable; 0 if the U.S., 1 if Germany
*** = Dummy variable; 0 if OEMs, 1 if Auto Suppliers

1. Each one additional level of concurrent engineering raises the estimated level of manufacturing cost reduction performance by 0.372, if the values of other independent variables are held constant.
2. Each one additional lev el of heavyweight product development managers raises the estimated level of manufacturing cost reduction performance by 0.107, if the values of other independent variables are held constant.
3. Each one additional level of platform product raises the estimated level of manufacturing cost reduction performance by 0.132, if the values of other independent variables are held constant.

The corresponding t-values are more than two and therefore pass the rule-of-thumb test of 95% significance. The R^2 is 0.227. F is 34.941, which means it is highly significant with a p-value of less than 0.0005. In a nutshell, the difference in manufacturing cost reduction performance is positively and significantly correlated with concurrent engineering, heavyweight product development managers, and platform products.

Because Germany has a higher level of manufacturing cost reduction compared to the U.S., as a consequence, it was then expected that the level of concurrent engineering, heavyweight product development managers, and platform products is higher in Germany than it is in the U.S. However, Table 21 reveals that, although the level of concurrent engineering is higher in Germany than it is in the US, the level of heavyweight product development managers are the same in both countries, and the level of platform products is lower in Germany than in the US. The standardized coefficients or beta coefficients in

Table 23 explain this seemingly contradicting result above. The beta for concurrent engineering is 0.372 whereas for heavyweight product development managers and the level of platform products are lower, i.e., 0.107 and 0.132, respectively. Therefore, the analysis suggests that the high level of concurrent engineering in Germany overcomes German's deficiency in heavyweight product development managers and platform products.

Table 23 also shows that the regression coefficients for country and supply chain do not exist, i.e., are not significant. This suggests that U.S. and German companies with similar levels of practice can achieve similar levels of performance regardless of whether they are OEMs or suppliers.

b. Suppliers' quality performance

Table 23 indicates that difference suppliers' quality performance is positively and significantly correlated with concurrent engineering (beta = 0.152) supplier involvement (b = 0.121), and information technology utilization (b = 0.151). The corresponding t-values are significant. The R^2 is 0.121. F is 12.253, which means it is highly significant with a p-value of less than 0.0005. This is supported by the results in Table 21 indicating that German companies have a higher level of concurrent engineering, supplier involvement, and information technology utilization than U.S. companies.

However, although the regression coefficient for the supply chain does not exists, the beta coefficient for country exists with b = 0.107. As discussed earlier, the dummy variable for the supply chain is 0 for the U.S. and 1 for Germany. Because the beta is positive, the result indicates that if a company is in Germany instead of in the U.S., it can increase suppliers' quality performance. This may be due to the fact that many large German suppliers have a high technical capability and are highly involved in the R&D activities of their customers as discussed earlier (Thompson and Strickland, 1992). Additionally, many executives in German companies have some engineering background that helps them to understand technical and R&D issues (Chen, 1990).

Ittner and Larcker (1997) also provide some additional insights regarding quality management practice differences between the U.S. and Germany. They find that German boards of directors review quality plans and results more often than their U.S. counterparts. They contribute this to the difference in corporate governance. Unlike U.S. companies, German companies always have two sets of directors. The first one is a management board that is responsible for daily operations and strategic objectives. The second one is a supervisory board that monitors the management board. This supervisory board is partially elected by employees. This structure results in more involvement of the German management board in company decisions than U.S. boards of directors (Sherman, 1991; Olivier, 1994).

4.4.2. Performance Differences in the Two Levels of Supply Chain

Table 21 indicates that OEMs have a higher performance in manufacturing cost reduction, suppliers' on-time performance, suppliers' quality, suppliers' cost performance, and customer satisfaction than those of auto suppliers. These five performance measures will be discussed as follows.

a. Manufacturing Cost Reduction

As discussed earlier in Section 4.4.1, the difference in manufacturing cost reduction performance is positively and significantly correlated with concurrent engineering, heavyweight product development managers, and platform products. The discussion also suggests that OEMs or suppliers with similar levels of practice can achieve similar levels of performance regardless of whether they are in Germany or in the U.S.

However, Table 21 reveals that, although the extent of concurrent engineering is higher for OEMs than that of auto suppliers, the extent of both heavyweight product development managers and platform products are the same in the two levels of the supply chain. Using the similar logic used in Section 4.4.1., it can be concluded that the higher extent of concurrent engineering in OEMs masks OEMs' non-superiority in heavyweight product development managers and platform products.

b. Suppliers' On-Time Performance

Table 23 indicates that a difference in suppliers' on-time performance is positively and significantly correlated with customer involvement (b = 0.183) and information technology utilization (0.138). The R^2 is very low, i.e., 0.087 but F is 11.242, which means it is highly significant with a p-value of less than 0.0005.

Although the regression coefficient for country does not exist, the regression coefficient for supply chain does exist with beta = - 0.188 (t = -3.496). As discussed earlier, the dummy variable for country is 0 for OEM and 1 for auto supplier. Because the beta is negative, this means that if a company is an OEM, it has a better suppliers' on-time performance. As mentioned earlier, OEMs are supplied by Tier 1 suppliers and Tier 1 suppliers are supplied by Tier 2 suppliers. The results also indicate that suppliers' on-time performance deteriorates if a company belongs to a lower level of supply chain.

While Table 23 indicates that a difference in suppliers' on-time performance is positively and significantly caused by customer involvement and information technology utilization, Table 21 offers another interesting insight. The later table suggests that OEMs have a higher level of information technology utilization but a lower level of customer involvement than auto suppliers. This is a paradox because it is expected that OEMs have a higher level of both IPD practices. Furthermore, it cannot be explained by suggesting that a higher level in information technology utilization can overcome the deficiency in customer involvement because the beta for customer involvement (b = 0.183) is higher than the one for information technology utilization (b = 0.138).

One possible explanation is that a higher level of customer involvement by auto suppliers make them vulnerable to the request by OEMs to improve suppliers' on-time performance. This is supported by a finding from Fitzgerald (1997) discussed earlier. In his survey, he asks OEM engineers about their dissatisfaction with suppliers. The OEM engineers indicate that suppliers' on-time performance is their number one concern in product development.

c. Suppliers' Quality Performance

Table 23 indicates that difference suppliers' quality performance is positively and significantly correlated with concurrent engineering (b = 0.152), supplier involvement (b = 0.121), and information technology utilization (b = 0.151). This is supported by the results in Table 21 indicating that OEMs have a higher level of concurrent engineering, supplier involvement, and information technology utilization than do the suppliers. The regression coefficient for country exists. It means that if a company is in Germany instead of in the U.S., it can increase suppliers' quality performance. As suggested earlier, this may be due to the technical capability of the German suppliers (Thompson and Strickland, 1992) and the fact that German directors pay more attention to quality program than their U.S. counterparts (Ittner and Larcker, 1997).

d. Suppliers' Cost Performance

Table 23 indicates that difference suppliers' cost performance is positively and significantly correlated with concurrent engineering (b = 0.233), supplier involvement (b = 0.156), and platform products (b = 0.145). The R^2 is 0.194. F is 20.991, which means it is highly significant with a p-value of less than 0.0005. This is supported by the results in Table 21 indicating that although OEMs have the same level of platform products compared to auto suppliers, OEMs have a higher level of both concurrent engineering and supplier involvement than auto suppliers.

Although the regression coefficient for country does not exist, the regression coefficient for supply chain exists with b = - 0.130 (t = -2.346). The dummy variable for country is 0 for OEM and 1 for auto supplier. This means that if a company is an OEM, it has a better suppliers' cost performance. The results indicate that suppliers' on-time performance deteriorates if a company belongs to a lower level of the supply chain.

e. Customer Satisfaction

Table 23 indicates that customer satisfaction is positively and significantly correlated with concurrent engineering (b = 0.198), heavyweight product development managers (b = 0.240), and information technology utilization (b = 0.165). The R^2 is 0.192. F is 29.586, which means it is highly significant with a p-value of less than 0.0005. This is supported by the results in Table 21. Although OEMs have the same level of heavyweight product development managers compared to auto suppliers, OEMs have a higher level of both concurrent engineering and information technology utilization than auto suppliers. Moreover, the regression coefficients for country and supply chain do not exists, i.e., are not significant. This suggests that U.S. and German companies with similar levels of practice can achieve similar levels of performance regardless of whether they are OEMs or suppliers.

The next chapter discusses the summary of the findings discussed in this chapter.

CHAPTER 5

SUMMARY, DISCUSSION, AND RECOMMENDATIONS

5.1. Summary

Section 1.2. presents four research questions that were answered in Chapter 4 of this dissertation. This section will revisit those four questions and summarize the findings.

Question No. 1: What is the relationship between integrated product development (IPD) practices (independent variables) and product development performance (dependent) variables?

Section 4.1. answers that research question. The analysis in Section 4.1. confirms that each of the IPD practices has a positive relationship with a set of product development performance variables. Six IPD practices and eleven product development performance variables were studied in this dissertation. Each IPD practice affects a certain number of product development performance variables. Concurrent engineering, customer involvement, supplier involvement, product development managers, platform products, information technology utilization each affect ten, four, three, eight, four, and six product development performance variables respectively. It is an illuminating revelation to discover that concurrent engineering affects ten of out eleven product development performance variables studied in this dissertation.

Question No. 2: Are there differences between U.S. and Germany in IPD practices and performance?

Section 4.2. confirms that there are differences between the U.S. and Germany in IPD practices and performance. The findings indicate that Germany has better IPD practices in concurrent engineering, supplier involvement and information technology utilization whereas the U.S. is better only in one IPD practice, i.e., platform products. Germany has better product development performance in manufacturing cost reduction and suppliers' quality performance whereas the U.S. has better product development performance in none of the eleven performance variables.

Question # 3: Are there differences between OEMs and suppliers in IPD practices and performance?

Section 4.3 confirms that there are differences between OEMs and auto suppliers in IPD practices and performance. The findings indicate that OEMs have better IPD practices in concurrent engineering, supplier involvement and information technology utilization whereas auto suppliers are better in only one IPD practice, i.e., customer involvement. OEMs have a better product development performance in manufacturing cost reduction, suppliers' on-time performance, suppliers' quality performance, and suppliers' cost performance whereas auto suppliers have better a product development performance in none of the eleven performance variables.

Section 4.3. also offers two additional insights. First, strong product development cooperation happens between OEMs and Tier 1 auto suppliers and vice versa but not between Tier 1 and Tier 2 suppliers. Secondly, in the auto industry supply chain, product development performance is deteriorating as product development activities descend from OEMs to Tier 1 auto suppliers and then to Tier 2 auto suppliers. This suggests that the overall auto industry has not been successful in integrating product development across the supply chain.

Question No. 4: Are the differences in product development performance between countries and stages of the supply chain due to differences in IPD practices?

Section 4.4. confirms that the differences in product development performance between countries and stages of the supply chain are due to differences in IPD practices. Once again, concurrent engineering is the IPD practice that appears for the most part to be the reason for the difference in product development performance. The supply chain effect explains the difference in suppliers' on-time performance and suppliers' cost performance, i.e., OEMs are doing better in both performance measures. The difference in the country can explain the difference in suppliers' quality performance, i.e., Germany is doing better in suppliers' quality performance than that of the U.S.

5.2. Discussion

The discussion in this section is divided into three subsections, i.e., substantive contribution, methodological contribution, and practical implication.

5.2.1. Substantive Contribution

The first major substantive contribution of this dissertation is to update previous studies related with the differences between the U.S. and German auto industry. This dissertation fills the holes left by previous researchers. For example, there was no previous study that compares the level of information technology utilization between the U.S. and Germany. In another example, previous studies indicate conflicting results with respect to the differences in the two countries related with concurrent engineering, platform products, suppliers' on-time performance and suppliers' quality performance. This is due to several factors including the use of single measure, unreliable instrument, small sample size, or invalid measures. Moreover, most comparative regional study in the auto industry (e.g., Clark and Fujimoto, 1991) do not break down their European data by country. Therefore, it is not clear if their conclusion can be applied specifically to Germany. In some cases, the researchers (e.g., Birou and Fawcett, 1994) use cross-industry data. As a consequence, conclusions regarding a specific industry such as the auto industry cannot be drawn. Another illustration is how some studies use crude approximations to measure other variables such as the one by Ittner and MacDuffie (1995) that uses labor cost as an approximation of the manufacturing cost. That approximation may be opposed by Drucker (1990). He finds that the share of direct labor cost to manufacturing cost excluding material cost was up to 80% in the 1920s. However, in the current auto industry, the number is only 18% and companies are pushing it down to 8-12%. Therefore, the use of labor cost as an approximation of manufacturing cost in the auto industry may lead to unwarranted conclusions.

