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Time-Based Competition: Developing a Nomological Network of Constructs and Instrument Development

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An Abstract of

TIME-BASED COMPETITION: DEVELOPING A NOMOLOGICAL NETWORK OF CONSTRUCTS AND INSTRUMENT DEVELOPMENT

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The purpose of this study is to develop standardized instruments to support organizational level research on time-based competition. This research focuses on the measurement of time-based product development and manufacturing practices, and competitive capabilities. The methodology used to derive measures includes a review of the literature, interviews with ten practitioners, and expert evaluation with fourteen participants. A pilot study was conducted with 32 firms with several objectives in mind: purification, unidimensionality, reliability, brevity, convergent and discriminant validity, as well as predictive validity. Where appropriate, items were deleted, modified, or added.

An exploratory data analysis with 244 firms followed, and the methodology included: purification, exploratory factor analysis, reliability, discriminant validity using

LISREL methodology and the Multitrait-Multimethod (MTMM) approach, convergent validity, predictive validity, and assessment of a second-order structure for each instrument.

The factor pattern matrix for each instrument exhibited a simple structure and was easily interpretable. Good discriminant and convergent validity was evident for all instruments. All eighteen recommended scales had Cronbach's alpha greater than 0.84. There were six scales derived for time-based product development practices; They consist of concurrent engineering, heavyweight product development managers, platform products, customer involvement, supplier involvement, and computer usage. Time-based manufacturing practices included cellular manufacturing, re-engineering setup, preventive maintenance, quality improvement efforts, pull production, shop-floor employee involvement in problem solving, and supplier dependability. The five scales for competitive capabilities contain value to customer quality, product innovation, competitive pricing, premium pricing, and customer delivery service. Reliabilities were found to be generalizable across the industries surveyed. To gain an initial understanding of relationships in a nomological network of time-based constructs and to further assess construct validity, structural equations modeling was employed. Both direct and indirect effects were assessed.

Directions and recommendations for future research include the re-validation of the scales, confirmatory factor analysis, factorial invariance tests, the use of multiple methods of obtaining data, testing alternative hypothesized models, and incorporation of contextual variables.

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CHAPTER 1: INTRODUCTION

Expanding global competition, rapidly changing markets, and the world-wide spread of advanced manufacturing technology are creating a more complex and uncertain environment (Manufacturing Studies Board, 1986; Lawrence and Dyer, 1983; Bayus, 1994). Manufacturing firms face a paradigm shift from industrial systems driven by efficiency to post-industrial systems where success depends on a quick response to customer demands for a variety of high-quality products (Huber, 1984; Masuda, 1980; Toffler, 1970; Naisbitt, 1982; Doll and Vonderembse, 1991; Hall, Johnson, and Turney, 1991). Success in the post-industrial environment hinges on satisfying multiple performance measures as enterprises anticipate markets and respond quickly and efficiently with products that provide high value to customers (Doll and Vonderembse, 1991).

In essence, time is becoming a critical dimension for competition, and many executives believe that time-based competition is the next competitive battleground for manufacturing. Blackburn (1991) and Stalk and Hout (1990) describe case studies where organizations who redesigned their business processes to compress time achieved higher productivity, increased market share, reduced risk, and improved customer service. In his worldwide survey of manufacturing, Schmenner (1991) demonstrated that reductions in throughput time are associated with greater productivity. Clark and Fujimoto (1991) report that in the highly competitive automobile industry, companies such as Honda maintain an advantage by virtue of the rate at which they can introduce new technology. Blackburn (1991) describes how Phillips, a Dutch electronics conglomerate, went from the first firm to introduce an affordable video cassette recorder in 1972 to a firm that no longer competes in that market. Blackburn attributes the failure of Phillips to its slow new product development process.

The efficacy of this new time-based paradigm is supported primarily by case studies and a very small number of survey type research efforts. Stalk and Hout (1990) and Blackburn (1991) focused attention on the competitive importance of time-based competition. Case studies by Merrils (1989), Hamilton (1991), Lindsley, Blackburn, and Elrod (1991), Mabert, Muth, and Schmenner (1992), Gupta and Wilemon (1990) improved our understanding of time-based practices and associated implementation issues. Handfield and Pannessi (1995) described antecedents of lead time competitiveness in make-to-order manufacturing firms. Sakakibara, Flynn, and Schroeder (1993) measured antecedents to lead time and cycle time in a JIT environment. Also, Karagozoglu and Brown (1993), Trygg (1993), Cooper and Kleinschmidt (1991), Clark and Fujimoto (1991), and Handfield (1994) described antecedents to accelerated product development time.

Large scale, organizational level empirical studies that develop standardized instruments and investigate the relationships between time-based practices and competitive capabilities are not available and represent an important missing element in manufacturing management and strategy literatures. The lack of broad based research on time-based competition has made it difficult to establish whether the shift in competitive priorities and assorted process improvements represent a broad movement in the industry, or whether observed changes merely depict changes found in a few successful, technology based companies (Trygg 1993).

In fields with an emerging tradition, instruments are often developed as a by-product of attempts to test substantive hypotheses of interest to the researcher. Often, these substantive studies lack the rigor in instrument development methods to merit being accepted as standardized instruments. Standardized instruments can improve theory development, enhance the additivity of manufacturing research, and make the testing of substantive hypotheses easier. Thus, standardized instruments can be the cause rather than the consequence of progress in empirical research in manufacturing.

The level of theory development in time-based competition poses challenges and opportunities for instrument developers. Without an existing nomological network of theoretical constructs and instrumentation, it becomes difficult to demonstrate the predictive or construct validity of new instruments. Thus, research design strategies need to focus on developing sets of related instruments rather than single instruments. This poses unique challenges in designing a long-term research strategy. It affects the methods used to generate items, eliminate items, and explore for hidden and unexpected causal relationships. Where it is necessary to measure sets of variables along a causal chain, the length of questionnaires and the cost of data gathering is affected. Finally, research design strategies that focus on the primary goal of developing standardized instruments may have to employ sophisticated methods such as LISREL for assessing discriminant validity, generalizability, and predictive and/or construct validity.

The purpose of this research is to develop standardized instruments to support organizational level research on time-based competition. Time-based competition includes the re-engineering of product development processes, manufacturing practices, delivery and distribution systems, and after sale services to improve competitive capabilities (Stalk and Hout 1990, Blackburn, 1991). While it would be a worthy goal to investigate all processes or practices and their competitive implications, this is a large and complex inquiry (Handfield and Pannessi, 1995). This research focuses on developing a systemic framework that links time-based product development practices and time-based manufacturing practices to competitive capabilities.

A systemic framework of time-based constructs and its theoretical support are presented in Chapter 2. The research methodology for generating items for standardized instruments appears in Chapter 3. This methodology includes interviews with practitioners, expert evaluation, and a pilot study with 32 firms. Large scale survey methods and reliability and validity results are reported in Chapter 4. In Chapter 5, an exploratory structural analysis is shown using LISREL methodology. Relationships depicted in the systemic framework developed in Chapter 2 are tested here. Chapter 6 highlights the contributions of this research and provides a discussion and recommendations for future research. Finally, the conclusion of this dissertation is presented in Chapter 7.

CHAPTER 2: THEORY DEVELOPMENT

As illustrated in Figure 1, manufacturing firms are redesigning their product development and manufacturing practices to enhance their competitiveness in response to the emerging post-industrial environment. Time-based product development practices affect competitive capabilities directly (Stalk and Hout, 1990; Blackburn, 1991; Rosenthal and Tatikonda, 1992); and indirectly through their impact on manufacturing practices (Boothroyd and Dewhurst, 1988; Susman and Dean, 1992) and through their effects on product development time (Clark and Fujimoto, 1991). Others suggest that these product development practices have an indirect effect on competitive capabilities through their influence on throughput time (e.g., Susman, 1992; Susman and Dean, 1992). Time-based manufacturing practices can cut throughput time and enhance competitive capabilities (Blackburn, 1991; Handfield and Pannessi, 1995). These manufacturing practices may affect competitive capabilities directly, and indirectly through their impact on throughput time (Wacker, 1987; Krupka, 1992).

Time-based researchers (e.g., Stalk and Hout, 1990; Blackburn, 1991; Schmenner, 1991; Wacker, 1987) support the notion that changes in throughput time have a direct effect on competitive capabilities. In essence, they suggest that when throughput time is reduced competitive capabilities are improved. A number of time-based researchers (e.g., Stalk and Hout, 1990; Blackburn, 1991; Clark and Fujimoto, 1991; Clark, Chew, and Fujimoto, 1988; Susman and Dean, 1992; Rosenthal and Tatikonda, 1992) also claim that

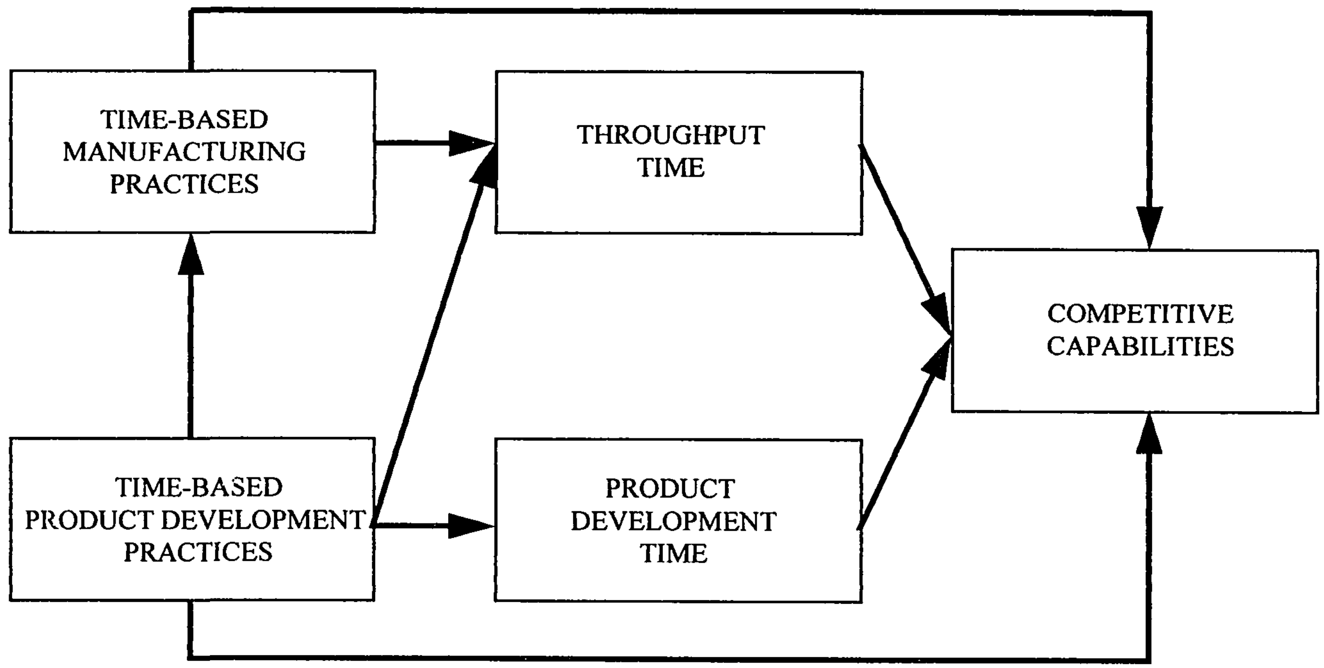

FIGURE 1: Time-Based Competition Framework

shorter product development cycles lead to improvements in competitive capabilities.

Before testing relationships, it is theoretically sound to identify, define, and discuss the various constructs. This can be done through a review of the current literature and theoretical rationale.

2.1 TIME-BASED PRODUCT DEVELOPMENT PRACTICES

The product development literature is diverse and includes contributions from a variety of disciplines (e.g., marketing, manufacturing, engineering, strategic management, purchasing), but it lacks an integrative framework. Recently, there has been considerable change in the concepts and techniques being advocated, suggesting that an implicit paradigm change has occurred. For example, where work in product development has been done sequentially, now it is done concurrently (Clark and Fujimoto, 1991). Despite the emergence of new concepts and techniques, no new integrative paradigm for viewing this field has yet emerged.

2.1.1 Empirical Research in Time-Based Product Development: A Critical Review.

Careful examination of the recent product development literature and a recent meta-analysis (Motaya-Weiss and Calantone, 1994) suggests that large scale organizational research on time-based product development is scarce. McDonough and Barczak (1991) state that while there is keen interest in understanding how to speed up development, very little is known at present about how to do so. Trygg (1993) notes that the lack of broad-based research on the topic has made it difficult to establish whether the shift in competitive priorities and assorted process improvements represent a broad movement in industry, or whether observed changes merely depict changes found in a few successful, technology-based companies.

Cooper and Kleinschmidt (1994) state that although there have been many prescriptions and formulas offered (Cordero, 1991; Crawford, 1992; Dumaine, 1989;1991; Gold, 1987; Mabert, Muth, and Schmenner, 1992; Millson, Raj, and Wilemon, 1992; Nayak, 1990; Rosenthal and Tatikonda, 1993), the fact is that most are based on speculation, opinion, anecdotal evidence and a handful of case studies--hardly what one would call "strong scientific evidence." Karagozoglu and Brown (1993) also note that in spite of the heightened concern over speeding up new product development, the majority of the published studies are based on scattered cases and anecdotal evidence. Case studies are valuable and necessary in the early stages of research, though they run the risk of leading us to a narrow and idiosyncratic understanding of the phenomena in question (Eisenhardt, 1989). Cooper and Kleinschmidt (1994) state that extensive studies on factors that reduce cycle time are more noticeable for their absence than their presence. Millson, Raj, and Wilemon (1992) also attest to the fact that published research involving cycle acceleration is meager but they mention that it is growing (Gupta and Wilemon, 1990; Rohan, 1990; Rosenau, 1990; 1988a) and there are a few such studies on drivers of cycle time reduction (McDonough and Barczak, 1991; 1992).

Cooper and Kleinschmidt (1994) provide three explanations for the lack of large scale research in the area. One reason for this lack of hard data is that the field of accelerated product development is relatively new. A second may be that it is a very profitable field for large number of consultants, pundits, and authors who argue for it unequivocally. Cooper and Kleinschmidt point that the third and most serious reason is that research is difficult in this area. Research in this area of measuring and comparing cycles is fraught with operational problems.

Another problem with the empirical research in time-based product development is that it focuses at the project level rather than the organizational level. It investigates single project specific practices and outcomes. New product success has been measured primarily at the project level by a single item financial measure (e.g., return on investment, sales, etc)(Cooper, 1985; Cooper and Kleinschmidt, 1987; Myers and Marquis, 1969; Rubenstein et al., 1976; SPRU Project Sappho, 1972). This difference between the project and the firm as the unit of analysis is important. Gluck and Foster (1975) showed long ago that we can claim short-term success for individual projects while jeopardizing the long-run future of a business. Far fewer studies have set out to measure factors specifically associated with success at the program or organizational level (Johne and Snelson, 1989).

A recent meta-analysis (Montaya-Weiss and Calantone, 1994) of the product development literature provided evidence that most studies are done at the project level. These authors conducted a comprehensive review of the product development literature and observed a wide variety of study designs and methodological approaches. The research investigated a total of 47 empirical studies and found that research is conducted at both the project and program level, but a great majority (78.7 %) of the studies were project-based. Project based studies ask the respondent to answer with respect to a specific successful or failed new product project. Other studies consider a firm's recent program or all of the new projects undertaken in the past few years. Program-based studies focus on generalizations regarding a firm's usual process of new product development. The authors conclude that more program based studies should be carried out. Program-based studies, they state, could inherently increase the generalizability of the findings given that respondents are specifically asked to give general answers. Project-specific characteristics may be atypical and widely variable from firm to firm, thus limiting the validity of indiscriminately combining results across projects and various firms. This narrow focus on the product rather than the firm could result in prescriptions that are both short term and non-optimal.

The product development literature has also been criticized for its lack of sophistication in both measurement and hypothesis testing methods (Montaya-Weiss and Calantone, 1994). Few studies have been undertaken that develop instruments for product development research. Instrument development for time-based product development practices is lacking. According to the Montaya-Weiss and Calantone report on measurement and analysis in product development research, only eight studies included measures of dimensionality (factor analysis, cluster analysis, and discriminant analysis) and 18 studies had statistical interpretation of parameters (correlation analysis, canonical correlation analysis, regression analysis, path analysis, and structural equations model). Instruments for time-based product development in particular have not been widely published. Without valid and reliable instruments, reported findings regarding relationships between practices and time may not be convincing.

A growing number of studies are reporting tests of hypothesized differences between new product success and failures, correlations between the determinants and new product performance, and other statistics based on various multivariate tests (Calantone and di Benedetto, 1988; Cooper, 1979a; 1979b; 1990; Cooper and Kleinschmidt, 1986; 1987a; 1987b; De Brentani and Droge, 1988; Dillon, Calantone, and Worthing, 1979; Droge and De Brentani, 1986; Dwyer and Mellor, 1991a; 1991b; Kleinschmidt and Cooper, 1991; Maidique and Zirger, 1984; Song and Parry, 1992a; 1992b; Souder and Chakrabarti, 1978; Storey, Chris, Edgett, Scott, Easingwood, Chris and Kleinschmidt, 1992; Thamhain, 1990, Utterback, Allen, Thomas, Hollomon, Herbert and Sirbu, and Marvin, 1976). However, in spite of increasingly rigorous statistical analyses, much past and current research remains exploratory in nature, focused on the identification rather than explanation of factors (Cooper and Kleinschmidt, 1987a).

2.1.2 Recent Empirical Research in Time-Based Product Development Practices.

McDonough and Spital (1984) investigated twelve new product development projects. From their study they concluded that important factors contributing to a rapid and successful completion of new product development projects included a clear delineation of product specifications, technical leaders with general business skills, and strong support by top management.

Gupta and Wilemon (1990) gathered data from 38 managers and technical personnel in twelve large technology-based companies. They asked their interviewees how New-Product-Development (NPD) could be accelerated in their companies, and suggestions included active and visible senior management commitment, early involvement of functional groups, adopting new work styles (e.g., employing parallel processing of new product development tasks, promoting flexible and more informal working modes), early market and technical testing, and replacing weak organizational matrix approaches with strong product champions.

McDonough and Barczak (1991) report on data collected from 30 new product development projects in twelve British companies in an effort to investigate the impact of leadership style and the source of the technologies employed in the project on speed of development. Their results suggest that leadership style influences speed of development. In particular, they found that a participative style of leadership is associated with faster development where the source of technology is internal, and that there was no relationship between the leaders's style and the speed of development in projects where the source of technology is external.

Mabert, Muth, and Schmenner (1992) report results from a comparative case study at six different firms. They note that the new product development process is very complex, sensitive to external forces like customer demands or expectations and to internal issues, like how team leadership is defined within the development team. Results indicate that the first priority point is that a project needs a knowledgeable team leader who can devote sufficient time to plan, manage and monitor the project. The second priority point is that a team approach is conducive as it reduces communications delays, enhances concurrent activities, and reduces overall development time.

Rochford and Rudelius (1992) examined the effects on new product performance by obtaining information from multiple functional areas during the stages of the new product development process in 79 firms. They found that for several stages of the new product process, obtaining information from more functional areas and sharing information among more functional areas had a positive impact on new product performance. Performance was measured on a 13 item scale and included items measuring the extent to which the product met its objectives such as timeliness, profit, sales, production schedules, and etc.