The second major substantive contribution of this dissertation is to give the progress of transferring product development practices from auto manufacturers to auto suppliers. This dissertation is the first large-scale study that compares OEMs with auto suppliers in product development practices and performance. Not only that, but this dissertation is the first large-scale study that gives a rare insight into product development performance down to Tier 2 suppliers. The analysis suggests that OEMs are not successful in transferring product development practices to auto suppliers

Along with the two major contributions described above, this dissertation also enhances the understanding of how product development practices improve product development performance in the two countries and the two levels of supply chain, including the interaction of country and supply chain that can affect product development performance. Furthermore, this study provides a set of integrated product development practice combinations that affects a certain product development performance variable. For example, engineering change time is mostly affected by concurrent engineering and heavyweight product development managers instead of by any other IPD practices.

5.2.2. Methodological Contribution

This dissertation is the first international large-scale study concerned with product development in the auto industry that uses multi-group invariance analysis to develop the measuring instrument. The step-by-step invariance analysis provided in this dissertation can be replicated in other research settings. Although invariance analysis is a time consuming process, this dissertation has proven that without the use of an invariance instrument, researches can potentially have harmful type I and II errors. Furthermore, this dissertation provides a set of universal product development instrument that is invariant across the two countries and the two levels of supply chain and can be used by other researchers.

5.2.3. Practical Implications

This study finds that concurrent engineering is very important in delivering higher product development performances. Thus, managers should engage in some activities to increase the level of concurrent engineering and therefore enhance their product development performance. The actions should include developing teams from various functions in a company, overlapping development stages, and involving constituents early in product development.

In some cases, however, managers must be made aware that their country and their position in the supply chain can affect their product development performance. Being on a highest level of the supply chain (i.e., OEM) and in Germany provides a favorable advantage in product development. Companies on a lower level of supply chain (e.g., Tier 1 and 2 suppliers) may improve their viability by improving their involvement in product development through increasing technical capability (Fujimoto, 1994; Wasti and Liker, 1997).

Finally, this dissertation provides a set of instruments that can be used by companies to benchmark their product development internally such as among different divisions or externally with their competitors. This benchmarking allows the companies to learn more about their strengths and weaknesses in product development so that they can improve their performance.

5.3. Recommendations

Recommendation: Future research should explore this dissertation data more fully.

This dissertation has a rich collection of data that demands further exploration. Many avenues are possible. One possibility is to conduct a full-blown investigation on the differences between each subgroup such as U.S. OEMs versus German OEMs, U.S. auto suppliers versus German auto suppliers, U.S. OEMs versus U.S. auto suppliers, and German OEMs versus German auto suppliers.

The second possibility is to explore the country of origin as a source of difference. Although the data for country of origin is available, this dissertation has not explored the effect of the country of origin for companies in the same country. Several studies indicate that the country of origin can affect practices and performance. For example, in a study conducted by Nishiguchi (1989) discussed earlier, he finds that the performance of Japanese auto suppliers in the U.S. is higher than U.S. suppliers in the U.S.

In another illustrative study, Cusumano and Takeishi (1991) collect data from three U.S. OEMs in the U.S., five Japanese OEMs in Japan, and six Japanese transplants in the U.S. Comparing the data from the Japanese OEMs and transplants, they find that Japanese supplier relations and management are transferable to some extent in the U.S. This leads to a higher suppler performance of Japanese transplants than that of U.S. OEMs. The performance dimensions include quality, target cost, and price reduction.

Third, future research should explore causal relationship and structural modeling among possible variables. Currently, the variables used in this dissertation are divided in a simple manner, i.e., they are divided only into IPD practices and performance. Causal relationship and structural modeling among variables have not been fully explored. One possibility is that teamwork performance in problem solving affects both product development time (Huang and Mak, 1999; Giachetti, 1999; Park and Baik, 1999; Rezayat, 2000b) and product integrity (Cusumano and Nobeoka, 1996; Sauter, Enkawa, and Adachi, 1998). The later two variables then affect customer satisfaction (Fujimoto, Iansiti, and Clark, 1996; Abdalla, 1999; Gilmore and Pine, 2000). Because this study collects a total of seventeen variables of IPD practices and performance, numerous combinations of how these variables interact are possible.

Recommendation: Future research should develop better measuring items for certain constructs.

Several constructs need to be reevaluated for future research. The first construct that needs a reevaluation is heavyweight product development managers. This construct was developed by Koufteros (1995). Looking at the items of this construct carefully, it can be concluded that this construct only measures internal aspects of product development such as the authority of product development managers over personnel. However, Clark and Fujimoto (1991), Fujimoto, Iansiti, and Clark (1996) argue that heavyweight product development managers also serve as external integrators to capture consumer demand and needs. This function has not been captured with the current heavyweight product development managers instrument. Moreover, as product development is becoming more demanding by involving suppliers, the instrument should also include the role of heavyweight product development managers in orchestrating the supplier in product development.

Second, the platform products instrument used in this dissertation has only three items. It also was developed by Koufteros (1995) and was not intended for further refinement using invariance analysis. Therefore, it is suggested to add more items so that future refinement by deleting variant items is possible.

Third, the development of new information technology tools such as STEP allows companies to use the tools as Interorganization Information System (IOS) by exchanging product data among different companies, e.g., between OEMs and suppliers. The information technology instrument that was used in this dissertation was developed earlier by Koufteros (1995) and does not capture the use of information to exchange data among different companies. Future research should include such a use.

Fourth, the team productivity instrument has a slightly low reliability level, i.e., Chronbach's alpha = 0.7623. Team productivity in this dissertation is defined as the amount of work that can be done by the product development team considering the resources used. Measuring productivity in product development is perplexing. Different levels of product newness and project complexity may result in different amounts of work and resources used. For example, Sheriff (1988) adds 20% for each additional body style and 10% for each additional wheelbase to his project complexity scale. Similarly, Clark and Fujimoto (1991) adjust their productivity calculation to reflect supplier involvement in engineering and the percentage of newly designed parts. By understanding the product development process better, further research should be able to develop measuring items that have a higher reliability.

Recommendation: Future research should validate the measurement instrument using companies from different industries and different countries.

The measuring instrument for product development performance was developed using data from the auto industry only. Some may argue that the instrument then has limited generalizability across different industries. However, the researcher argues that the very nature of the auto industry is fairly heterogeneous. For example, OEMs develop products at the vehicle level whereas auto suppliers may develop products at the system, subassembly, or component level. Moreover, those companies develop various types of products such as electronic, engine, and fuel system that justify the heterogeneity of the auto industry (Curkovic, Vickery, and Dröge, 2000).

In any case, to test the generalizability and validity of the instrument, the instrument must be tested again using data from companies in different industries. Moreover, the instrument was invariant only across the supply chain in the U.S. and Germany. It is not clear, however, if the instrument is also invariant in a different country. Therefore, the researcher suggests conducting research in a different country to test this instrument. Because Japan is another major auto producer, the researcher suggests that future data should be collected from Japan.

Recommendation: Future research should study antecedents of integrated product development.

This dissertation, among other things, explains how different level of IPD practices can create a different level of product development performance. While studying the link between IPD practices and performance is important, the link is not complete without studying the antecedents of IPD practices. These antecedents can drive or restrain IPD practices. For example, Asanuma (1989), Kamath and Liker (1994), Fujimoto (1994) and Wasti and Liker (1997) argue that the supplier's technical capability is an important driver of supplier involvement. However, one must also be aware that not all suppliers have enough resources to increase their technical capability.

Other researchers such as Swink, Christopher, and Mabert (1996) find that collocation of a cross-functional product development team encourages concurrent engineering. However, some argue that a long period of collocation may also have a detrimental effect to the knowledge and career of functional engineers. Functional engineers move up through their functional specialty such as from piston engineer to chief engineer for engine (Womack et al., 1990). As those engineers are taken away from their functional specialty to join a cross-functional product development team, they may lose touch with both their functional cohorts and newer knowledge related to their specialty. Because of those conflicting arguments, the study of the antecedents of IPD practices remains open.

Recommendation: Future research should engage in a longitudinal study.

All data used in this study came from a cross-sectional survey. Realizing the limitation of such a one-time research design, it is prudent to suggest a longitudinal research over a period of time for this product development research. One advantage of longitudinal research instead of a cross-sectional research includes a better understanding of the sequence of the two variables under study. Longitudinal research may also uncover unseen or unmeasured variables not captured in cross-sectional research (Walizer and Wiener, 1978). Parallel with the concept of continuous improvement, measuring trends using longitudinal research (rather than one time measurement) can better capture the effect of changing the levels of IPD practices and how it effects the change in the levels of performance.

Recommendation: Future research should study Tier 2 suppliers more deeply.

This dissertation mostly studies OEMs and Tier 1 suppliers. It finds that Tier 1 suppliers are being squeezed by OEMs to improve their performance. In addition, it provides a rare glimpse into a product development performance of Tier 2 suppliers. Tier 2 suppliers have not lived up to expectation. It also indicates that Tier 2 suppliers typically are not involved in product development. However, Mitchell (1997) finds that Tier 1 auto suppliers are beginning to realize that they should also involve Tier 2 suppliers in product development. He further suggests that Tier 1 suppliers should study the knowledge and competence that reside in Tiers 2 suppliers. Does a higher involvement of Tier 2 suppliers lead to a better performance of the overall auto industry supply chain? This question needs to be explored.

CHAPTER 6

CONCLUSION

This dissertation has successfully answered the four research questions mentioned in Chapter 1. From a methodological standpoint, this dissertation has contributed to the development of a step-by-step invariance analysis and universal product development instrument that can be used by other researchers.

Two substantive contributions have been made. The first one includes updating previous prominent international product development studies related with the differences between U.S. and Germany auto industries. The second contribution is to give the progress of transferring integrated product development practice from OEMs to auto suppliers. Furthermore, this study indicates that OEMs have not been successful in transferring IPD practices across the auto industry supply chain.

For practitioners, this dissertation finds that concurrent engineering is among the most important IPD practices that drive product development performance. In spite of that, one must remember that concurrent engineering is not only about "engineering" per se by overlapping product and process development stages, but also about working together with different functions within an organization and incorporating their input early on during the development stage. This dissertation also provides a set of instrument that can be used to benchmark product development internally within a company or externally with competitors.

Finally, this dissertation also suggests some recommendations for further research. For example, the richness of the data collected for this dissertation demands further exploration such as a more detailed subgroup analysis, exploring the country of origin as a source of IPD differences, and exploring the structural relationship among possible variables. Another set of recommendations includes a longitudinal study, developing better measuring items for certain constructs, studying antecedents of IPD, studying Tier 2 suppliers better, and validating instruments through studying companies in different industries or even different countries.

REFERENCES

Abdalla, H.S. 1999. Concurrent engineering for global manufacturing. ***International Journal of Production Economics***, 60-61: 251-260.

Alford, D., Sackett, P., & Nelder, G. 2000. Mass customisation — An automotive perspective. ***International Journal of Production Economics***, 65(1): 99-110.

Allen, T.J. 1971. Communications, technology transfer, and the role of technical gatekeeper. ***R&D Management***, 1: 14-21.

Allen, T.J. 1977. ***Managing the Flow of Technology***. Cambridge, MA: MIT Press.

American Supplier Institute. 1989. ***Quality Function Deployment: Workshop Handbook***. Milton Keynes.

Asanuma, B. 1989. Manufacturer-supplier relationship in Japan and the concept of relation-specific skill. ***Journal of the Japanese and International Economics***, 3:1-30.

Bagozzi, R.P. & Foxall, G.R. 1996. Construct validation of a measure of adaptive-innovative cognitive styles in consumption. ***International Journal of Research in Marketing***, 13: 201-213.

Balachandra, R. 1996. A comparison of R&D project termination factors in four industrial nations. ***IEEE Transactions on Engineering Management***, 43(1): 88-96.

Balachandra, R., Brockhoff, K.K, & Pearson, A.W. 1996. R&D project termination decisions: Processes, communication and personnel changes. ***The Journal of Product Innovation Management***, 13(3): 245-256.

Balachandra, R. & Brockhoff, K.K.L. 1995. Are R&D project termination factors universal? ***Research Technology Management***, 38(4): 31-36.

Balakrishnan, N. & Chakravarty, A.K. 1996. Managing engineering change: Market opportunities and manufacturing costs. ***Production and Operations Management***. 5(4): 335-356.

Balakrishnan, A., Kumara, S.R.T., & Sundaresan, S. 1999. Manufacturing in the digital age: Exploiting information technologies for product realization. ***Information Systems Frontiers,*** 1(1): 25-50.

Bentler, P.M. 1990. Comparative fit indexes in structural models. ***Psychological Bulletin***, 107(2): 238-246.

Bentler P.M. & Bonnet, D.G., 1980. Significance tests and goodness-of-fit in the analysis of covariance structure. ***Psychological Bulletin***, 88(3): 588-606.