Trygg (1993) reports on his findings from a broad-based survey of 109 cases within the Swedish manufacturing industry. The survey suggested that the Swedish manufacturing industry, in general, has a broad awareness about the important and strategic role that the product development processes play, and especially the strategic role of the time factor. More than half of the companies (54%) claimed that they were using a program in order to increase the efficiency and effectiveness of their development efforts. The most widely used practices of these programs are integrated product development, parallel product development, and simultaneous product development. The top ranked motive for these programs was to reduce product development time. It was expressed as the underlying incentive in 83% of the programs.

Karagozoglu and Brown (1993) identified several product development acceleration methods based on data collected from 35 high-technology companies. Results revealed unexpected, and at times inconsistent, insights compared to findings from the case study and anecdotally based literature, and implied also that some of the well documented approaches to successful new product development need to be replaced with their time-based versions. The data from this study showed that multifunctional teams (58%), customer involvement (58%), and computer aided tools (48%) were the three highest use categories in order to accelerate new product development.

Cooper and Kleinschmidt (1994) report results from of an extensive study of 103 new product projects in the chemical industry. The key questions addressed in the study were, "What are the drivers of an on-time, fast-paced project:" and "To what extent are timeliness and profitability connected?" The strongest driver of project timeliness was the use of a cross-functional, dedicated, accountable team, with a strong leader and top management support. The researchers have found also unexpectedly that being "first in" the market had a positive impact, but only marginally.

Handfield (1994) used data obtained from structured interviews with product managers and engineers to test several hypotheses regarding 31 make-to-order products from various industries. The results suggest that concurrent engineering may be appropriate for incremental innovation, but may have some "hidden costs" in the form of increased defects when applied to new "breakthrough" innovations. Concurrent engineering decreased defects for incremental innovations. Concurrently engineered products were developed in approximately 60% of the time required for sequentially developed products. Millson, Raj, and Wilemon (1992) concluded from their examination of the product development literature that practices used by time-based manufacturers essentially accelerate time in 5 basic approaches: (1) simplify, (2) eliminate delays, (3) eliminate steps, (4) speed up operations, and (5) parallel process.

2.1.3 Identification of Time-Based Product Development Practices and Theory Development.

A variety of specific product development practices that accelerate product development can be found in the empirical as well as theoretical literatures. Seven dominant time-based practices that allegedly compress time are identified in Table 1.

Concurrent Work-Flow

As early as 1971 researchers (e.g., Mansfield et al., 1971) discuss the role of overlapping stages of product development in reducing lead times. Clark and Fujimoto (1991) and Clark, Chew, and Fujimoto (1992) report on the impact of overlapping activities. Their research surveys concurrent practices in the automobile industry. Abernathy (1971) and Imai, Nonaka, and Takeuchi (1985) stress that concurrent work-flow is a critical element of success of the Japanese new product development process. Murmann (1994) reports that parallel tasking and efficiency improvements account for potential savings of 30% in product development time in 14 projects in the German Mechanical Engineering (industrial machinery) industry.

Traditionally, product development work has been done sequentially (i.e., sequential phases), "over the wall" approach. There was little if any involvement by internal or external (customers and suppliers) constituents in the process until very late. Post-industrial systems instead employ concurrent work flow (i.e., overlapped phases) (Doll and Vonderembse, 1991). Post-industrial systems support the notion that concurrent or simultaneous efforts in product development would yield the best performance. According to Barius (1994), the aim of concurrent engineering is to reduce the lead time

Table 1: List of Time-Based Product Development Practices

Practice	Definition	Literature
1. Concurrent Work-flow	The extent to which product and process design is concurrent.	Clark, Chew, & Fujimoto (1992); Clark & Fujimoto (1991); Imai, Nonaka, & Takeuchi (1985); Sanderson (1992)
2. Product Development Teams	The extent to which team principles are used for product development.	Clark & Fujimoto (1989, 1991); Imai, Nonaka, & Takeuchi (1985); Susman & Dean (1992); Barkan (1992)
3. Heavyweight Project Managers	The extent to which product managers have significant clout.	Clark & Fujimoto (1991); Hayes, Wheelwright, & Clark (1988); Clark, Chew, & Fujimoto (1988); Wolff (1992).
4. Early Involvement of Constituents	The extent to which internal and external groups are involved early during product development.	Susman & Dean (1992); Boothroyd & Dewhurst (1988); Moeneart & Souder (1990).
5. Supplier Responsibilities	The extent to which suppliers are responsible for product development efforts.	Imai, Nonaka, & Takeuchi (1985); Clark, Chew, & Fujimoto (1988); Wolff (1992).
6. Incremental Product Innovation	The extent to which innovations are small and frequent.	Sanderson (1992); Clark & Fujimoto (1991); Sanderson & Uzumeri (1990); Barkan (1992).
7. Computerization	The extent to which automation tools are being used for product development.	Rosenthal & Tatikonda (1992); Sanderson (1992); De Meyer (1992).

from the specification of a concept to the delivery of the first product to the first customer. Not only will this be more efficient, but it will yield products the customers crave, reduce manufacturability problems, reduce engineering change orders, and improve quality and cost.

Millson, Raj, and Wilemon (1992) discuss parallel processing as one of the approaches in accelerating the product development process. The concurrent approach accelerates product development by substantially changing the phased approach (Bertrand, 1986; Bower and Hout, 1988; Brazier and Leonard, 1990; Burt and Soukup, 1985; Burt, 1989; Cordero, 1991; Dumaine, 1989; Fraker, 1984; Goldstein, 1989; Larson, 1988; Matt, 1984; Merrills, 1989; Port, Schiller, and King, 1990; Stalk, 1988; Stalk and Hout, 1990; Takeuchi and Nonaka, 1986; Uttal, 1987). During concurrent or overlapped phases, the product and manufacturing processes are being designed simultaneously (Susman and Dean, 1992; Clark and Fujimoto, 1991). Overlapping activities shorten the project cycle time in two important ways. First, parallel activities are stimulated. With early release of information, engineers can begin working on different phases of the problem while final designs are evolving. Second, time-consuming rework is avoided because the early release of information promotes early detection that the product design is veering off target. Test engineering for example, may use early design information to assure that new products are tested and inspected in a systematic way. Purchasing may be able to order long lead time items in advance of the formal issue of engineering documents.

To achieve concurrent work-flow many companies have begun to implement Quality Function Deployment (QFD). The QFD concept emphasizes increased interaction between engineering design and marketing to facilitate communication of customer's needs to the product engineers (Hauser and Clausing, 1988). According to Trygg (1993), QFD ensures that the product meets the customer's requirements when it goes into production by a systematic focus on these customer attributes during the whole development process.

Product Development Teams

Hershock, Cowman, and Peters (1994) provide an example of the successful use of teams in product development. They discuss how 3 M's Occupational Health and Environmental Safety Division used teams to successfully design, build, and introduce products in less than half the time it would have previously taken without the team. Crawford (1992) concludes that one publicized tool for accelerated product development is the team, or venture team, involving a strong leader, little formality and structure, and the full range of functions.

Industrial systems were characterized by high vertical and horizontal specialization where each level and each function had its own unique and often conflicting goals. Although sometimes teams of people were formed in industrial systems, these teams tended to be functional rather than cross-functional. There was limited interfunctional interaction and exchange of information. Interaction and exchange of information is most critical in dealing with the complex and fast changing environment faced by post-industrial competitors. The hierarchical structure manifested itself as an efficient posture for the industrial era. However, the complexity and quantity of information that needs to be dealt with in a post-industrial environment makes the adoption of hierarchical structures probably unsuitable (Doll and Vonderembse, 1991).

McKee (1992) suggests that cross-functional teams are conducive to accelerating the product development process because they enhance communication and organizational learning. Communication is a vital and basic element in organizational activity. Organizations are conceptualized as information processing entities (Cyert and March, 1963; O'Reilly and Roberts, 1977; Thompson, 1967; Tushman and Nadler, 1980) that must interact with their respective environments in order to receive, process, and transmit information for survival. Communication for a complex process such as the new product development process becomes extremely important. According to Rochford and Rudelius (1992), developing new products is a complex process involving many functional groups within an organization and external groups such as customers and vendors. Fischer (1980) has described the innovation process as basically a process in which ideas rather than physical technologies are transferred from originators to users. Similarly, Utterback (1971) claims that innovation is most often the result of communication of a need followed by a search for information about a technical means to meet the need.

Organizational learning also requires that information be shared with all relevant organizational members (Strata, 1989). Argyris and Schon (1978) define organizational learning as "experience-based improvement in organizational task performance" (p. 323). Similarly, Shrivastava and Grant (1985) define it as "the autonomous capacity of organizations to create, share and use strategic information about themselves and their environments for decision making" (p. 98). Organizational learning involves sharing assumptions, developing knowledge action-outcome relationships and institutionalizing experience (Shrivastava, 1983). For organizational learning to occur knowledge must be accessible to others beyond the individual discoverers, and it must be subject to application, change, and adaptation by others in the organization (Jelinek, 1979).

According to McKee (1992) the logical answer to overcome barriers to communication and information sharing comes in the form of lateral decision processes which cut across the traditional vertical lines of functional authority. McKee suggests that one of the more useful forms of lateral communication in product development situations, where joint efforts across multiple functional departments are required, is the cross-functional team.

Donnellon (1993) also suggests that teams produce more creative solutions (Osborn, 1957), make better decisions (Davis, 1973), improve the implementation of decisions, and increase commitment (Cohen and Ledford, 1991; Hoffman, 1979). Work teams have been also identified as one of several mechanisms for integrating the differentiated perspectives of the environment that are likely to develop as a function of specialization within a firm (Lawrence and Lorsch, 1967). It has also been argued that certain tasks require teams because they can be only accomplished through constant mutual adjustment to the information provided by each team member (Pinto and Pinto, 1990; Thompson, 1967).