Bergen, S.A., Miyajima, R. & McLaughin, C.P. 1988. The R&D/Production interface in four developed countries. ***R&D Management***, 18(3): 227-233.

Birou, L.M. & Fawcett, S.E. 1994. Supplier involvement in integrated product development: A comparison of US and European practices. ***International Journal of Physical Distribution & Logistics Management,*** 24(5): 4-14.

Blackburn, J. (Ed.). 1991. ***Time-Based Competition***. Homewood, IL: Business One Irwin.

Bollen, K.A. 1989. ***Structural Equations with Latent Variables***. New York, NY: John Wiley and Sons.

Bowen, H. K., Clark, K.B., Holloway, C.A. & Wheelwright, S.C. 1994. ***The Perpetual Enterprise Machine: Seven Keys to Corporate Renewal through Successful Product and Process Development***. New York, NY: Oxford University Press.

Brockhoff, K. 1994. R&D project termination decisions by discriminant analysis - An international comparison. ***IEEE Transactions on Engineering Management*** 41(3): 245-254.

Brown, L.S. & Eisenhardt, K.M. 1995. Product development: Past research, present findings, and future directions. ***Academy of Management Review***, *20*: 343-378.

Browning, T.R. 1998. Integrative mechanisms for multiteam integration: Findings from five case studies. ***Systems Engineering***, 1(2): 95 - 112 .

Campbell, D.T. & Fiske. D.W. 1959. Convergent and discriminant validation by the Multitrait-Multimethod Matrix. ***Psychological Bulletin***, 56(1): 81-105.

Campbell, A., Sorge, A., & Warner, M. 1989. Microelectronics applications, product strategies, and competence needs in Great Britain and West Germany. ***Human Systems Management*** , 8(2): 155-166.

Chen, K.T. 1990. Contrasting strategies are pursued by Big Three Economic Powerhouses. ***IEEE Spectrum,*** 27(10): 76-78.

Churchill, G.H. 1979. A paradigm for developing better measures of marketing constructs. ***Journal of Marketing Research***, 16: 64-73.

Clark, K.B., Chew, B.W., & Fujimoto, T. 1987. Product development in the world auto industry. ***Brookings Papers on Economic Activity***, 3: 729-781.

Clark, K.B. & Fujimoto, T. 1989. Lead time in automobile product development: Explaining the Japanese advantage. ***Journal of Engineering and Technology Management***, 6(1): 25-58.

Clark, K. B. 1989. Project scope and performance: The effect of parts strategy and supplier involvement on product development. ***Management Science***, 35(10): 1247-1263.

Clark, K.B. & Fujimoto, T. 1990. The power of product integrity. ***Harvard Business Review***, 68(6): 107-118.

Clark, K.B. & Fujimoto, T. 1991. ***Product Development Performance: Strategy, Organization, and Management in The World Auto Industry***. Boston, MA: Harvard Business School Press.

Cooper, R.G. & Kleinschmidt, E.J. 1987. New products: What separates winners from losers. ***Journal of Product Innovation Management***. 4: 169-187.

Corso, M., Muffatto, M., & Verganti, R. 1999. Reusability and multi-product development policies: a comparison of approaches in the automotive, motorcycle and earthmoving machinery industries. ***Robotics and Computer-Integrated Manufacturing***, 15(2): 155-165.

Curkovic, S., Vickery, S.K., & Dröge, C. 2000. An empirical analysis of the competitive dimensions of quality performance in the automotive supply industry. ***International Journal of Operations and Production Management***, 20(3): 386-403.

Cusumano, M. A. & Takeishi. A. 1991. Supplier relations and management: A survey of Japanese, Japanese-transplant, and U.S. auto plants. ***Strategic Management Journal***, 12 (8): 563-588.

Cusumano, M.A. & Nobeoka, K. 1996. Strategy, structure, and performance in product development: Observations from the auto industry. In T. Nishiguchi (Ed), ***Managing Product Development***, Oxford, UK: Oxford University Press: 75-120.

Dröge, C., Jayaram, J., & Vickery, S.K. 2000. The ability to minimize the timing of new product development and introduction: an examination of antecedent factors in the North American automobile supplier industry. ***The Journal of Product Innovation Management***, 17(1): 24-40.

Doll, W.J., Hendrickson, A., & Deng, X. 1998. Using Davis's perceived usefulness and ease-of-use instruments for decision making: A confirmatory and multigroup invariance analysis. ***Decision Sciences***, 29(4): 839-869.

Dowling, M. & Albrecht, K. 1991. Technical workers and competitive advantage: What we can learn from the Germans, ***Business Horizons***, 34(6): 68-75.

Drucker, P.F. 1990. The emerging theory of manufacturing. ***Harvard Business Review*** , 68(3): 94-102.

Durgee, J.F., O'Connor, G.C., & Veryzer, R.W. 1998. Using mini-concepts to identify opportunities for really new product functions. ***Journal of Consumer Marketing***, 15(6): 525-543.

Dyer, J.H. 1996. How Chrysler created an American Keiretsu. ***Harvard Business Review,*** 74(4): 42-56.

Ealey, L., Robertson, D., & Sinclair, J. 1996. Beyond suppliers tiers: Facing the platforming challenge. ***International Motor Business***, 1st Quarter: 107-120.

Edgett, S.J., Shipley, D., & Forbes, G. 1992. Japanese and British companies compared: Contributing factors to success in NPD. ***Journal of Product Innovation and Management***, 9: 3-10.

Emmanuelides, P.A. 1993. Towards an integrative framework of performance in product development projects. ***Journal of Engineering and Technology Management***, 10: 363-392.

Ettlie, J.E 1997. Integrated design and new product success. ***Journal of Operations Management***, 15(1): 33-55.

Evans, J.R. & Lindsay, W.L.1996. ***The Management and Control of Quality***. 3rd ed. St. Paul, MI: West Pub. Co.

Fynch, B.J. 1999. Internet discussions as a source for consumer product customer involvement and quality information: an exploratory study. ***Journal of Operations Management***, 17(5): 535-556.

Fitzgerald, K.R. 1997. What OEM engineers want from suppliers. ***Purchasing***, 123(2): 111-112.

Fleischer, M. 1997. Tier relationship. ***Automotive Manufacturing & Production***, 109(5): 14.

Fleming, Q.W. & Koppleman, J.M. 1997. Integrated project development teams: Another fad ... or a permanent change. ***Project Management Journal***, 28(1): 4-11.

French, J.L. 1995. Japanese and German human resource practices: Convergence of West with East. In ***Advances in International Comparative Management***, JAI Press Inc., 10: 201-226.

Fujimoto, T. 1989. ***Organizations for Effective Product Development: The Case of the Global Automobile Industry***. Unpublished D.B.A. dissertation, Harvard Business School, Cambridge, MA.

Fujimoto, T. 1994. ***The Origin and Evolution of the Black Box Parts Practice In the Japanese Auto Industry***. Presented at Fuji Conference, January, Japan.

Fujimoto, T., Iansiti, M., & Clark, K.B. 1996. External integration in product development. In T. Nishiguchi (Ed.), ***Managing Product Development***: Oxford, UK: Oxford University Press: 121-161.

Garvin, D.A. 1991. ***The Boeing 767: From Concept to Production***. Harvard Business School Case #9-688-040, Boston, MA.

Gerpott, T.J. & Domsch M. 1985. The concept of professionalism and the management of salaried technical professionals: A cross-national perspective. ***Human Resource Management***, 24(2): 207-226.

Gersbach, H., Lewis, W., Mercer, G., & Sinclair, J. 1994. Production in the automotive assembly industry. ***International Motor Business***, 1st Quarter: 102-132.

Giachetti, R.E. 1999. A standard manufacturing information model to support design for manufacturing in virtual enterprise. ***Journal of Intelligent Manufacturing***, 10(1): 49-60.

Gilmour, A.D. 1991. The auto industry: People, product, quality, and productivity. ***Executive Speeches***, 6(1): 17-22.

Gilmore, J.H. & Pine, J.B. 2000. ***Markets of One : Creating Customer-Unique Value Through Mass Customization,*** Boston, MA: Harvard Business School.

Greenley, G.E. & Bayus, B.L. 1994. A comparative study of product launch and elimination decisions in U.K. and U.S. companies. ***European Journal of Marketing***, 28(2): 5-29.

Gu, P. & Chan, K. 1996. Generative inspection process and probe path planning for coordinate measuring machines. ***Journal of Manufacturing Systems*** , 15(4): 240-255.

Gunasekaran, A. 1999. Agile manufacturing: A framework for research and development. ***International Journal of Production Economics***, 62(1-2): 87-105.

Gupta, A.K., Brockhoff, K, & Weisenfeld, U. 1992. Making trade-offs in the new product development process: A German/U.S. Comparison. ***Journal of Product Innovation Management***, 9:11-18.

Gupta, A.K. & Willemon, D.L. 1990. Accelerating the development of technology-based new products. ***California Management Review***, 32(2): 24-44.

Hair, J.F.H., Anderson, R.E., Tatham, R.L., & Black, W.C. 1998. ***Multivariate Data Analysis with Readings***. 5th edition, New York, NY: Macmillan Publishing Co.

Handfield, R.B. 1994. Effects of concurrent engineering on make-to-order products. ***IEEE Transactions on Engineering Management***. 41(4): 384-393.

Harland, C. 1996. International comparisons of supply-chain relationships. ***Logistics Information Management***, 9(4): 35-38.

Hauptman, O. & Hirji, K.K. 1999. Managing integration and coordination in cross-functional teams: An international study of concurrent engineering product development. ***R & D Management***, 29:(2): 179-191.

Hegarty, W. H. & Hoffman, R.C. 1990. Product/market innovations: A study of top management involvement among four vultures. ***The Journal of Product Innovation Management*** , 7(3): 186-199

Heizer, J. & Render, B. 1999. ***Operations Management***, 5th ed. Upper Saddle River, N.J: Prentice Hall.

Hout, T.M. 1996. Time-based competition is not enough. ***Research-Technology Management***, July-August: 15-17.

Huang, G. Q. & Mak, K. L. 1999. Web-based morphological charts for concept design in collaborative product development. ***Journal of Intelligent Manufacturing***, 10(3/4): 267-278.

Imai, K., Nonaka, I. & Takeuchi, H. 1985. Managing the new product development process: How Japanese companies learn and unlearn. In R.H. Hayes, K.B. Clark, & C. Lorenz (Eds.). ***The Uneasy Alliance: Managing The Productivity-Technology Dilemma,*** Boston, MA: Harvard Business School Press: 337-375.

Ittner, C.D. & MacDuffie, J.P. 1995. Explaining plant-level differences in manufacturing overhead: Structural and executional cost drivers in the world auto industry. ***Production and Operations Management***, 4(4); 312-334.

Ittner, C.D. & Larcker, D.F. 1997. Quality strategy, strategic control systems, and organizational performance. ***Accounting, Organizations and Society*** , 22(3): 293-314.

Ittner, C.D., Larcker, D.F., Nagar, V., & Rajan, M.V. 1999. Supplier selection, monitoring practices, and firm performance. ***Journal of Accounting and Public Policy***, 18(3): 253-281.

Izuchukwu, J.I. 1996. Process and technology perspective on integrated product development. ***Journal of Manufacturing Science and Engineering***, 118: 455-457.

Jacobs, L. & Herbig, P. 1998. Japanese product development strategies. ***Journal of Business & Industrial Marketing,*** 13(2): 132-154.

Jarvenpaa, S.L., Tractinsky, N., Saarinen, L., & Vitale, M., 1999. Consumer trust in an internet store: A cross-cultural validation. ***Journal of Computer – Mediated Communication***, 5(2)

Johne, A. & Snelson, P. 1988. Teamwork : Lessons from successful high-tech firms. ***Industrial Marketing Digest*** , 13(3): 95-99.

Joreskog. K.G. & Sorbom, D. 1996. ***LISREL 8: User's Reference Guide***. Chicago, IL: Scientific Software.

Kamath, R. R. & Liker, J. K. 1994. A second look at Japanese product development. ***Harvard Business Review***, 72(6) 154-170.

Karagozoglu, N. & Brown, W. B. 1993. Time based management of the new product development process. ***Journal of Product Innovation Management*** 10: 204-215.

Karlsson, C., Nellore, R. & Söderquist, K. 1998. Black box engineering: redefining the role of product specifications. ***The Journal of Product Innovation Management***, 15(6): 534-549.

Katz. R. & Tushman, M . 1981. An investigation into the managerial roles and career paths of gatekeepers and project supervisors in a major R&D facility. ***R & D Management***, 11(3): 103-110.

Kerlinger, F.N. 1973. ***Foundations of Behavioral Research***, 2nd ed., New York, NY: Holt, Rinehart, and Winston, Inc.

Kern, H. & Sabel, C. 1991. Trade unions and decentralized production: A sketch of strategic problems in the West German labor movement. ***Politics and Society***, 19, 373-401.

Kerwin, K. & Vlasic, W. 1996. A shrinking supply of suppliers. ***Business Week***, January 8: 83.

Khuri, F.P. & Plevyak, H.M. 1994. Implementing integrated product development; A case study of Bosma Machine and Tool Corporation. ***Project Management Journal***, 25(3): 10-15.

Kleinschmidt, E.J. 1994. A comparative analysis of new product programmes: European versus North American. ***European Journal of Marketing***. 28(7): 5-29.

Kline, R.B. 1998. ***Principles and Practices of Structural Equation Modeling***. New York, NY: The Guilford Press.

Kobe, G. 1994. OEMs slash number of tier one suppliers. ***Automotive Industries***, 1:28.

Koufteros, X. 1995. ***Time-Based Competition: Developing A Nomological Network Of Constructs And Instrument Development***. Unpublished Ph.D. Dissertation, Toledo, OH: The University of Toledo

Krafcik, J.F. 1988. The triumph of the lean production system. ***Sloan Management Review***, Fall: 41-52.

Krafcik, J.F. 1990. ***The Effect of Design Manufacturability on Productivity and Quality: An Update of the IMVP Assembly Plant Study***. Working paper, MIT International Vehicle Program, Cambridge, MA.

LaBahn, D.W. & Krapfel, R. 2000. Early supplier involvement in customer new product development: A contingency model of component supplier intentions ***Journal of Business Research***, 47(3) :173-190.

Lamming, R. 1989. ***The International Automotive Component Industry: The Next "Best Practices" for Suppliers***. Working paper, MIT International Vehicle Program, Cambridge, MA.

Leonard-Barton, D. 1992. Core capabilities and core rigidities: A paradox in managing new product development. ***Strategic Management Journal***, 13: 111-115.

Liker, J.K., Fleischer, M., Nagamichi, M., & Zonnevylle, M.S. 1992. Designers and their machines: CAD use and support in the US and Japan. ***Communications of the ACM***, 35(2): 76-95.

Liker, J.K., Collins, P.D., & Hull, F.M., 1995. Standardization and flexibility: Test of a hybrid model of concurrent engineering effectiveness. ***Proceedings of Academy of Management Meeting***, Technology and Innovation Management Division, August.

Liker, J.K., Kamath, R.R, Wasti, S.N., & Nagamachi, M. 1996. Supplier involvement in automotive component design: Are there really large US Japan differences? ***Research Policy***, 25(1): 59-89.

Loch, C.H. & Terwiesch, C. 1999. Accelerating the process of engineering change orders: Capacity and congestion effects. ***The Journal of Product Innovation Management***, 16(2): 145-159.

Marsh, H.W. 1987. The factorial invariance of responses by males and females to a multidimensional self-concept instrument: Substantive and methodological issues. ***Multivariate Behavioral Research***, 22: 457-480.

McDermott, C. & Stock, G. 1994. The use of common parts and designs in high-tech industries: A strategic approach. ***Production and Inventory Management Journal***, 35(3): 65-69.

Mercer, G.A. 1994. Don't just optimize – unbundled. ***The McKinsey Quarterly,*** 3: 103-116.

Meyer, M. H. & Lehnerd, A.P. 1997. ***The Power of Product Platforms: Building Value and Cost Leadership***, New York, NY: Free Press.

Milligan, B. 2000. Pressure still on tier-one suppliers to cut costs, ***Purchasing,*** 128(2): 59-68.

Moffat, L.K 1998. Tools and teams: competing models of integrated product development project performance. ***Journal of Engineering and Technology Management,*** 15(1): 55-85.

Monden, Y. 1993. ***Toyota Production System: An Integrated Approach to Just-in-Time***. Norcross, GA: Industrial Engineering and Management Press.

Muffato, M. 1998. Reorganizing for product development: Evidence from Japanese automobile firms. ***International Journal of Production Economics***, 56-57: 483-493.

Muffato, M. 1999. Introducing a platform strategy in product development. ***International Journal of Production Economics***, 60-61: 145-153.

Murakoshi, T. 1994. Customer-driven manufacturing in Japan. ***International Journal of Production Economics,*** 37(1): 63-72.

Myers, S. & Marquis, D.G. 1969. ***Successful Industrial Innovations***. (NSF 69-71). Washington, DC: National Science Foundation.

Neale, M.R. & Corkindale, D.R. 1998. Co-developing products: Involving customers earlier and more deeply. ***Long Range Planning***, 31(3): 418-425.

Neter, J., Kutner, M.H., Natchtsheim, C.J., & Wasserman, W. 1996. ***Applied Linear Statistical Models***, 4th ed. Chicago, IL: Irwin.

Nishiguchi, T. 1989. ***Strategic Dualism: An Alternative in Industrial Societies (Manufacturing Subcontracting, Subcontracting).*** Unpublished Ph.D. Dissertation, Oxford, U.K: Oxford University.

Nishiguchi, T. (Ed) 1996. ***Managing Product Development***. Oxford, UK: Oxford University Press.

Nunnally, J.C. 1978. ***Psychometric Theory***. New York, NY: McGraw-Hill.

Olivier, C. 1994. One board or two? ***Corporate Finance***, 113:40.

Paashuis, V. 1998. ***The Organization of Integrated Product Development***. London, UK: Springer-Verlag.

Park, H.G. & Baik, J.M. 1999. Enhancing manufacturing product development through learning agent system over internet. ***Computers & Industrial Engineering***, 37(1-2): 117-120.

Peterson, M.F. & Smith, P.B. 1997. Does national culture or ambient temperature explain cross-national differences in role stress? No sweat! ***Academy of Management Journal***, 40(4): 930-946.

Pilkington, A. 1999. Strategic alliance and dependency in design and manufacture: The Rover-Honda case. ***International Journal of Operations & Production Management.*** 19(5/6): 460-474.

Pinto, M.B., Pinto, J.K., & Prescott, J.E. 1993. Antecedents and consequences of project team cross-functional cooperation. ***Management Science***, 39(10): 1281-1297.

Pitta, D. & Franzak, F. 1996. Boundary spanning product development in consumer markets: Learning organization insights. ***Journal of Consumer Marketing***, 5: 66-81.

Ponticel, P. 1996. Integrated product process development. ***Automotive Engineering***, 104 (October): 103-104.

Porter, M.E. 1990. ***The Competitive Advantage of Nations.*** New York, NY: Free Press.

Quinn, J.B. 1985. Managing innovation: Controlled chaos. ***Harvard Business Review***. 63(3): 73-84.

Rezayat, M. 2000a. Some aspects of product and process development in the 21st Century. Part I. ***Computer-Aided Design***, 32(2): 83.

Rezayat, M. 2000b. The enterprise-web portal for life-cycle support. ***Computer-Aided Design***, 32(2): 85-96.

Rothwell, R. 1972. ***Factors for Success in Industrial Innovations from Project SAPPHO - A Comparative Study of Success and Failure in Industrial Innovation***. Brighton, Sussex, England: S.P.R.U.

Rothwell, R., Freeman, C., Horsley, A., Jervis, V.T.P., Robertson, A., & Townsend, J. 1974. SAPPHO updated - Project SAPPHO phase II. ***Research Policy***, 3: 258-291.

Russell, R.S. & Taylor, B.W. 2000 , ***Operations Management : Multimedia Version.*** 3rd ed. Upper Saddle River, N.J: Prentice Hall.

Sako, M. 1996. Suppliers' associations in the Japanese automobile industry: Collective action for technology diffusion. ***Cambridge Journal of Economics***, 20(6): 651-671.

Sako, M. & Helper, S. 1998. Determinants of trust in supplier relations: Evidence from the automotive industry in Japan and the United States. ***Journal of Economic Behavior & Organization***, 34(3): 387-417.

Sako, M. Lamming, R., & Helper, S.R. 1998. Supplier relations in the multinational automotive industry. In Mudambi, R. & Ricketts, M. (Eds.), ***The Organisation of the Firm : International Business Perspectives,*** New York, NY: Routledge: 178-193.

Sanderson, S. 1992. Design for manufacturing in an environment of continuous change. In Susman, G.I. & Dean, J.W., Jr. (Eds.), ***Integrating Design and Manufacturing for Competitive Advantage***. New York, NY: Oxford University Press, 36-55.

Sanderson, S. & Uzumeri, M. 1995. Managing product families: The case of the Sony Walkman. ***Research Policy***, 24(5): 761-782.

Schmidt, R., 1997. The implementation of simultaneous engineering in the stage of product concept development: A process orientated improvement of quality function deployment. ***European Journal of Operational Research***, 100(2): 293-314.

Sethi, V. & King, W.R. 1994. Development of measures to assess the extent to which an information technology application provides competitive advantage. ***Management Science***, 40(12): 1601-1627.

Sharma, S., Niedrich, R.W., & Dobbins, G. 1999. A framework for monitoring customer satisfaction. ***Industrial Marketing Management,*** 28(3): 231-243.

Sheriff, A.M. 1988. ***Product Development in the Automobile Industry: Corporate Strategies and Project Performance***. Unpublished master thesis, MIT Sloan School of Management, Cambridge, MA.

Sherman, H.D. 1991. Governance lessons from abroad. ***Directors and Boards***, 15(3): 24-28.

Sloan, A.P. 1963. ***My Years with General Motors***. Garden City, NY: Anchor/Doubleday.

Song, X.M., & Parry, M.E. 1996. What separates Japanese new product winners from losers. ***Journal of Product Innovation Management***, 13(5): 422-439.

Souder, W.E. & Jenssen, S.A. 1999. Management practices influencing new product success and failure in the United States and Scandinavia: A cross-cultural comparative study. ***The Journal of Product Innovation Management***, 16(2): 183-203.

Souder, W.E. , Buisson, D. , & Garrett, T. 1997. Success through customer-driven new product development: A comparison of U.S. and New Zealand small entrepreneurial high technology firms. ***The Journal of Product Innovation Management*** , 14(6): 459-472.

SPSS. 1998. ***SPSS Base 8.0 Application Guide***. Chicago, IL: SPSS, Inc.

Stalk, G. & Hout, T. 1990. ***Competing Against Time***. New York, NY: The Free Press.

Stalk, G. 1988. Time: The next source of competitive advantage. ***Harvard Business Review***, 66(4): 41-51.

Stevens, J. 1996. ***Applied Multivariate Statistics for the Social Sciences***, Mahwah, New Jersey: Lawrence Erlbaum Associates.

Sundgren, N. 1999. Introducing interface management in new product family development. ***The Journal of Product Innovation Management***, 16(1): 40-51.

Suzaki, K. 1985. ***The New Manufacturing Challenge.*** New York, NY: Free Press.

Susman, G.I. & Dean, J.W., 1992. Development of a model for predicting design for manufacturability effectiveness. In Susman, G.I. & Dean, J.W., Jr. (Eds.), ***Integrating Design and Manufacturing for Competitive Advantage.***, New York, NY: Oxford University Press: 178-193.

Susman, G.I. & Ray, J.M. 1999. Test of a model of organizational contributors to product development team effectiveness. ***Journal of Engineering & Technology Management*** ,16(3): 223-245.

Swink, M.L., Christopher S.J., & Mabert, V.A. 1996. Customizing Concurrent Engineering Processes: Five Case Studies. ***The Journal of Product Innovation Management***, 13(3): 229-244.

Swink, M.L. 1998. A tutorial on implementing concurrent engineering in new product development programs. ***Journal of Operations Management***. 16(1): 103-116.

Takeuchi, H., & Nonaka, I. 1986. The new new product development game. ***Harvard Business Review***, 64(1): 137-146.

Tatikonda, M.V. 1994. Design for assembly: A critical methodology for product reengineering and new product development. ***Production and Inventory Management Journal***, 35(1): 31-38.

Tatikonda, M.V. 1999. An empirical study of platform and derivative product development projects. ***The Journal of Product Innovation Management*** ,16(1): 3-26.

Taylor. A., III. 1994. Auto industry meets the new economy. ***Fortune***, 130(5): 52-60.

Terwiesch, C. & Loch, C.H. 1999. Measuring the effectiveness of overlapping development activities. ***Management Science***, 45(4): 455-465

Thompson, A.A. & Strickland A.J. 1992. ***Strategic Management: Concepts and Cases.*** 6th ed. Boston, MA: Irwin/McGraw-Hill.

Tucker, L. & Lewis, C. 1973. The reliability coefficient for maximum likelihood factor analysis. ***Psychometrika***, 38: 1-10.

Usher, J.M., Roy, U., & Parsaei, H.R. 1998. ***Integrated Product and Process Development: Methods, Tools, and Technologies***. New York, NY: John Wiley.

van Dierdonck, R. 1990. The manufacturing/design interface. ***R&D Management***, 20(3): 203-209.

Venkatraman, N. 1989. Strategic orientation of business enterprises: The construct, dimensionality, and measurement. ***Management Science***, 35(8): 942-962.