Merely putting a group of people together and calling them a team, however, hardly ensures that they will interact productively and creatively to solve design problems. In general, an atmosphere of coordination between functions has been linked to less severe mismatches between new products and production capabilities (Langowitz, 1988). Team processes may include considerations regarding the range of discretion vested in the team, the continuity of the team, the composition of the team, the frequency of meetings, the size of the team, the location of team members in relation to each other, the degree of sharing of provisional information, the degree to which integrative solutions are sought, and the degree of trust built between members (e.g., Barkan, 1992; Susman and Dean, 1992; Clark and Fujimoto, 1989;1991; Bergen and McLaughlin, 1988). The amount of discretion vested with the team is a determining factor in reducing development time. Susman and Dean (1992) suggest that teams should be given a wide range of discretion in matters concerning the new product. They explain that it is quite time consuming and destructive for a group constantly to be held up while members seek approval for their decisions from their functional organizations.

After conducting a study of successful Japanese product development efforts, Imai, Nonaka, and Takeuchi (1985) report that top management intentionally leaves considerable room for discretion and local autonomy to the development team. In an empirical study, Bergen and McLaughlin (1988) found a significant relationship between the autonomy allowed for project personnel and performance. The performance of the team is also related to a smooth and continuous process. Susman and Dean (1992) report that one major enemy of process continuity is turnover within the team. In only a few projects in their study did the team remain intact throughout the project. Thus, reassignments of team members appears to cause considerable disruption. The composition of the team also seems to be important. Stalk and Hout (1990) state that it is best to include only essential functions in the team and to exclude people whose job is peripheral. Related to the issue of composition is the size of the team. Naturally, small teams work better than large ones because large groups create communication problems of their own. The frequency of meetings and co-location are also very important for the product development team to be successful. For example, co-location allows close coordination and interaction between the participants in the team and it further reduces differentiation between team members. The degree to which team efforts for problem solving are successful depends also on the willingness of members to share provisional information, whether team members trust each other, whether members treat their decisions tentative until late in the project, and whether they seek integrative solutions (e.g., Clark and Fujimoto, 1989; Susman and Dean, 1992).

Heavyweight Product Managers

Heavyweight product managers are usually senior in the organization and often at the same or higher rank than the heads of the functions. Roberts (1977) suggests that an innovation requires both the sponsorship of someone in the organization who has political influence and someone who has access to necessary resources. It also requires championing by someone who is an enthusiastic salesperson for the new idea (Maidique, 1980; Kanter, 1983). Such champions guide innovation through the organization decision making process, and their presence is important throughout the development process (Leonard-Barton, 1993). According to Clark and Fujimoto (1991), the heavyweight product manager effectively functions as a general manager of the product. In some organizations, project managers are little more than meeting-schedulers and report filers whereas in others they have the authority to override functional managers. Susman and Dean (1992) suggest that product managers should be given real authority and allow him or her to get on with the job (Cooper and Kleinschmidt, 1994). Clark and Fujimoto (1991) state that the "heaviness" of product managers stems from the fact that organizations empower these managers to lead, coordinate, and champion the effort.

Efforts in reducing product development time may be diluted if the product development practices are overcome by the functional structure of the organization. Post-industrial systems have a "heavyweight" product leader who promotes a project orientation rather than a functional one and who has significant clout in the organization to make things happen. The assignment of "heavyweight" project managers facilitates an efficient and effective alternative to the traditional functional structure. Crawford (1992) notes that many honored innovators have extolled the value of product champions and argued that they are needed anytime there is internal opposition to a new program, and such opposition may come from any interest group in the organization. He warns that a project that needs no champion is virtually certain to bring about very little institutional change.

In a study of the world automotive industry, projects with "heavyweight" project managers used fewer engineering hours than those with "lightweight" project managers or no project managers at all (Clark, Chew, and Fujimoto, 1988; Clark and Fujimoto, 1991). Delays in product development were common in industrial systems due to the often functional and hierarchical structure they employed. Delays occurred because representatives in the product development group had to inform and get authorization from their functional area every time a decision was to be made. Millson, Raj, and Wilemon (1992) suggest from their research that many approval procedures are cumbersome, and they point that some of these procedures are required solely to support individual power needs.

Early Involvement of Constituents

Industrial systems, abiding with their sequential product development process, saw little need to involve various constituents early in the development process. Each phase of the process was to be carried out sequentially and different constituents would begin work once work was "finished" at a previous phase. On the other hand, early involvement of many internal (e.g., manufacturing, purchasing, top management, marketing), as well as external (e.g., suppliers, customers), constituencies is essential for cycle time reduction and improvements in capabilities for time-based manufacturing. Customers (Whybark, 1994; Fitzsimmons, Kouvelis, and Mallick, 1991; Murakoshi, 1994) and suppliers (Dumaine, 1989; Bonaccorsi and Lipparini, 1994; Asanuma, 1975; Cusumano and Takeishi, 1992; Imai, Nonaka, and Takeuchi, 1985) may suggest new ways of dealing with problems and participate in the problem solving efforts while internal groups may identify manufacturability problems early in the development process.

In fact, the most cited reason for delays in product development projects in manufacturing systems is engineering change orders (Barkan, 1992; Millson, Raj, and Wilemon, 1992). This occurs when designs and parameters about the product do not match manufacturing capabilities and/or customer expectations, and/or materials are unavailable. Designers may find out that manufacturing cannot meet the specifications or that the specified material is unavailable or that customers are not satisfied. Time is wasted when physically separate functions need to communicate. Early involvement of various constituents in the development process provides an avenue for various interest groups to express their concerns and to provide their input early into the process. Design characteristics such as manufacturability, complexity, and design for quality can be improved through greater cross-functional involvement, leading to shorter manufacturing lead times later in the product life-cycle (Putnam, 1985; Whitney, 1988; Raturi et al., 1990; Fleischer and Liker, 1992; Ulrich et al., 1993).

Manufacturing can inform design engineering about its existing manufacturing capabilities so that design can take these capabilities into account in the product design (e.g., machine tolerances). Taking such capabilities into account during the product design phase reduces the chance that designers will have to modify the design late in the product development cycle. The benefits are derived from fewer mismatches between product characteristics and existing process capabilities. These mismatches are due primarily to the designer's ignorance of existing factory capabilities (Langowitz, 1988). Manufacturing may also suggest ways to design the product for ease of manufacturing. Manufacturing may suggest how products can be designed with fewer parts, assembled or tested more easily, or accommodated to automated equipment (Boothroyd and Dewhurst, 1988). Susman and Dean (1992) suggest the early involvement of manufacturing, bringing manufacturability issues into light, can reduce lead time from design conception to delivery of the product. This early involvement of constituents begins as early as the concept stage. It is plausible that potential problems can be identified early enough to avoid costly delays later.

Supplier Responsibilities

The importance of suppliers is evident in the works of both Wilkes and Norris (1972) and Brockhoff and Urban (1988) who came to the conclusion that about 30% of the delays in product development are due to vendors. De Meyer and Van Hooland (1990) report that improved vendor relations was the single most important factor explaining the increase in speed in introducing new products. Handfield and Pannessi (1995) also found some measure of support that supplier involvement in design can have an effect (indirect) on lead time performance, primarily through the introduction of more manufacturable designs. Mendez and Pearson (1994) investigated the role of purchasing in product development for time based strategies by interviewing managers at four Fortune 500 corporations. Results suggest that suppliers are critical team members who assist through initial product design suggestions, technological contributions, and quality assurance considerations, all of which contribute to efficient manufacturability and minimization of the design to market cycle time.

In industrial systems, suppliers were looked upon with suspicion and a broad supplier base was retained to assure competition and low prices. Suppliers, being considered as outsiders, were only given as little information as possible and only got involved in the development process after product design and specifications were determined. This was in accord with the overall sequential product development process.

In post-industrial working environments, suppliers get involved early during the development process (Doll and Vonderembse, 1991) and it is not uncommon for suppliers to be responsible for the development of whole subassemblies for their customers. Fewer suppliers are used but they are viewed as long-term partners.

The capabilities of suppliers are reflected by the responsibilities assigned to them. More capable suppliers are given more responsibilities in product development. Clark, Chew, and Fujimoto (1988) in their world automobile study indicate that Japanese manufacturers use not quite half the number of engineering hours to produce an automobile of comparable size, style, and price as do American manufacturers and partially attribute the difference on the supplier responsibilities. The authors found that satellite suppliers account for over 50% of Japanese engineering hours versus only 10% of American engineering hours. The American projects made only modest use of suppliers in design and engineering, but they rely relatively heavily on common parts.

In the Japanese system, suppliers are an integral part of the development process: they are involved early, assume significant responsibilities and communicate extensively and directly with product and process engineers. The ability of the Japanese firm to operate efficiently while using a larger fraction of unique parts is due in significant part to the capability of the supplier network (Clark, 1989). Imai, Nonaka, and Takeuchi (1985) and Clark (1989) have also documented in their study of the world's automobile industry the role of vendors in the design of assembled products. Responsibilities for Japanese suppliers include product and process design and in some cases prototype development (Clark and Fujimoto, 1991).

Collaborative supplier relations are seen as the way to speed the pace of new product introduction and sustainable long-term performance. According to Bonaccorsi and Lipparini (1994) this may be especially true for first-tier suppliers or primary suppliers, who are responsible for design, development, and sometimes assembly of integrated parts and systems. Burt and Soukup (1985) stress the efforts companies will have to make to incorporate vendors into their own in-house design processes and to forge a stronger link between purchasing and engineering.

Incremental Product Innovation

Gomory (1989) suggests that firms that are successful in fast paced product lines like automobiles and consumer electronics are masters of incremental innovation. Sanderson (1992) and Sanderson and Uzumeri (1992) discuss the use of incremental innovation by Sony which has dominated the personal stereo (Walkman) sales since 1979. They report that Sony has successfully used platforms from which to spin out its product variety. Shintaku (1990) also reports that Casio and Sharp have used a similar pattern of successful regular innovations that are based on basic platforms. These platforms provide a basic core that is altered and enhanced to produce variants with different features or external appearances. Each of these platforms optimizes a particular design goal that is matched to market needs.