Voss, C., Blackmon, K., Hanson, P., & Claxton, T. 1996. Managing new product design and development: An Anglo-German study. ***Business Strategy Review***, 7(3): 1-15.

Walizer, M.H., & Wiener, P.L. 1978. ***Research Methods and Analysis: Searching for Relationships.*** New York, NY: Happer and Row.

Wasti, S.N. & Liker, J.K. 1997. Risky business or competitive power? Supplier involvement in Japanese product design. ***The Journal of Product Innovation Management***, 14 (5): 337-355.

White, J.B. 2000 Japanese, European auto makers top J.D. Power Quality Survey. ***The Wall Street Journal***. May 5.

Wheelwright, S.C. & Clark, K.B. 1995. ***Leading Product Development : The Senior Manager's Guide to Creating and Shaping the Enterprise.*** New York, NY: Free Press.

Womack, J.P., Jones, D.T., & Ross, D. 1991. ***The Machine that Changed the World: The Story of Lean Production***. New York, NY: HarperCollins.

APPENDIX 1

Research Instrument for Pilot Study in the U.S.

International Product Development Benchmarking in the Auto Industry Supply Chain

Until recently, no one has undertaken international, systematic research to study the Integrated Product Development (IPD) process in both auto manufacturers and auto suppliers. As part of this research, we are interested in any new product your company currently has on the market. In the spaces below, please identify the generic type of product and its year of introduction. The generic type of product can be a motor vehicle (e.g., passenger car, minivan, sport utility vehicle, etc.) or a part of a motor vehicle (e.g., chassis, door, alternator, temperature sensor, etc.). If you do not want to fill out the spaces below, please leave them blank.

Type of the product: ______________________________

Year of introduction: ______________________________

Even if you choose to leave them blank, please respond to the following survey questions with the specific product you have identified in mind. There are no correct or incorrect answers. We are interested only in your actual perceptions of the above product, not as you wish it to be, or plan it to be in the future. <u>Your responses will be kept completely confidential</u>. None of your responses will be disclosed to any other person. We will only analyze the responses for each country (e.g., companies in the U.S.) as a whole data set, not individually. You may fax or mail your responses in the enclosed pre-paid envelope to:

Ahmad Syamil
Department of Information Systems and Operations Management (ISOM)
College of Business Administration
The University of Toledo
2801 West Bancroft Street; Toledo, OH 43606, USA
Office: Phone: 419-530-2366; Fax: 419-530-2365, 530-7744
Home: 419-472-6937 (Phone/Fax); E-mail: asyamil@uoft02.utoledo.edu

INTEGRATED PRODUCT DEVELOPMENT PRACTICES

The following statements measure the extent to which your product development team employs IPD practices when developing the specific product you mentioned on page 1. Please circle the number that best describes your evaluation according to the following 5-point scale illustrated below:

Not at all	A little	Moderately	Much	A great deal
1 <————	2 ————	3 ————	4 ————	>5

A. Concurrent/Simultaneous Engineering					
1. Product development group members share information	1	2	3	4	5
2. Much of process design is done concurrently with product design	1	2	3	4	5
3. Product development group members represent a variety of disciplines	1	2	3	4	5
4. Various disciplines are involved in product development from the early stages	1	2	3	4	5
5. Process engineers are involved from the early stages of product development	1	2	3	4	5
6. Manufacturing engineers are involved from the early stages of product development	1	2	3	4	5
7. Product and process designs are developed concurrently by a group of employees from various disciplines	1	2	3	4	5
B. Customer Involvement					
1. We study how our customers use our products	1	2	3	4	5
2. Our product development people meet with customers	1	2	3	4	5
3. We visit our customers to discuss product development issues	1	2	3	4	5
4. In developing the product concept, we listen to our customer needs	1	2	3	4	5
5. We involve our customers in the early stages of product development	1	2	3	4	5
C. Supplier Involvement					
1. Our suppliers develop component parts for us	1	2	3	4	5
2. Our suppliers develop whole subassemblies for us	1	2	3	4	5
3. Our suppliers do the product engineering of component parts for us	1	2	3	4	5
4. Our suppliers are involved in the early stages of product development	1	2	3	4	5
5. We ask our suppliers for their input on the design of component parts	1	2	3	4	5
6. We make use of suppliers for their input on the design of component parts	1	2	3	4	5
D. Heavyweight Product Development Managers					
1. Product development managers have a final say in budget decisions	1	2	3	4	5
2. Product development managers are given a real authority over personnel	1	2	3	4	5
3. Product development managers have a final say in product design decisions	1	2	3	4	5
4. Product development managers have broad influence across the organization	1	2	3	4	5
5. Product development managers have enough influence to make things happen	1	2	3	4	5
6. Product development managers derive their influence from expert knowledge of manufacturing process	1	2	3	4	5
E. Platform Products					
1. Our product designs are drawn to accommodate future generations of products	1	2	3	4	5
2. Our product designs enable us to accommodate several generations of products	1	2	3	4	5
3. Our core products are designed as platforms for multiple generations of products to come	1	2	3	4	5
F. Information Technology Utilization					
1. We use computers to improve designs	1	2	3	4	5
2. We use computers to evaluate designs	1	2	3	4	5
3. Computers help us in main engineering changes	1	2	3	4	5
4. We use computers to develop product prototypes	1	2	3	4	5
5. We use computerized systems for product development	1	2	3	4	5
6. We use computers to coordinate product development activities	1	2	3	4	5

PRODUCT DEVELOPMENT EFFECTIVENESS AND EFFICIENCY

The following statements pertain to your evaluation of the effectiveness and efficiency of your company's efforts in developing the specific product you mentioned on page 1. Please circle the number that best describes your evaluation according to the following 5-point scale illustrated below:

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1<————	2 ————	3 ————	4 ————	>5

A. Engineering Change Time

Our product development team:

1. Modifies part specifications on time	1	2	3	4	5
2. Modifies engineering drawings on time	1	2	3	4	5
3. Modifies material specifications on time	1	2	3	4	5
4. Modifies engineering specifications on time	1	2	3	4	5
5. Modifies dimensional specifications on time	1	2	3	4	5
6. Makes simple engineering changes on time	1	2	3	4	5
7. Finishes engineering change orders on time	1	2	3	4	5
8. Delivers engineering change notices on time	1	2	3	4	5
9. Makes complex engineering changes on time	1	2	3	4	5
10. Meets engineering change deadlines regularly	1	2	3	4	5

B. Teamwork Performance

Our product development team:

1. Works well together	1	2	3	4	5
2. Communicates effectively	1	2	3	4	5
3. Identifies design problems early	1	2	3	4	5
4. Implements decisions efficiently	1	2	3	4	5
5. Resolves design conflicts on time	1	2	3	4	5
6. Solves design problems creatively	1	2	3	4	5
7. Resolves design conflicts constructively	1	2	3	4	5
8. Coordinates design activities effectively	1	2	3	4	5
9. Identifies manufacturing problems early	1	2	3	4	5

C. Team Productivity

Our product development team:

1. Is productive	1	2	3	4	5
2. Completes works quickly	1	2	3	4	5
3. Uses overtime acceptably	1	2	3	4	5
4. Allocates personnel efficiently	1	2	3	4	5
5. Uses engineering hours efficiently	1	2	3	4	5
6. Works on product improvements successfully	1	2	3	4	5
7. Works within predetermined engineering hours	1	2	3	4	5
8. Develops unique product features successfully	1	2	3	4	5
9. Uses product development budgets reasonably	1	2	3	4	5
10. Uses all product development resources reasonably	1	2	3	4	5
11. Brings new products successfully to enter the market	1	2	3	4	5
12. Completes works successfully using predetermined resources	1	2	3	4	5
13. Increases the number of product lines successfully to enter the market	1	2	3	4	5

D. Product Cost Reduction

Our product development team:

1. Simplifies the design successfully	1	2	3	4	5
2. Reduces product costs successfully	1	2	3	4	5
3. Reduces material costs successfully	1	2	3	4	5
4. Reduces product weight successfully	1	2	3	4	5
5. Reduces assembly costs successfully	1	2	3	4	5
6. Reduces the number of parts successfully	1	2	3	4	5
7. Reduces manufacturing costs successfully	1	2	3	4	5
8. Reduces the number of assembly steps successfully	1	2	3	4	5
9. Reduces the number of manufacturing steps successfully	1	2	3	4	5
10. Reduces production tooling and equipment costs successfully	1	2	3	4	5

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1<-	-2-	-3-	-4-	->5

E. Internal Product Integrity

In our experience:

1. All components fit together easily	1	2	3	4	5
2. All components work well together	1	2	3	4	5
3. All components are well integrated	1	2	3	4	5
4. All components are easy to assemble	1	2	3	4	5
5. All assembled components function well	1	2	3	4	5
6. All assembled components have high quality	1	2	3	4	5
7. All assembled components have high performance	1	2	3	4	5
8. All assembled components pass product testing easily	1	2	3	4	5
9. All component layouts achieve maximum space-usage	1	2	3	4	5

F. Supplier Performance

Our parts or material suppliers:

1. Design parts on time	1	2	3	4	5
2. Meet our target price	1	2	3	4	5
3. Design high quality parts	1	2	3	4	5
4. Work well with our design teams	1	2	3	4	5
5. Deliver the parts they design on time	1	2	3	4	5
6. Solve our design problems successfully	1	2	3	4	5
7. Suggest ideas that benefit our customers	1	2	3	4	5
8. Manufacture the parts they design on time	1	2	3	4	5
9. Suggest ideas that reduce our product costs	1	2	3	4	5
10. Design parts that are easy for us to assemble	1	2	3	4	5
11. Are flexible in meeting our design requirements	1	2	3	4	5
12. Design parts that are easy for us to manufacture	1	2	3	4	5
13. Provide parts or materials that conform to our specifications	1	2	3	4	5

G. Product Development Time

Compared to our competitors' teams, our product development team:

1. Starts production trial run faster	1	2	3	4	5
2. Launches products to the market faster	1	2	3	4	5
3. Delivers products to the customers faster	1	2	3	4	5
4. Enables our company to start volume production faster	1	2	3	4	5
5. Brings products to the market before our competitors do	1	2	3	4	5
6. Develops products from concept to commercial production faster	1	2	3	4	5
7. Makes better progress in reducing total product development time	1	2	3	4	5
8. Enables our company to start selling products to the customers faster	1	2	3	4	5
9. Transfers all job responsibilities to the manufacturing department faster	1	2	3	4	5

H. Product Customer Fit

Compared to our competitors' products, our products:

1. Are more distinctive	1	2	3	4	5
2. Satisfy customers better	1	2	3	4	5
3. Have more repeat buyers	1	2	3	4	5
4. Fit target customers better	1	2	3	4	5
5. Have more loyal customers	1	2	3	4	5
6. Generate more new customers	1	2	3	4	5
7. Meet customer demands better	1	2	3	4	5
8. Anticipate customer needs better	1	2	3	4	5
9. Are more highly valued by customers	1	2	3	4	5
10. Further exceed customer expectations	1	2	3	4	5
11. Are more successful in the marketplace	1	2	3	4	5
12. Represent more successful responses to market opportunities	1	2	3	4	5

GENERAL INFORMATION

Please write in the space provided or circle the appropriate response.

1. Your title is: ______________________________

2. The country you are working in is:

   1) U.S. 2) Japan 3) Germany 4) Other (please specify): __________

3. Your parent company (if any) is located in:

   1) U.S. 2) Japan 3) Germany 4) Other (please specify): __________

4. The primary status of your company is (**choose only one**):

   1) Auto manufacturer (Original Equipment Manufacturer/OEM)
   2) Auto supplier 3) Other (please specify): __________

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

   1) An auto supplier owned (partially or fully) by an OEM
   2) An independent auto supplier not owned by an OEM

6. If you are an auto supplier, the primary status of your company is:

   1) First-tier supplier 2) Second-tier supplier 3) Third-tier supplier
   4) Other (please specify): __________

7. If you are an auto supplier, in which vehicle system(s) are your company's products primarily used?

   1) Body exterior 2) Body interior 3) Powertrain 4) Chassis
   5) Electrical/electronic 6) Other: __________

8. If you are an auto supplier, what type(s) of product/service does your company primarily supply to your customers?

   1) Integrated systems (see # 7 above) 2) Subsystems/subassemblies
   3) Simple components/parts 4) Materials
   5) Testing/instrumentation 6) Consulting services
   7) Computer/engineering tools 8) Production equipment/tools/dies
   9) Engineering/design services 10) Manufacturing support services
   11) Other : __________

9. Number of individuals in your product development team when developing the specific product you mentioned on page 1: ________

10. Total number of individuals who were directly involved in developing the specific product you mentioned on page 1: ________

11. Number of employees in your company's auto-related business worldwide: ________

12. Total annual sales of your company's auto-related business worldwide:

    1) Less than \$50 million 2) \$50 - \$500 million 3) \$ 500 million - \$1 billion
    4) \$1 - \$5 billion 5) More than \$5 billion 6) Not available

OPTIONAL DATA

If you give your name below or attach your business card, we will send you a summary of the survey findings. However, you may also send your card in a separate envelope. This will allow us to communicate with you while keeping your responses anonymous.

Mr./Ms.____

Title: ____

Company: ______________________________________

Address: ______________________________________

____

____

City: _____________________ State: ____ ZIP: _______

Phone: _____________________ Fax: _______________

E-mail: ____

THANK YOU FOR YOUR ASSISTANCE

APPENDIX 2

Assessment of Unidimensionality (and Convergent Validity) of Product Development Performance Dimensions: Description and Rationale of the Procedure

A. Engineering Change Time

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	EC1 ... EC10	96.65	35	0.000	4.27	0.19	0.56	0.66	0.884

The hypothesized model was rejected because of both low NNFI (Non-Normed Fit Index) and low CFI (Comparative Fit Index). An exploratory factor analysis (EFA) using SPSS indicated that this construct consisted of two dimensions: (EC1, 2, 3, 4) and (EC5,6,7, 8,9,10). A closer look at the first dimension (EC1 to EC4) revealed that this dimension was related with a more specific portion of engineering changes (e.g., part changes) whereas EC5 to EC10 were more closely associated with general engineering changes. A further analysis disclosed that (EC1 ..EC4) and (EC5 . EC10) had no significant differences in model fit criteria. Therefore, for the purpose of parsimony, only (EC5 . EC10) were analyzed further.

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 1	EC5,6,7,8,9,10	20.39	9	0.016	1.39	0.17	0.81	0.88	0.8732

This model indicated that EC9 had a low squared multiple correlation (SMC) of 0.39. EC9 was deleted in further analysis.

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 2	EC5,6,7,8,10	18.95	5	0.002	1.22	0.27	0.69	0.84	0.8712

This model indicated that the error terms of EC5 and EC6 were highly correlated. They had a modification index (MI) of 6.93. Because EC5 and EC4 had almost the same SMC, further analysis would be done to compare two models: one without EC5 (alternative 3) and another without EC6 (alternative 4).

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 3	EC6,7,8,10	7.14	2	0.028	0.72	0.30	0.76	0.92	0.862
Alternative 4 (Recommended)	EC5,7,8,10	5.72	2	0.057	0.68	0.21	0.82	0.94	0.862

The alternative 4 (EC 5,7,8,10) was selected for further large-scale study because the alternative 4 provided better model fit compared to the alternative 3. An EFA of the alternative 4 indicated that it had a simple factor structure as an evidence of unidimensionality.

B. Teamwork Performance

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	TW1 ... TW9	39.51	27	0.057	2.36	0.12	0.89	0.92	0.9073

The hypothesized model was rejected because the error terms of TW3 and TW9 were highly correlated, i.e., the modification index was 8.57. A further EFA indicated that the model consisted of two dimensions: (TW1,2,4,5, 8) and (TW3,9). TW6 and TW7 cross-loaded on the two dimensions. For the purpose of simplification, TW6 and TW7 as well as TW3 and TW9 were deleted in further analysis.

	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 1 (Recommended)	TW1,2,4,5,8	0.86	5	0.973	0.65	0.00	1.14	1	0.8608

This first alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure.

C. Team Productivity

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	TP1 ...TP13	126.31	65	0.000	5.69	0.17	0.64	0.7	0.8924

The hypothesized model was rejected because NNFI was low and the MI of error terms were high, especially between TP7 and TP10 (MI = 8.43) and between TP9 and TP10 (MI=16.69). A further EFA indicated that the model consisted of 4 dimensions with many cross-loadings. The remaining items, which made a simple structure, were TP1, 2, 6, and 7

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 1 (Recommended)	TP1,2,6,7	0.67	2	0.715	0.52	0.00	1.09	1	0.8213

The first alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure.

D. Product Cost Reduction

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	PC1 ..PC10	108.91	35	0.000	4.65	0.26	0.6	0.69	0.9137

The hypothesized model was rejected because of low NNFI and CFI. Additionally, it had many correlated error terms. Subsequent analysis using EFA indicated that the model consisted of 3 dimensions: (PC1, 2, 3, 6), (PC7, 8, 9, 10), and (PC4, 5). After comparing PC4 and PC5, the researcher selected PC4 because it has a higher loading. Deleting PC4 made PC5 loaded in the same group with PC7, 8, 9, 10. (PC1, 2, 3, 4) and (PC5, 7, 8, 9, 10) were then analyzed independently.

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 1 (Recommended for product-cost reduction)	PC1,2,3,6	1.48	2	0.477	0.55	0.00	1.02	1	0.8833

The first alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 2	PC5,7, 8, 9, 10	20.88	5	0.001	1.28	0.32	0.75	0.87	0.9054

PC8 had high error term correlations with PC9 (MI=10.65) and PC10 (MI=8.53). PC8 was deleted in further analysis.

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 3 (Recommended for manufacturing-cost reduction)	PC5,7, 9, 10	1.83	2	0.401	0.56	0.00	1.01	1	0.87

This model has good fit indices However, a closer look at EC10 indicated that this item must be split into two items: "production tooling" and "equipment costs." Other items are modified as necessary.

E. Product Integrity

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	IP1 ... IP9	96.65	35	0.000	4.27	0.25	0.56	0.66	0.9442

The hypothesized model was rejected because of low NNFI and low CFI. Additionally, many error terms are correlated. IP9 was deleted in further analysis because of low factor loading (.47) and low squared multiple correlation (SMC = 0.26)

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 1	IP 1 .. IP8	69.95	20	0.000	3.19	0.28	0.74	0.82	0.9516

IP7 was deleted in further analysis because error terms were highly correlated with IP2, 5, and 8.

Model	Items	X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Alternative 2	IP 1,2, 3,4,5,6,8	38.23	14	0.000	2.07	0.23	0.83	0.89	0.944

The error terms of IP2 and IP3 were highly correlated. Both IP2 and IP3 had a similar SMC

(0.82 and 0.81 respectively). IP3 was retained because it had a better wording. IP2 was deleted in further analysis.

Alternative 3	IP 1,3,4,5,6,8	11.23	9	0.260	1.1	0.09	0.97	0.98	0.9315

The error terms of IP1 and IP4 were highly correlated. IP1 was retained because it had a higher SMC. IP4 was deleted in further analysis.

Alternative 4 (Recommended)	IP 1,3,5,6,8	3.39	5	0.640	0.73	0.00	1.03	1	0.9249

The fourth alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure.

F. Supplier Performance		X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	SP1 ... SP13	141.12	65	0.000	6.03	0.19	0.39	0.49	0.7929

The hypothesized model was rejected because of poor NNFI and CFI. Additionally, an EFA indicated that the model consisted of four dimensions with some cross-loadings. SP1, 5 & 8 loaded on one dimension and could be easily interpreted as on-time supplier performance in product development. The rest of the 3 dimensions could not be easily interpreted and have many cross-loadings. For the large scale study, supplier performance were then reconceptualized as a 3-dimension constructs consisting of time, cost, and quality performances. Each dimension consisted of 4 items.

G. Product Development Time		X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	PT1 ... PT9	86.95	27	0.000	3.84	0.26	0.62	0.71	0.9162

The hypothesized model was rejected because of low NNFI and CFI. An EFA indicated that the model consisted of two dimensions: (PT2, 3, 4, 5, 6, 8) and (PT7, 9). PT1 and PT8 loaded on both dimensions. Between PT7 and PT9, PT9 has the higher factor loading. Deleting PT9 made all items loaded into a single factor. PT1 was also deleted in further analysis because the wording was different from other items.

Alternative 1	PT2, 3, 4, 5, 6,7,8	45.1	14	0.000	2.28	0.26	0.67	0.78	0.9009

The error terms of PT2 and PT3 as well as PT7 and PT8 were highly correlated. PT2 and PT7 were kept because they had better wording.

Alternative 2 (Recommended)	PT2, 4, 5, 6,7	8.28	5	0.141	0.88	0.00	0.89	0.91	0.8459

The second alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure.

H. Customer Satisfaction		X^2	df	p	ECVI	RMSEA	NNFI	CFI	alpha
Hypothesized Model	CS1...CS12	106.66	54	0.000	4.83	0.17	0.76	0.8	0.9315

The hypothesized model was rejected because it had relatively low NNFI and CFI. Additionally, it had many high correlated error terms. An EFA indicated that the model had two dimensions with many cross-loadings. CS3, 8 and 10 were deleted in further analysis because they have the lowest corrected item to total correlations (CTICs).

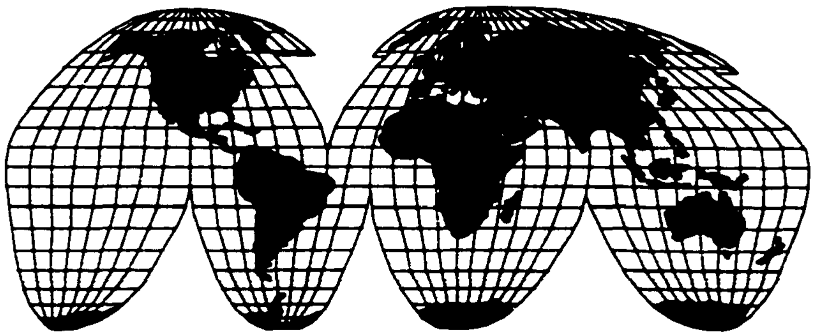
Alternative 1	CS1,2,4,5,6,7,9,11,12	33.7	27	0.175	2.18	0.09	0.95	0.96	0.9234

CS7 was later deleted because it had a lower SMC.

Alternative 2	CS1,2,4,5,6,9,11,12	24.39	20	0.226	1.76	0.08	0.96	0.97	0.9193
	The second alternative indicated that the error terms of CS11 and CS12 were highly correlated. CS12 was later deleted because the wording was too long. CS1 was also deleted because it had low SMC.								
Alternative 3 (Recommended)	CS2,4,5,6,9,11	7.66	9	0.569	0.99	0.00	1.02	1	0.9096
	The third alternative will be used for the large-scale survey because it has good fit indices and displays a simple structure.								

APPENDIX 3

Instrument for Large Scale Survey in the U.S.



International Product Development Benchmarking in the Auto Industry

Until recently, no one has undertaken international, systematic research to study the Integrated Product Development (IPD) process in both auto manufacturers and auto suppliers. As part of this research, we are interested in any new product your company currently has on the market. Please respond to the following survey questions with the specific product you have identified in mind. There are no correct or incorrect answers. We are interested only in your actual perceptions of the above product, not as you wish it to be, or plan it to be in the future. Your responses will be kept completely confidential. None of your responses will be disclosed to any other person. We will only analyze the responses for each region (e.g., companies in the U.S.) as a whole data set, not individually. You may fax or mail your responses in the enclosed pre-paid envelope to:

Dr. William J. Doll
Department of Management
College of Business Administration
The University of Toledo
2801 West Bancroft Street; Toledo, OH 43606, USA
Phone: 419-530-2850; Fax: 419-530-2365, 530-7744
E-mail: william.doll@utoledo.edu

INTEGRATED PRODUCT DEVELOPMENT PRACTICES

The following statements measure the extent to which your product development team employs IPD practices when developing the specific product you identified on page 1. Please circle the number that best describes your evaluation according to the following 5-point scale illustrated below:

Not at all	A little	Moderately	Much	A great deal
1	2	3	4	5

Concurrent/Simultaneous Engineering

• Much of process design is done concurrently with product design	1	2	3	4	5
• Product development group members represent a variety of disciplines	1	2	3	4	5
• Various disciplines are involved in product development from the early stages	1	2	3	4	5
• Process engineers are involved from the early stages of product development	1	2	3	4	5
• Manufacturing engineers are involved from the early stages of product development	1	2	3	4	5
• Product and process designs are developed concurrently by a group of employees from various disciplines	1	2	3	4	5
• Product development group members share information	1	2	3	4	5

Customer Involvement

• We study how our customers use our products	1	2	3	4	5
• Our product development people meet with customers	1	2	3	4	5
• We visit our customers to discuss product development issues	1	2	3	4	5
• In developing the product concept, we listen to our customer needs	1	2	3	4	5
• We involve our customers in the early stages of product development	1	2	3	4	5

Supplier Involvement

• Our suppliers develop component parts for us	1	2	3	4	5
• Our suppliers develop whole subassemblies for us	1	2	3	4	5
• Our suppliers do the product engineering of component parts for us	1	2	3	4	5
• Our suppliers are involved in the early stages of product development	1	2	3	4	5
• We ask our suppliers for their input on the design of component parts	1	2	3	4	5
• We make use of suppliers for their input on the design of component parts	1	2	3	4	5