Innovation in industrial systems was usually major but very infrequent. This approach is known as the "great-leap-forward" method. Innovation was traditionally viewed by manufacturing as a disruption of their efficient flows. Product variety was often anathema for production schedulers. Post-industrial systems pursue innovation in a different way (Doll and Vonderembse, 1991). They encourage small and frequent innovations. They build platform products that enable future generations of products to be accommodated. Incremental innovation strategies enable firms not only to bring products to the market faster but also to incorporate the newest technology as it becomes available. New features are added as customer cravings change and technology becomes available. Moreover, incremental innovation fosters organizational learning as the process is repeated with greater frequency.

Gomory and Schmitt (1988) note that repeated rapid developments accumulate to major product changes that leave competitors behind if they lack a quick response capability. Many successful Japanese firms have used an incremental product innovation approach in their efforts to reduce product development time and improve competitive capabilities. Clark and Fujimoto (1991) explain how the incremental or "rapid inch-up" works. They state that a new design tends to be a small jump from its predecessor but the rate of design renewal is relatively high. The "rapid inch-up" or "evolutionary" strategy of Japanese firms offers some potential advantages over the "infrequent great-leap-forward" or "revolutionary" strategy western firms have tended to follow. Because next-generation designs use established processing concepts, firms may avoid start up confusion. Moreover, repetitive and frequent changes of technology enable the product development organization to establish a "rhythm" of development, streamline the development process, and orient the entire organization to continual learning and improvement.

Computerization

Sanderson (1992) discusses the role of automated design and planning tools and cites an accomplishment of Toyota engineers who have used a CAD/CAM system for the body development of an automobile and report a lead time reduction of 25% for die design and manufacturing. De Meyer (1992) has found in his empirical study that CAD and CAM are widely used but their integration is not. With these techniques Perkin-Elmer can send blueprints for fabrication in about 25% of the time that it took previously (Goldstein, 1989), and 3M saved the two years that it takes to test an experimental heart pump (Cordero, 1991; Uttal, 1987).

Computer resources in industrial systems were used primarily to automate tasks (Zuboff, 1984). According to Zuboff, post-industrial systems use computers to eliminate tasks, and when it is not possible to eliminate them, they are used to simplify tasks. Computer technology enables product development not only by speeding the process but by increasing the chances the product is manufacturable and of high performance because computer technology enables the design of products and the testing of performance attributes by simulating countless operating conditions. It also accommodates engineering change orders fast because alterations on original designs can be handled efficiently. It enables coordination of product development efforts (Standish, Jones, Sumpter, and Sharp, 1994) and it increases the integration of professionals as it can provide access to the same information to multiple interest parties. Time-consuming efforts in prototype development can also be eliminated through the use of computer technology. Computer technology can also accommodate incremental innovation strategies as design and specifications can be stored and easily accessed for future alterations and enhancements.

In order to accelerate the new product development cycle, many advanced manufacturing and design automation processes may be employed. Computer Aided Design(CAD)/Computer Aided Manufacturing(CAM) systems are examples of engineering tools that can speed new product design. Today's CAD technology makes it relatively easy to create line drawings that represent three dimensional models of a part (Clark and Fujimoto, 1991). Rosenthal and Tatikonda (1992) explain that CAD systems also allow for quicker (relative to traditional manual methods) retrieval, drawing and redrawing of parts and schematics. In addition, the CAD package can provide other related and required documentation for manufacturing and purchasing purposes, tasks that, if not computer supported, would have to be done by hand. CAD tools not only speed up the accomplishment of certain required tasks, but may also reduce errors and support more consistent and reliable information. Computer Aided Engineering (CAE) allows quicker dimensioning, testing and analysis of proposed designs (Sanderson, 1992). Increases in quantitative information that result from the need to develop more products can be handled by CAD/CAM systems that integrate three dimensional design, two dimensional drafting, engineering databases, numerically controlled systems, and finite element analysis (Primrose, 1987). Trygg (1993) suggests that in order to maximize the benefits of concurrent engineering efforts, the two separated computer environments (i.e., CAD and CAM) must be effectively integrated.

2.2 TIME-BASED MANUFACTURING PRACTICES

Time-based competitors not only attempt to reduce development time but they try to shorten throughput time as well. Certain practices on the shop-floor have been identified as conducive to throughput time reduction and improvements in other competitive capabilities. Reduction in throughput time has received considerable attention due to the emergence and diffusion of Just-In-Time (JIT) production practices (Blackburn, 1991; Stalk and Hout, 1990).

The litarature review that will follow shows that large scale organizational level empirical research in manufacturing is plagued with several problems. First, large scale empirical research is scarce. Most empirical research is in the form of case studies and only a few large scale organizational level studies have emerged. Second, the available empirical research lacks rigor in both instrument development and hypothesis testing methods.

2.2.1 Empirical Research in Time-Based Manufacturing: A Critical Review.

Swamidass (1991) analyzed 221 articles published in 8 selected journals during 1987 to identify the research emphasis in the Operations Management (OM) area. OM papers accounted for 221 out of 410 papers. Only 11% of them were field-based and those included case studies, model validation, and test of formal theory. It is apparent that empirical research in manufacturing is scarce.

Methods used to conduct empirical research are also very weak when compared to methods used in other disciplines such as psychology, sociology, management, and marketing. Chase (1980) states "Based on articles surveyed, OM research is far less sophisticated in terms of alternative research designs employed than is that reported in such research journals as the Administrative Science Quarterly, Academy of Management Journal, or Journal of Applied Psychology" (p. 13). Even for the most popular topics of manufacturing management, such as JIT, empirical research that discusses reliability and validity issues was not published until 1992 (i.e., Davy et al., 1992). Flynn et al. (1990) in their report of empirical research in the Production and Operations management field show that over the years 1980 to 1989 there were only two empirical studies that included reliability and validity issues. Flynn et al. (1990) and Sakakibara et al. (1993) report, however, that the manufacturing academic community is awakening to the need for valid and reliable empirical methods for testing and developing a theory.

Instrument development is also lacking in the manufacturing management field. However, a few recent publications have created an interest in the area. These initial instrument development efforts provide a groundwork for future empirical research. These efforts should be complimented however by certain techniques and methods that will enhance their value; to raise the level of sophistication to standards adhered to by other disciplines with an organizational research tradition. For example, pilot studies are not routinely used as a part of instrument development. Pilot studies provide an opportunity to remove "bugs" from the scales and provide results that can be used to assess preliminary reliability and other estimates. Also, there is a lack of scale purification. This can be accomplished through corrected-item total correlation analysis. Reducing the number of items before going for the large scale administration may improve the quality of the scales in terms of reliability; it can also improve the ratio of respondents to the number of items and thus facilitate a more stable factor structure. Reported reliabilities in the relevant manufacturing literature are, in general, below 0.80 with a few exceptions (i.e., Saraph, Benson, and Schroeder, 1989; 1991). Although future research may improve scales, De Vellis (1991) points out that some of the apparent covariation among items may be due to chance and therefore, he advocates to strive for alphas that are high during the development stage. Then, if the alphas deteriorate somewhat when used in a new research context, they will still be acceptably high.

The utility of existing instruments would also be enhanced with the assessment and establishment of factorial validity. There is a systematic avoidance of establishing factorial validity for the scales. When factor analysis is performed in the manufacturing literature, it is usually done to establish unidimensionality and not factorial validity within a systematic framework of related constructs. In addition, there is no empirical research in manufacturing that has included a discussion or has carried out sophisticated discriminant and convergent validity tests such as the Multitrait-Multimethod (MTMM) method (Campbell and Fiske, 1959) and/or LISREL methodology. Confirmatory studies of instruments have not been published widely either and empirical researchers in manufacturing have systematically avoided presentation of the item correlation matrix and item standard deviations. A recent exception is Handfield (1993), and Handfield and Pannesi (1995). Testing alterative models using the original data or re-examining the research findings is impossible without a correlation matrix. Many multivariate analysis techniques make use of the correlation matrix. For example, LISREL methodology requires either a correlation matrix and standard deviations or a covariance matrix as input.

2.2.2 Recent Empirical Research in Time-Based Manufacturing Practices.

The recent empirical research on manufacturing practices is reviewed in a chronological order. Some of the studies, especially those that employed LISREL methodology, include both measurement and structural parts.

Saraph, Benson, and Schroeder (1989) developed an instrument for measuring the critical factors of quality management. Using prescriptions in the literature, they developed 120 quality management items. These items were reviewed by professors and graduate students and were subjected to a formal pre-test with seven managers. After the evaluation, 78 items were retained and grouped into eight critical factors of quality management. The questions asked the managers to indicate the degree or extent of practices of each item by the business unit. Data included responses from 162 general managers and quality managers of 89 divisions of 20 companies. The eight factors and their respective reliability alphas are as follows: (1) management leadership (alpha=.94), (2) role of quality department (alpha=.87), (3) training (alpha=.87), (4) product/service design (alpha=.71), (5) supplier quality management (alpha=.81), (6) process management (alpha=.76), (7) quality data and reporting (alpha=.88), and (8) employee relations (alpha=.85). The researchers also evaluated the assignment of items to scales using a method proposed by Nunnally (1967)(comparing correlations between the item and the other items within a scale against the correlations of the item and the other scales). No item posed any problem. Content validity, criterion related validity, and construct validity (unidimensionality) were assessed. All factors seemed to be unidimensional except the process management scale where two factors emerged. Factor loadings within each scale were in general low, ranging from 0.40 to 0.84.

Saraph, Benson, and Schroeder (1991) factor analyzed a 26 item instrument measuring organizational quality context using responses from 152 managers from 77 business units of 20 manufacturing and service companies. Four significant factors emerged with loadings ranging from 0.42 to 0.87. Eight items had factor loadings less than 0.70. The first factor was interpreted as corporate support for quality (alpha=.91), the second was interpreted as managerial knowledge of quality issues (alpha=.84), the third as past quality performance, and the fourth as marketplace environment. No alphas are reported for two of the factors.

Davy et al. (1992) addressed exploration, construct development, and hypotheses generation for JIT based on a review of the relevant literature and on empirical derivation of constructs. Using a sample of 446 responses the researchers derived three underlying constructs: (1) operating structure and control, (2) product scheduling, and (3) quality implementation. The research began by developing fifty-four descriptive items of individual's perception of JIT. Ten scales were formed with at least four items each. The reliability of the ten subscales had alphas ranging from 0.40 to 0.70. Initial principal components analysis resulted in 19 factors with eigenvalues greater than 1. Based on a scree test and factor loadings only three or four factors appeared nontrivial. After a varimax rotation of four factors the fourth factor was dropped. Reliability alpha was 0.77

for operating structure and control, 0.76 for product scheduling, and 0.69 for quality implementation. The highest and lowest loadings in magnitude for each factor were 0.62 and 0.50 for operating structure and control, 0.67 and 0.52 for product scheduling, and 0.55 to 0.50 for quality implementation.

Sakakibara, Flynn, and Schroeder (1993) also developed a measurement instrument for JIT manufacturing. Overall sixteen JIT dimensions were identified based on a literature review and plant visits. The questionnaires were then administered in 41 plants in the United States. The number of respondents per scale varied from 80 for an accounting adaptation to JIT scale to 615 for the small group problem solving scale. The scales were assessed for reliability and validity. Four scales were eliminated due to reliability problems. The reliabilities for the sixteen scales varied between 0.43 for multifunctional workers and accounting adaptation to JIT to 0.88 for kanban. Three out of 16 alpha reliabilities were above 0.70 while the majority were between 0.60 and 0.70. The remaining twelve scales, after reliability analysis, were factor-analyzed to assess unidimensionality. A factor analysis was then carried out at the construct level and three overall factors have emerged. The first was interpreted as management of people and schedules in a JIT system, the second as simplified physical flow, and the third as supplier management. Content validity and predictive validity were also assessed.

Flynn, Schroeder, and Sakakibara (1994) developed a set of 14 perceptual scales of quality management through an extensive literature review. The scales were assessed for reliability and validity with a sample of respondents from 42 plants in the U.S. The number of respondents varied from 41 for selection for teamwork potential to 613 for teamwork. Reliabilities varied from 0.60 for product design simplicity to 0.85 for process control. There was only one alpha greater than 0.80. Nine scales had alphas between 0.70 to 0.80 and four scales had alphas between 0.60 and 0.70. After further investigation, three scales were dropped due to reliability problems across different groups of respondents. Content validity as well as criterion related validities were assessed in addition to testing for unidimensionality using factor analysis.

Handfield (1993) hypothesized and tested a model where supplier base reduction was a response to increased uncertainty in demand, and that JIT was preceded by greater information sharing with fewer suppliers. Handfield also proposed that the success of JIT purchasing system is sustained through reduced transaction uncertainty with critical suppliers. Using a sample of production, purchasing, and engineering personnel at forty make-to-order (MTO) facilities and in regards to 50 product lines, Handfield tested the hypothesized model. Reported scale reliabilities include information sharing (alpha=.82), JIT purchasing (alpha=.74), and transaction uncertainty (alpha=.68). Measures of goodness of fit for the model were reasonable with the p-value of the chi-square test being greater than 0.10. In addition, Bentler and Bonnet's (1980) and Bollen's (1989) fit indices were greater than 0.90. Using LISREL methodology the results of the study supported the idea that purchasing departments in MTO firms are likely to reduce the number of critical suppliers in response to uncertainty in demand. There was also evidence of the relationship between information sharing and supply base reduction while information sharing was shown to be an antecedent to JIT purchasing. Supplier base reduction was not found to be an antecedent to JIT purchasing. Results also showed that a program of both JIT purchasing and supplier based consolidation can lead to significant reduction in transaction uncertainty.

Adam (1994) investigated the relationships between multiple quality and productivity approaches to eight quality, three operating, and three financial performance measures for 187 U.S. business firms. A 20-item instrument was developed to measure quality improvement and productivity improvement approaches. After orthogonal factor rotation, five factors emerged with eigenvalues greater than 1. They were interpreted as behavior, conformance and design, knowledge, rewards and SPC, and traditional engineering. Three of the items had significant cross-loadings. No reliabilities were reported. The hypotheses testing part was assessed using stepwise multiple regression. Results indicate a strong relationship between a quality improvement approach and performance quality. Quality improvement approach was also significantly related to operating or financial performance but the relationship was weaker. Results have also indicated that productivity improvement efforts help predict quality, operating performance, and financial performance. Adam concludes from the study that the profile of quality and productivity approach depends on whether the firm is interested in performance quality, operating improvement or financial performance.

Handfield and Pannesi (1995) studied a few aspects of time-based manufacturing in Make-To-Order (MTO) markets through the use of LISREL methodology. In particular, they studied whether cross-functional project design participation, JIT purchasing system with suppliers, improved supplier delivery and quality performance, and WIP lot size reduction have a significant effect on cycle competitiveness. The researchers developed an instrument to measure each of the five constructs identified in their model, namely cross-functional design (alpha=.79), JIT purchasing (alpha=.78), supplier performance (alpha=.70), WIP lot size (1 item), and lead time competitiveness (alpha=.68). The instrument was pre-tested with thirteen managers while the large scale administration was conducted in 40 plants and referred to data from 50 independent product lines in nine industries. Reported statistics for the measurement model included the multiple squared correlation (R^2, or item reliability). Six of twelve R^2s reported were below 0.50 with five of them significantly below 0.50. Unidimensionality and convergent validity were assessed by evaluating the correlation matrix and through confirmatory factor analysis. The fit of the structural model was evaluated based on a chi-square test and two other fit indices, the Normed Fit Index (0.89) and Bollen's (1989) incremental index (0.92). Based on the chi-square test (p-value= 0.53 with 57 degrees of freedom) and the two fit indices, the model seemed to have a reasonably good fit. Through the use of a structural equations model both JIT purchasing and supplier performance were found to have a significant effect on lead time competitiveness.

The use of sophisticated methods and tools for hypotheses testing are rare in the manufacturing literature. A recent exception is Handfield (1993) and Handfield and Pannessi (1995) who used LISREL methodology and were discussed earlier. In addition, most research that attempted to do hypotheses testing has used relatively small sample sizes by standard research methodology guidelines.

The literature reviewed here is a rich source of potential time-based manufacturing variables. A few of those studies in fact have used time as a dependent variable or a criterion.

2.2.3 Identification of Time-Based Manufacturing Practices and Theory Development

Based on theoretical arguments and a literature review seven manufacturing practices which are linked to reductions in throughput time and improved capabilities are identified. These practices along with numerous contributors are listed in Table 2.

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Setup Re-engineering

Traditional systems tried to achieve efficiency by producing large lots. Machines were kept running while inventories were piling up in an effort to maximize task specific performance. This can be explained because manufacturing often had utilization as the primary performance criterion. Setup time and activities were taken as granted and large lots were produced to minimize the setup costs. Post-industrial enterprises, on the other hand, attack flexibility problems at their heart and efforts to reduce setup are an essential component of time-based manufacturers (Doll and Vonderembse, 1991). They emphasize a reduction in setup time which enables the firm to switch production between products with minimum penalties. Taichi Onho, one of Toyota's Vice Presidents stressed that reduction or possible elimination of setup times was the key to increase flexibility. Much of the work on setup time reduction has been done by a colleague of Ohno, Shigeo Shingo, who pioneered the single minute exchange of die (SMED) system. The use of this procedure has resulted in significant reductions in time in hundreds of cases (Shingo, 1985).

Table 2: List of Time-Based Manufacturing Practices and Definitions

Practice	Definitions	Literature
1. Re-engineering Setup	The extent to which efforts are taken to reduce setup time.	Monden (1981a, 1983, 1989); Shingo (1985); Schonberger (1982, 1986).
2. Cellular Manufacturing	The extent to which units are produced in a product oriented layout.	Hyer & Wemmerlow (1984); Huber & Hyer (1985); Huber & Brown (1991); Brown & Mitchell (1991).
3. Quality Improvement Efforts	The extent to which methods are used to prevent defects.	Garvin (1983); Juran (1981a, 1981b); Saraph et. al. (1989); Deming (1981, 1982, 1986).
4. Preventive Maintenance	The extent to which equipment is maintained.	Nakajima (1988); Schonberger (1986); Monden (1983).
5. Dependable Suppliers	The extent to which suppliers facilitate customer needs for service and quality.	Lee & Ansari (1985); O'Neal (1987, 1989); Ansari & Modaress (1986, 1988).
6. Shop-Floor Employee Involvement in Problem Solving	The extent to which employees participate in efforts to solve problems.	Sugimori, et. al. (1977); Hall (1987, 1993); Huber & Brown (1991); Suzaki (1987); Showalter & Mulholland (1992).
7. Pull Production	The extent to which production is driven by the demand of the next stations.	Monden (1981b, 1983); Sugimori et. al. (1977); Schonberger (1983, 1986).

Shingo (1985) concentrates on the scientific techniques to reduce setup time and reports on the Toyota experience in re-engineering setup. Compressed setup times allow for smaller batches of units to be produced. Producing smaller lots implies also a greater flexibility to respond to changing customer needs and reduces the need for inventories. The exposure to the risk of producing a large number of defective units is also reduced by producing smaller lots. Shingo's principles include the classification of setup activities into external and internal, the completion of external activities prior to setup, the conversion of internal activities to external activities, the installation of parallel activities, and the smoothing and simplification of setup steps. Internal setup activities are those that can only be performed while the machine is shut down; external activities can be performed while the machine is running. Monden (1981, 1983) also reflects on the Toyota experience and argues that ultimately we would like to eliminate setup altogether. Setup time is not only an inherent component of throughput time, but is also a determinant factor in shop floor responsiveness. The literature for setup time reduction has been particularly influenced from the work of Shingo (1985), and Monden (1981a, 1983).