Product Development Managers

• Product development managers have a final say in budget decisions	1	2	3	4	5
• Product development managers are given a real authority over personnel	1	2	3	4	5
• Product development managers have a final say in product design decisions	1	2	3	4	5
• Product development managers have broad influence across the organization	1	2	3	4	5
• Product development managers have enough influence to make things happen	1	2	3	4	5
• Product development managers derive their influence from expert knowledge of manufacturing process	1	2	3	4	5

Platform Products

• Our product designs are drawn to accommodate future generations of products	1	2	3	4	5
• Our product designs enable us to accommodate several generations of products	1	2	3	4	5
• Our core products are designed as platforms for multiple generations of products to come	1	2	3	4	5

Computer Technology Utilization

• We use computers to improve designs	1	2	3	4	5
• We use computers to evaluate designs	1	2	3	4	5
• Computers help us in main engineering changes	1	2	3	4	5
• We use computers to develop product prototypes	1	2	3	4	5
• We use computerized systems for product development	1	2	3	4	5
• We use computers to coordinate product development activities	1	2	3	4	5

PRODUCT DEVELOPMENT PERFORMANCE

The following statements pertain to the specific product you identified on page 1. Please circle the number that best describes your evaluation according to the following 5-point scale illustrated below:

Strongly Disagree 1<-----------------2 -------------3 -----------4 -------------->5 Strongly Agree
(Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5)

Teamwork

Our product development team:					
▪ Works well together	1	2	3	4	5
▪ Communicates effectively	1	2	3	4	5
▪ Implements decisions efficiently	1	2	3	4	5
▪ Resolves design conflicts on time	1	2	3	4	5
▪ Coordinates design activities effectively	1	2	3	4	5

Engineering Change Time

Our product development team:					
▪ Modifies dimensional specifications on time	1	2	3	4	5
▪ Finishes engineering change orders on time	1	2	3	4	5
▪ Delivers engineering change notices on time	1	2	3	4	5
▪ Meets engineering change deadlines regularly	1	2	3	4	5

Product Cost Reduction

Our product development team:					
▪ Simplifies the design successfully	1	2	3	4	5
▪ Reduces product costs successfully	1	2	3	4	5
▪ Reduces material costs successfully	1	2	3	4	5
▪ Reduces the number of parts successfully	1	2	3	4	5

Team Productivity

Our product development team:					
▪ Is productive	1	2	3	4	5
▪ Completes works quickly	1	2	3	4	5
▪ Works on product improvements successfully	1	2	3	4	5
▪ Works within predetermined engineering hours	1	2	3	4	5

Manufacturing Cost Reduction

Our product development team:					
▪ Successfully reduces assembly cost	1	2	3	4	5
▪ Reduces equipment costs successfully	1	2	3	4	5
▪ Reduces manufacturing costs successfully	1	2	3	4	5
▪ Reduces production tooling cost successfully	1	2	3	4	5
▪ Reduces the number of manufacturing steps effectively	1	2	3	4	5

Product Integrity

In our experience:					
▪ All components fit together easily	1	2	3	4	5
▪ All components are well integrated	1	2	3	4	5
▪ All assembled components function well	1	2	3	4	5
▪ All assembled components have high quality	1	2	3	4	5
▪ All assembled components pass product testing easily	1	2	3	4	5

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1<---------------	---2 ---------------	---3 ---------	---4 -------------	-->5

Suppliers' On Time Performance

Our suppliers:

▪ Design parts on time	1	2	3	4	5
▪ Deliver the parts they design on time	1	2	3	4	5
▪ Manufacture the parts they design on time	1	2	3	4	5
▪ Meet engineering change deadlines on time	1	2	3	4	5
▪ Meet our product development schedules on time	1	2	3	4	5

Suppliers' Quality Performance

Our suppliers:

▪ Provide high quality parts	1	2	3	4	5
▪ Design high quality products	1	2	3	4	5
▪ Meet our quality specification	1	2	3	4	5
▪ Deliver high quality materials	1	2	3	4	5
▪ Improve their quality performance	1	2	3	4	5

Suppliers' Cost Performance

Our suppliers:

▪ Meet our target cost	1	2	3	4	5
▪ Help reduce our overall cost	1	2	3	4	5
▪ Improve their cost performance	1	2	3	4	5
▪ Suggest ideas that reduce our product cost.	1	2	3	4	5
▪ Design parts that reduce our manufacturing cost	1	2	3	4	5

Product Development Time

Compared to the average in the industry, our product development team:

▪ Launches products to the market faster	1	2	3	4	5
▪ Enables our company to start volume production faster	1	2	3	4	5
▪ Brings products to the market before our competitors do	1	2	3	4	5
▪ Develops products from concept to commercial production faster	1	2	3	4	5
▪ Makes better progress in reducing total product development time	1	2	3	4	5

Customer Satisfaction

Compared to the average in the industry, our products:

▪ Satisfy customers better	1	2	3	4	5
▪ Fit target customers better	1	2	3	4	5
▪ Have more loyal customers	1	2	3	4	5
▪ Generate more new customers	1	2	3	4	5
▪ Are more highly valued by customers	1	2	3	4	5
▪ Are more successful in the marketplace	1	2	3	4	5

GENERAL INFORMATION

Please check the appropriate box (☑) or write in the space provided:

1. The country you are working in is:

   ❑ Germany ❑ U.S.A. ❑ Japan ❑ Other (please specify): ____________

2. Your parent company is located in:

   ❑ Germany ❑ U.S.A. ❑ Japan ❑ Other (please specify): ____________

3. In which vehicle system is your company's product mentioned in page 1 primarily used? **Choose only one.**

   ❑ Body exterior ❑ Body interior ❑ Powertrain ❑ Chassis
   ❑ Electrical/electronic equipment ❑ Other: ________________

4. The primary status of your company is (**choose only one**):

   ❑ Auto manufacturer/Original Equipment Manufacturer/OEM. **Go to # 9.**
   ❑ Auto supplier
   ❑ Other: ____

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

   ❑ An auto supplier owned partially or fully by an OEM
   ❑ An independent auto supplier not owned by an OEM

6. If you are an auto supplier, the primary status of your company is:

   ❑ First-tier supplier ❑ Second-tier supplier
   ❑ Third-tier supplier ❑ Other: __________

7. If you are an auto supplier, what is the most complex product your company primarily supply to your customers? **Choose only one.**

   ❑ Integrated systems ❑ Subsystems/subassemblies/modules
   ❑ Components/parts ❑ Materials
   ❑ Other: ______________________________________

8. If you are an auto supplier, how are you primarily involved by your customer in the design of your products? **Choose only one.**

   ❑ Customer provides concept, we do the rest
   ❑ Customer provides critical specification, we do the rest
   ❑ We work with the customer to co-develop the design
   ❑ We provide initial feedback to the customer on their design
   ❑ Customer provides complete design, we are not involved
   ❑ Other: ________________________________

9. In what form do you primarily involve your suppliers in product development? **Choose only one.**

- ❑ We provide concept, suppliers do the rest
- ❑ We provide critical specifications, suppliers do the rest
- ❑ We work with suppliers to co-develop the design
- ❑ Suppliers provide initial feedback to our design
- ❑ We provide complete specifications to suppliers
- ❑ Other: ____________________

10. Total number of individuals who were directly involved in developing the specific product you mentioned on page 1: __________

11. Number of employees in your company's auto-related business worldwide: __________

12. Total annual sales of your company's auto-related business worldwide:

❑ Less than $50 million ❑ $50 - $500 million ❑ $ 500 million - $1 billion
❑ $1 - $5 billion ❑ More than $5 billion ❑ Not available

OPTIONAL DATA

If you give your name below or attach your business card, we will send you a summary of the survey findings. However, you may also send your card in a separate envelope. This will allow us to communicate with you while keeping your responses anonymous.

Mr./Ms.____________________

Title: ____________________

Company: ____________________

Address: ____________________

____

____

City: ______________ State: _____ ZIP: _______

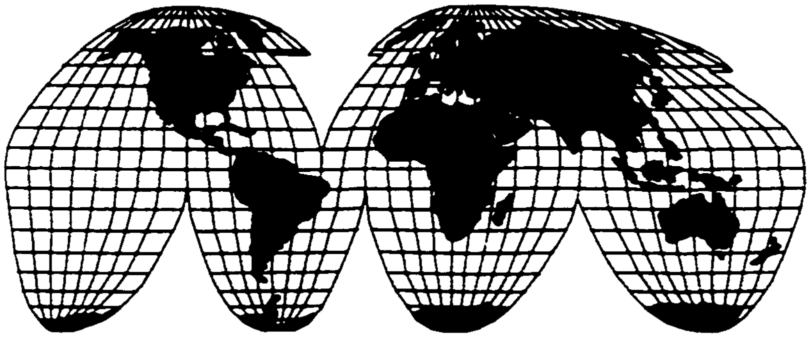
Phone: ______________ Fax: ______________

E-mail: ____________________

THANK YOU FOR YOUR ASSISTANCE

APPENDIX 4

Research Instrument for Large Scale Survey in Germany



Internationales Produktenwicklungsbenchmarking in der Automobilindustrie

Bis vor kurzem hat niemend internationale, systematisch Forschung betrieben um den Integrated Product Development (IPD) Prozess der Automobilhersteller und Zulieferer zu untersuchen. Als einen Teil dieser Forschungsarbeit, sind wir an allen neuen Produkten interessiert die Ihre Frima zur Zeit auf dem Markt anbietet. Bitte beantworten Sie den folgenden Fragebogen unter Berücksichtigung von nur einem bestimmten Produkt ihrer Firma. Es gibt keine falschen oder richtige Antworten. Wir sind an ihrem persönlichen Eindruck über das Produkt interessiert nicht an Ihren Wünschen oder zukünftigen Planungen. Ihre Anworten weden absolut streng vertaulich behandelt. Keine Ihrer Anworten wird Dritten zugänglich gemacht. Wir werden die Antworten nur als ganzes je nach Region, z.B. Frimen in der USA, analysieren und nicht individuell. Sie können den ausgefüllten Fragebogen entweder an uns zurückfaxen oder in dem von uns beigelegten Rückumschlag an folgende Addresse unseres Deutschlandkorrespondenten zurücksenden:

Dr. M. Nurhuda
Universität Bielefeld
D4-145
Universitätstr. 25
Bielefeld 33615
Telefon: 49-521-106-5278; Fax: 49-521-106-5244
E-mail: mnurhuda@post.uni-bielefeld.de

INTEGRIERTE PRODUKTENTWICKLUNGSPRAKTIKEN

Die folgenden Aussagen bemessen den Umfang zu welchem ihr Produktentwicklungsteam IPD Praktiken anwendete. als Sie das Produkt entwickelt haben. welches Sie auf Seite eins auserwählt haben. Bitte kreisen Sie die Nummer ein. *die am besten ihre Bewertung beschreibt nach folgender illustrierter 5-Punkte Scala:*

Überhaupt nicht	Ein bißchen	Mäßig	Viel	Sehr viel
1	2	3	4	5

Simultane Produktentwicklung

- Viel des Prozeßdesigns wird gleichzeitig mit dem Produkdesign getätigt 1 2 3 4 5
- Gruppenmitglieder der Produktentwicklung repräsentieren eine vielzahl von Bereichen 1 2 3 4 5
- Viele verschiedene Bereiche sind eingebettet in den Produktentwicklungsprozeß von einem frühen Zeitpunkt an 1 2 3 4 5
- Prozeßingenieure sind beteiligt am Produktentwicklungsprozeß von einem frühen Zeitpunkt an 1 2 3 4 5
- Produktsionsingenieure sind beteiligt am Produktentwicklungsprozeß von einem frühen Zeitpunkt an 1 2 3 4 5
- Produkt und Prozeßdesign werden gleichzeitig entwickelt von einer Gruppe von Angestellten aus verschiedenen Bereichen 1 2 3 4 5
- Gruppenmitglieder der Produktionsentwicklung teilen Information 1 2 3 4 5

Kundeneinbindung

- Wir untersuchen wie unsere Kunden unsere Produkte gebrauchen 1 2 3 4 5
- Unsere Produktentwicklingsleute treffen sich mit Kunden 1 2 3 4 5
- Wir besuchen unsere Kunden um Fragen der Produktentwicklung zu diskutieren 1 2 3 4 5
- Um Produktkonzepte zu entwickeln berücksichtigen wir die Bedürfnisse unserer Kunden 1 2 3 4 5
- Wir beteiligen unsere Kunden an der Produktentwicklung von einem frühen Zeitpunkt an 1 2 3 4 5

Einbindung der Zulieferbetriebe

- Unsere Zulieferer entwickeln Komponententeile für uns 1 2 3 4 5
- Unsere Zulieferer entwickeln ganze Teilmontagen für uns 1 2 3 4 5
- Unsere Zulieferer übernehmen die technische Entwicklung der Komponententeile für uns 1 2 3 4 5
- Unsere Zulieferer werden früh in den Produktentwicklungsprozeß eingebunden 1 2 3 4 5
- Wir fragen unsere Zulieferer nach Vorschlägen zum Design von Komponententeilen 1 2 3 4 5
- Wir berücksichtigen die Vorschläge unserer Zulieferer bei dem Design der Komponententeile 1 2 3 4 5