Cellular Manufacturing

Machines in industrial systems often were grouped based on their processing similarities and parts were moved from a group of machines to another group in batches, spending most of their time just waiting to be moved or to be machined. Inventories were build between stations to buffer differences in productivities between stations. No stations were to starve or to be blocked.

Post-industrial systems have instead adopted product oriented layouts which enable families of products to be produced by a group of machines in a cell (Pullen, 1976; Wemmerlov and Hyer, 1989). Within each cell there is minimal time spent on setup as only parts or products that are similar are produced in each cell. Little movement is also taking place due to the proximity of machines forming a cell. It is posited that because parts in a family share similar characteristics, the cost and time to switch production from one kind of part to another within a cell are minimized.

Parts produced in a cell share similar characteristics, such as design, and/or process, and/or appearance. The equipment is usually general purpose and flexible in order to handle small variations between different parts within a cell. Equipment is closely linked in order to shorten travel distance and material handling, and to allow the operation of multiple machines by a single operator. Firms adopting a cellular manufacturing approach have been rewarded with improvements in inventory levels, throughput time, quality, and flexibility (Fry, Wilson, and Breen, 1987; Hyer and Wemmerlov, 1984).

Quality Improvement Efforts

Quality efforts have traditionally been centered on inspecting quality at the end of the line. Specialists awaited finished products at the end of the production line to identify if indeed products conformed to specifications. By then, however, too much had been invested only to find out that the product is deficient in some way. Instead, post-industrial systems design products and processes to avoid defects and problems in the first place. They also empower and hold their workers responsible to build quality throughout the value chain.

Quality assurance efforts in post-industrial systems are essentially targeted at improving customer satisfaction, reducing throughput time, and reducing costs. Time spent in recovering from internal quality problems is an inherent component of throughput time and thus emphasis should be placed in preventing defects. Schmenner (1992) states:

> "If one measures throughput time properly it should be a weighted average of the times required to make all of the units in a batch of the product. Such a weighted average includes not only those units that finish quickly without having to be reworked or scrapped, but also those units of the initial batch that spend time in the rework area. And, if such units are scrapped and that causes another order to be cut to complete what was planned, then the 'Catch-up-time' should be counted" (p. 111).

Quality assurance efforts, by preventing defects, are expected to reduce the time spent on rework and lost yield and thus shorten throughput time. Quality assurance efforts include the use of statistical quality charts by operators, making employees and suppliers responsible for their own quality, empowering employees to shut down production if quality problems are detected, and using tools such as fishbone diagrams to identify causes of problems. Quality assurance efforts have been influenced from the work of Deming (1981, 1982, 1986), Juran (1974, 1978, 1981a,b), Ishikawa 1976, Garvin 1983, and Leonard and Sasser (1982) among others.

Preventive Maintenance

Responsiveness to changes in customer demand has also been hampered by the often unreliable equipment employed in industrial systems. Efforts in maintenance have not traditionally received the attention they deserve. The attitude was "if it is not broke, don't fix it." Putting down the machine for service was anathema for production managers who had to show high utilization and meet predetermined production goals. In the post-industrial system, maintenance is done preventively in order to avoid costly and time consuming efforts of bringing a broken machine up to speed.

Improvements in throughput time achieved through setup reduction and cellular manufacturing may also be diluted if downtime increases. Few would dispute that properly maintained equipment is more reliable than equipment that is not maintained on time. Equipment that has not been properly maintained induces stoppages and downtime which have the potential of prolonging throughput time. Unreliable equipment may also increase the need for just-in-case standby equipment. It is also partly responsible for deviations from targeted product specifications. In addition, equipment that is not maintained may also operate at reduced speed and cause process defects. Nakajima (1988) provides a thorough introduction to preventive maintenance.

Preventive maintenance begins with simple housekeeping procedures. For example, if equipment is kept clean, signs of trouble, such as oil leaks can be spotted before seals fail completely. Operators could be trained to perform minor maintenance tasks especially during their idle time. Management could allocate time for preventive maintenance tasks and employees could keep track of maintenance activities (Bockerstette and Shell, 1993; Schonberger, 1986).

Dependable Suppliers

Boundary spanning activities of industrial systems have been guided by cost and efficiency objectives. Function specific performance objectives forced purchasing to adopt a myopic perspective in procuring parts and materials from suppliers. Multiple sources of supply were sought out in an effort to identify the cheapest supplier, usually disregarding its quality and other performance characteristics. To maximize purchasing performance, buyers squeezed suppliers for more and more price reductions and offered little in return. Short-term contracts were the norm and as such, discouraged suppliers from developing capabilities to satisfy specific customer needs. Treated as "outsiders," suppliers often received as little information as possible with the fear that such information would be passed to competitors. In post-industrial systems, suppliers are viewed as an extension of the manufacturing enterpise (Doll and Vonderembse, 1991).

The dependability of suppliers has a potential in reducing throughput time and improving capabilities. The dependability of suppliers may be manifested in many different ways. The supplier could take the responsibility of delivering quality products at the time needed and of the quantity needed. Bad supplier quality has the potential to increase throughput time. If parts delivered are defective then rework has to be done or time has to be wasted until new quality parts arrive. Poor quality in procured materials (Handfield and Pannesi, 1992) can lead to inflated lead times through rework and non-value added time. If materials are also delivered late and no inventory is on hand with the customer, a shut down of the production line is possible. Improved supplier performance can help to reduce downtime and shortages associated with delivery delays

(Chapman and Carter, 1990; Clark, 1989; Im and Lee, 1989; Ansari and Modaress, 1990; Blackburn, 1991). Frequent deliveries in small lots from suppliers allow the customer to keep low levels of inventory and require less space for storage.

Many researchers have dealt with the supplier-customer integration (Ansari and Modaress, 1986; 1988; Giunipero, 1990; Im and Lee, 1989; Lee and Ebrahimpour, 1984; O'Neal, 1987; 1989) and report on the potential benefits of having dependable suppliers. Three common measures of supplier performance found in the purchasing literature are (1) delivery reliability, (2) quality, and (3) part count accuracy (Handfield and Pannesi, 1995; Hahn et al., 1983; Ho and Carter, 1988; Chapman and Carter, 1990).

Shop-Floor Employee Involvement in Problem Solving

Shop-floor employees have not been recognized as a sources of potential improvement drivers in industrial systems. They were merely seen as a necessity to perform certain tasks which machines could not perform as efficiently. In post-industrial manufacturing, work became more intellectual and employees participate in improvement efforts (Zuboff, 1984). Shop-floor employees are recognized as the actors who carry out the work and as such should be in a position to contribute to the improvement of tasks. The motivation and participation literatures support the notion that higher levels of involvement increase the likelihood that they will accept the proposed innovation (Locke and Schweiger, 1979; Johnson and Rice, 1987). Participative decision making has been suggested as an effective implementation tactic (Nutt, 1986; Robey and Farrow, 1982). Such involvement causes users to develop commitment to the innovation (Markus, 1983), to internalize the norms associated with its way, and to influence its shape (Robey and Farrow, 1982).

Employee involvement or participation in problem solving efforts is important in reducing throughput time and enhancing capabilities. Tasks undertaken by employee involvement programs include setup time reduction, better customer service, improvements in quality, and elimination of inventory. Hall (1987, 1993) and Showalter and Mulholland (1992) describe employee participation practices. In fact Hall (1987) suggests that people involvement is one of the three constructs of JIT (the other two are total quality and manufacturing technology). Various programs (i.e., individual and group) have been established to accommodate employee participation.

Pace (1989) points out three general categories of employee participation programs: parallel suggestion involvement, job involvement, and high involvement work system. These range in scope from simple suggestion boxes and involvement teams to joint goal setting and gainsharing. Employees contribute ideas by putting suggestions in a box; they may also be asked to join a formal group effort in solving problems.

Pull Production

Industrial systems produced large lots and pushed them through the system. It was not uncommon to freeze the schedules for several weeks and produce according to "requirements" even if information regarding customer requirements was not updated. The lack of responsiveness of industrial systems can be traced to their long setups, a process oriented layout for the shop-floor, low maintenance efforts, low quality levels, unreliable suppliers, and low shop-floor employee involvement in problem solving. Post-industrial enterprises, enabled by their flexibility, can respond faster to changes in customer requirements. Production is driven by what is needed and when it is needed. In other words, production is pulled or driven by customer demand.

Monden (1981b, 1983), Shingo (1985), and Ohno (1978) describe the pull system as has been applied at Toyota while Schonberger (1986) reports on applications in the U.S. The pull system is a very visible method (usually a card, such as kanban, is used for the transmission of relevant information) for shop floor control. When a work center needs material, a signal is sent to the preceding activity to replenish according to the pull signal (a standard container's worth). By allowing only a small amount of work-in-process inventory to flow at any time, pull systems shorten the time parts stay in the system. In addition, time wasted in queues is avoided due to the reduction in complexity of the system (only a small and fixed number of cards circulates between stations to control production). Batches are small and only large enough to fill a single container. Smaller batches may allow the identification of defects faster.

What is common about the product development and manufacturing practices identified, is that all seem to be antecedents to time. Some in fact may have impact on both product development time, throughput time, and other competitive capabilities.