Produktentwicklungsmanager

- Produktentwicklungsmanager haben das endgültige sagen in Budgetentscheidungen 1 2 3 4 5
- Produktentwicklungsmanager haben wirkliche Autorität über das Personal 1 2 3 4 5
- Produktentwicklungsmanager haben das endgültige sagen in Entsheidungen des Produktdesigns 1 2 3 4 5
- Produktentwicklungsmanager haben weitreichenden Einfluß in der gesamten Firma 1 2 3 4 5
- Produktentwicklungsmanager haben genügend Einfluß um Sachen durchzusetzen 1 2 3 4 5
- Produktentwicklungsmanager haben Einfluß aufgrund ihres großen Sachverständnisses über den Produktionsablauf 1 2 3 4 5

Platformprodukte

- Unsere Produktdesigns sind so ausgerichtet. daß sie die nachste Produktgeneration beherbergen können 1 2 3 4 5
- Unsere Produktdesigns sind so ausgerichtet. daß sie einige Produktgenerationen beherbergen können 1 2 3 4 5
- Unsere Hauptprodukte sind als Platformen designed für viele Generationen von zukünftigen Produkten 1 2 3 4 5

Nutzung von Computertechnologie

- Wir nutzen Computer um das Design zu verbessern 1 2 3 4 5
- Wir nutzen Computer um Designs zu bewerten 1 2 3 4 5
- Computer helfen uns in großen Entwicklungsänderungen 1 2 3 4 5
- Wir nutzen Computer um Prototypen zu entwickeln 1 2 3 4 5
- Wir nutzen Computersysteme für Produktentwicklung 1 2 3 4 5
- Wir nutzen Computer um Produktentwicklungsaktivitäten zu koordinieren.......... 1 2 3 4 5

PERFORMANCE DER PRODUKTENTWICKLUNG

Die folgenden Aussagen betreffen dem Produkt den Sie auf Seite eins auserwählt haben. Bitte kreisen Sie die Nummer ein die am besten ihre Bewertung beschreibt nach folgend illustrierter 5-Punkte Scala:

1 <————2————3————4————>5

Völlig unzutreffend | Etwas unzutreffend | Neutral | Eingermaßen zutreffend | Vollkommen zutreffend

Teamwork
Unser Produktentwicklungsteam:
- Arbeitet gut zusammen 1 2 3 4 5
- Kommuniziert effektiv 1 2 3 4 5
- Implementiert Entscheidungen effizient 1 2 3 4 5
- Löst Designkonflikte pünktlich 1 2 3 4 5
- Koordiniert Designaktivitäten effektiv 1 2 3 4 5

Änderungszeiten der technischen Entwicklung
Unser Produktentwicklungsteam:
- Modifiziert dimensionale Spezifikationen pünktlich 1 2 3 4 5
- Beendet technische Entwicklungsänderungen pünktlich 1 2 3 4 5
- Liefert Benachrichtigungen über technische Entwicklungsänderungen rechtzeitig 1 2 3 4 5
- Hält normalerweise Deadlines über technische Änderungen ein 1 2 3 4 5

Reduktion der Produktkosten
Unser Produktentwicklungsteam:
- Simplifiziert das Design erfolgreich 1 2 3 4 5
- Reduziert Produktkosten erfolgreich 1 2 3 4 5
- Reduziert Materialkosten erfolgreich 1 2 3 4 5
- Reduziert die Anzahl von Teilen erfolgreich 1 2 3 4 5

Teamproduktivität
Unser Produktentwicklungsteam:
- Ist produktiv 1 2 3 4 5
- Vervollständigt Arbeit schnell 1 2 3 4 5
- Arbeitet on Produktverbesserungen erfolgreich 1 2 3 4 5
- Arbeitet nach vorher festgesetzten Entwicklungsstunden 1 2 3 4 5

Kostreduzierung in der Produktion
Unser Produktentwicklungsteam:
- Reduziert erfolgreich die Montagekosten 1 2 3 4 5
- Reduziert Equipmentkosten erfolgreich 1 2 3 4 5
- Reduziert Produktionskosten erfolgreich 1 2 3 4 5
- Reduziert Werkzeugbaukosten erfolgreich 1 2 3 4 5
- Reduziert die Anzahl von Produktionsinstanzen erfolgreich 1 2 3 4 5

Produktintegrität
Unserer Erfahrung nach:
- Passen alle Komponenten einfach zusammen 1 2 3 4 5
- Sind alle Komponenten sehr gut integriert 1 2 3 4 5
- Funktionieren alle montierten Komponenten sehr gut 1 2 3 4 5
- Sind alle montierten Komponenten von hoher Qualität 1 2 3 4 5
- Passieren alle montierten Komponenten die Qualitätskontrolle 1 2 3 4 5

1 <------------------2 ------------------3 ------------------4 ------------------------->5				
Völlig unzutreffend	Etwas unzutreffend	Neutral	Eingermaßen zutreffend	Vollkommen zutreffend

Zeitperformance der Zulieferbetriebe

Unsere Zulieferer:

▪ Designen Teile pünktlich	1	2	3	4	5
▪ Liefern die Teile, die sie designen pünktlich	1	2	3	4	5
▪ Produzieren die Teile, die sie designen pünktlich	1	2	3	4	5
▪ Halten Deadlines über technische Änderungen pünktlich ein	1	2	3	4	5
▪ Halten unsere Produktionzeitpläne pünktlich ein	1	2	3	4	5

Qualitätsperformance der Zulieferer

Unsere Zulieferer:

▪ Versorgen uns mit hochqualitativen Produkten	1	2	3	4	5
▪ Designen hochqualitativen Produkten	1	2	3	4	5
▪ Treffen mit unserem Qualitätsspezifikationen über ein	1	2	3	4	5
▪ Liefern hochqualitative Materialien	1	2	3	4	5
▪ Verbessern ihre Qualitätsperformance	1	2	3	4	5

Kostenperformance der Zulieferer

Unsere Zulieferer:

▪ Treffen mit unseren Kostenzielen überein	1	2	3	4	5
▪ Helfen uns unsere Gesamtkosten zu senken	1	2	3	4	5
▪ Verbessern ihre Kostenperformance	1	2	3	4	5
▪ Machen Verbesserungsvorschläge die unsere Produktkosten senken	1	2	3	4	5
▪ Designen Teile die unsere Produktionskosten senken	1	2	3	4	5

Produktentwicklungszeit

Verglichen mit dem Industriedurchschnitt, unser Produktentwicklungsteam:

▪ Bringt Produkte schneller auf den Markt	1	2	3	4	5
▪ Ermöglicht unserer Firma Volumenproduktion eher zu starten	1	2	3	4	5
▪ Bringt Produkte auf den Markt schneller als unsere Konkurrenten	1	2	3	4	5
▪ Entwickelt Produkte vom Konzept zur kommerziellen Produktion schneller	1	2	3	4	5
▪ Macht besseren Fortschritt in der Reduzierung der Gesamtentwicklungszeit	1	2	3	4	5

Kundenzufriedenheit

Verglichen mit dem Industriedurchschnitt, unsere Produkte:

▪ Machen Kunden mehr zufrieden	1	2	3	4	5
▪ Passen besser zu unseren Zielkonsumenten	1	2	3	4	5
▪ Haben mehr loyale Kunden	1	2	3	4	5
▪ Gewinnen mehr neue Kunden	1	2	3	4	5
▪ Werden höher geschätzt von Kunden	1	2	3	4	5
▪ Sind erfolgreicher auf dem Markt	1	2	3	4	5

ALLGEMEINE ANGABEN

Bitte haken Sie das zutreffende Kästchen ab (☑) oder schreiben sie in den dafür vorhergesehenen Platz.

1. Das Land in dem sie arbeiten ist:

❑ USA ❑ Deutschland ❑ Japan ❑ Anderes Land (Bitte erläutern):______

2. Der Hauptsitz Ihrer Firma ist in:

❑ USA ❑ Deutschland ❑ Japan ❑ Anderes Land (Bitte erläutern):______

3. Zu welchem Vehiclesystem ist das Produkt Ihrer Firma das auf Seite 1 erwähnt ist vorrangig zuzuordnen (Bitte wählen sie nur eine Kategorie):

❑ Außenausstattung ("Body Exterior")
❑ Innenausstattung ("Body Interior")
❑ Getriebe ("Powertrain/Engine/Transmission")
❑ Karosserie ("Chasis/Frame")
❑ Elektronik ("Elektrical/Electronic Equipment")
❑ Anderes:____________________________________

4. Der vorrangige Status Ihrer Firma ist (Bitte wählen sie nur eine Kategorie):

❑ Automobilhersteller (Gehen Sie bitte zu Punkt 9)
❑ Automobilzulieferbetrieb
❑ Anderes: ____

5. Falls Sie Zulieferer sind, dann ist Ihre Firma (Bitte wählen sie nur eine Kategorie):

❑ Ein Zulieferer zum Teil oder ganz im Besitz eines Automobilherstellers.
❑ Ein unabhängiger Zulieferer der keinem Automobilhersteller gehört.

6. Falls Sie ein Zulieferer sind, der vorrangige Status Ihrer Firma ist (Bitte wählen sie nur eine Kategorie):

❑ Dieketer Zulieferer ("Tier 1 Supplier")
❑ Indirekter Zulieferer ("Tier 2 Supplier)
❑ Zulieferer für einen indirekten Zulieferer ("Tier 3 Supplier")
❑ Anderes:________________________________

7. Falls Sie ein Zulieferer sind, was ist Ihr höchstkomplexes Produkt, das Ihre Firma an Kunden ausliefert? (Bitte wählen sie nur eine Kategorie)

❑ Vollintegrierte Systeme ("Integrated System")
❑ Teilsysteme/ Teilmontagen/ Module ("Subsystems/Subasemblies/Modules")
❑ Komponenten/ Teile ("Components/Parts")
❑ Material ("Material")
❑ Anderes: ____

8. Falls Sie ein Zulieferer sind, wie sind Sie vorrangig von Ihren Kunden an deren Produktdesign beteiligt? (Bitte wählen sie nur eine Kategorie)

- ❑ Der Kunde gibt das Konzept vor, wir erledigen den Rest.
- ❑ Der Kunde gibt spezifische Informationen an, wir erledigen den Rest.
- ❑ Wir arbeiten mit den Kunden, um das Design kozuproduzieren.
- ❑ Wir geben ein erstes Feedback zu dem Design des Kunden.
- ❑ Der Kunde erstellt das gesamte Design und wir sind nicht daran beteiligt
- ❑ Anderes: ____________________

9. In welcher Form binden Sie vornehmend Ihre Zulieferer in der Produktentwicklung ein? (Wählen Sie bitte nur eine Antwort aus)

- ❑ Wir erschaffen das Konzept, Zulieferer machen den Rest.
- ❑ Wir erschaffen kritische Spezifikationen, Zulieferer machen den Rest.
- ❑ Wir arbeiten mit unseren Zulieferern, um das Design kozuproduzieren.
- ❑ Unsere Zulieferer geben ein erstes Feedback zu dem Design.
- ❑ Wir geben den Zulieferern komplette Spezifikationen.
- ❑ Andere: ____________________

10. Gesamtanzahl der Individuien die direkt an der Entwicklung des auf Seite eins gewählten Produktes beteiligt waren: ____________________

11. Anzahl der Mitarbeiter Ihrer Firma in der Automobilindustrie weltweit: ____________

12. Jahresgesamtumsatz Ihrer Firma in der Automobilindustrie weltweit:

- ❑ Weniger als DM 75 Millionen
- ❑ DM 75- DM 750 Millionen
- ❑ DM 750 Millionen - DM 1.5 Milliarden
- ❑ DM 1.5 Milliarden - DM 7.5 Milliarden
- ❑ Mehr als DM 7.5 Milliarden
- ❑ Nicht bekannt

NICHT OBLIGATORISCHE ANGABEN

Wenn Sie Ihren Namen unten angeben oder ihre Visitenkarte beilegen, werden wir Ihnen eine Zusammenfassung unsere Forschungsergebnisse schicken. Sie können auch gerne ihre Visitenkarte in einem separaten Umschlag an uns schicken. Dies wird uns gewährleisten mit Ihnen zu kommunizieren und gleichzeitig Ihre Angaben so anonym wie möglich zu halten.

Herr/Frau: ____________________

Titel: ____________________

Firma: ____________________

Addresse: ____________________

____

____

Plz: ____________ Stadt: ____________

Land: ____________________

Telefon: ____________ Fax: ____________

E-mail: ____________________

Vielen Dank für Ihre Mitarbeit.