2.3 PRODUCT DEVELOPMENT TIME AND THROUGHPUT TIME

Perceptions about the value of time have not always been the same. Industrial systems were concerned with task-specific time. On the other hand, post-industrial systems are more interested on the total response time. This research focuses on two components of response time, product development time and throughput time. This was done because this research sets out to investigate only time-based manufacturing and product development practices. The effects of time-based manufacturing practices and time-based product development practices on response time may be diluted by other antecedents, such as the distribution system and/or order processing system and/or inbound logistics network (Blackburn, 1991). Considering the number of other variables investigated in this research, it is not practical to assess other antecedents to response time.

2.3.1 Historical Perspective on Time

The industrial paradigm was characterized by norms which were efficiency based. Frederick Taylor put forth a paradigm that has guided businesses throughout the industrial era environment (Bockerstette and Stoll, 1994). Taylor, considered "the father of scientific management," advocated breaking work down into little parts known as elements and finding the best way or most efficient way of performing each task. His work was extended by other efficiency "gurus" such as Frank Gilbreth and Henry Ford. Frank Gilbreth founded the modern motion study techniques which enabled the elimination of unnecessary motions and simplification of necessary motions to achieve maximum efficiency. Henry Ford saw the need for low cost transportation and developed an efficient and timely system for producing cars. Though his facility had high efficiency, it had no flexibility. The work of these pioneers was continued by industrial engineers who engaged in work simplification and methods engineering in an attempt to increase productivity. The industrial era efficiency experts took a microscope to the work place, broke a job into its parts, and tried to ensure that the human labor in a task was performed at utmost efficiency. The industrial paradigm value orientation was internal, driven towards maximizing task-specific efficiency and reducing costs.

For decades, firms adhered to this paradigm and formed a "mind set" of objectives, processes, and patterns of thinking. The industrial paradigm was probably good for its time. Skinner (1985) contends that this mind set is now dysfunctional. The industrial paradigm leads to a pattern in the evolution of industrial systems that substitutes efficiency for flexibility, leaving firms less able to adapt to market and competitive forces (Utterback and Abernathy, 1975).

It was not until the 1970's that a new, post-industrial, paradigm was put into place and emphasized responsiveness to market changes. Responsiveness was vital as customers demanded a wide variety of quality products to be delivered when needed. Toyota was one of the first firms that appreciated this need and reacted with an array of practices. Setup time reduction efforts, along with the employment of a pull production system, quality improvement efforts, preventive maintenance, employee involvement in problem solving, and supplier support, became what was termed the Toyota Production System. JIT is based on the Toyota Production System and aspires to improve competitive capabilities through accelerated throughput time. Many academics (e.g., Blackburn, 1991; Schmenner, 1988; 1991; Wacker, 1987) argue that reductions in throughput time lead to improved competitive capabilities.

George Stalk and his colleagues at the Boston Consulting Group originated the term Time-Based Competition and viewed it as the application of JIT principles to every part of the product delivery cycle (Abegglen and Stalk, 1985). Time-based competitors focus on the bigger picture, on the entire value delivery system. The goal is not to devise the best way to perform a task, but rather to either eliminate the task altogether or perform it in parallel with other tasks so that the overall system response time is reduced. Becoming a time-based competitor requires making revolutionary changes in the ways that both product development and manufacturing processes are organized and carried out.

2.3.2 Product Development Time

Product development time is defined as the elapsed time from concept generation to market introduction. A similar definition is given by Clark, Chew, and Fujimoto (1992), and Fitzsimmons, Kouvelis, and Mallick (1991). Reductions in product development time can potentially provide a competitive advantage. A recent Wall Street Journal article (1988) has suggested that the competitive edge that short development cycle producers enjoy is dramatic: "Not only can they charge a premium price for their exclusive products but they can also incorporate many-up-to-date technologies in their goods and respond faster to emerging market and changes in taste" (p. 1). Karagozoglu and Brown (1993), and Rosenau (1990), Smith and Reinersten (1991) note that earlier product introduction improves profitability by extending a product's sales life, creating an opportunity to charge a premium price, and allowing development and manufacturing cost advantages.

The rapid development cycle also allows the organization to incorporate new technological advances faster than competitors and thus allows it to reap the benefits of being first in the market. Short cycle times are conducive to becoming responsive to customers' emerging needs. Customer needs may be incorporated in the product faster than competition, and thus customer satisfaction may increase. If product development time is shortened, more products can also be developed within the same interval and thus, product variety can be expanded. In addition, the cost of development may be reduced because less time is spent on each development project.

A study produced by McKinsey & Company Consultants (Dumaine, 1989) showed that a product that is six months late to market will miss out on one third of the potential profit over the product's lifetime. Crawford (1992), however, notes that the McKinsey data were taken out of context, and indeed the report's author warns the reader of the dangers of an overemphasis on speed. Nayak (1990) suggested that a 20% reduction in time to market could increase the net present value of new automobiles by $350 million. Clark and Fujimoto (1991) report that in the highly competitive automobile industry, companies, such as Honda maintain an advantage by virtue of the rate at which they can introduce new technology. They also report that during the 1980's Japanese automakers turned out an automobile development project on average in 50-60 % of the engineering hours required by the Big Three automakers. Clark (1989) indicates that the Japanese on average complete a new product development project about 18 months faster than either their U.S. or Western European competitors. Clark, Chew, and Fujimoto (1988) concluded that for the case of a $10,000 car, each day of delay in introducing a new car model into the market represents, conservatively, $1 million in lost profits. Blackburn (1991) describes how Phillips, a Dutch electronics conglomerate, went from the first to introduce an affordable video cassette recorder in 1972 to one that has no VCRs in the market. By the end of 1970's, Phillips was introducing its second generation of VCRs while the Japanese competitors were retiring their 3rd generation. The majority of the time-based literature see the acceleration of product development cycles as a way to improve customer response time and enhance competitive capabilities.

2.3.3 Throughput Time

Throughput time is defined as the total time a unit spends in the manufacturing system, that is, from receiving raw material until the product is shipped. Schmenner (1988, 1992) provides a similar definition and adds that throughput time includes not only value added time, but it incorporates elements of inefficiency as well.

Wacker (1987) argues that the major manufacturing goals of demand responsiveness, low cost, and high quality can all be closely related to throughput time. He proposes a "throughput time" theory to relate the effectiveness of alternative manufacturing designs and policies to overall manufacturing goals. Wacker suggests that low internal throughput time means that the manufacturing system can respond quicker to changes in demand, thereby achieving a high customer service rate. Also, according to Wacker, low throughput time means less inventory resources are utilized, thereby increasing productivity and lowering costs. Additionally, lower throughput time can only be achieved if quality is relatively high so rework time is relatively small. He concludes that the key linkage between the macro manufacturing goals and their macro operationalization is throughput time.

Schmenner also supports the notion that as time is reduced, competitive capabilities are improved, and he describes how each capability is improved with time reduction. Schmenner (1988) reflects on the importance of throughput time and states that "reducing throughput time is the single most important determinant of improved factory productivity" (p. 11).

Empirical research findings are consistent with the alleged relationships between time and other competitive capabilities. Lieberman, Lau, and Williams (1990), in a longitudinal study of the world automobile industry, observed that those firms that had the fastest throughput time also had the highest labor productivity. Northern Telecom found that after simplifying operations, manufacturing cycle times shrank by 50 % over a four year period while its overhead dropped by 30 % (Merrils, 1989).

Monden (1981a, 1983) has discussed how throughput time is an essential ingredient of the Toyota Production System. Monden (1981a) attributes the following advantages to the shortening of the production lead time: (a) Toyota can achieve job-order oriented production that requires only a short period to deliver a particular car to the customer, (b) the company can adapt very quickly to changes in demand, (c) work-in-process inventory can be significantly decreased, and (d) the amount of "dead" stock on hand is minimal. Schonberger (1986) mentions that several U.S. firms, including Motorola, Westinghouse, and several divisions of Hewlett-Packard and General Electric, have chosen lead time reduction as a dominant measure of how well they are doing. Schonberger further states that lead time drops when problems are solved, and that short lead times are vital to the world class manufacturer.

It is expected that variation in both product development and throughput times would be reflected in other competitive capabilities. Time-based researchers argue that when time is shortened, other competitive capabilities are enhanced.

2.4 COMPETITIVE CAPABILITIES

Building capabilities to compete on multiple and global objectives would seem paradoxical to industrial era executives and academics who more often than not argued that a firm may only compete based on one strategy (e.g., cost or differentiation). Porter (1980) argued, that a firm may only use one strategy at a time and warned against "getting stuck in the middle." This encouraged firms to assume a competitive posture with limited options.

The manufacturing literature has also adopted a similar perspective. Skinner (1969) put in motion a manufacturing strategy agenda that emphasized the importance of trade-offs among strategic objectives. His work was supported until very recently (e.g., Banks and Wheelwright, 1979; Miller, 1983). Increasingly, however, we are witnessing the emergence of manufacturers who do not seem to be trading-off one capability to develop another (Ferdows and De Meyer, 1990; Wheelwright, 1981; Schonberger et al., 1986; Roth, 1987; Shawnee, 1987). Others have also stated that those capabilities are compatible to some degree (e.g., Wacker, 1987; Wheelwright, 1981; Schonberger, 1982; Hellerman and Smith, 1982; Sugimori et al., 1977; Rice and Yoshikawa, 1982; Shingo, 1981). The Japanese have exhibited a capability to pursue multiple strategies and objectives simultaneously (Schie and Goldhar, 1989). Many companies who are engaged in quality programs for example, enjoy higher quality levels and report lower costs (Deming, 1982; Juran, Gryon and Bingham, 1974; Crosby, 1979; Garvin, 1987).

Recent empirical research attests to the fact that firms may compete on multiple dimensions. Roth and Miller (1992) studied success factors in manufacturing from data collected from 180 manufacturing executives. They included relative manufacturing capability measures of the unit's manufacturing strength relative to its primary competitors in quality, delivery, dependability, flexibility, and the ability to compete with low prices. The data showed that for the high performers (leaders) there were no tradeoffs among strategic objectives. The high performers demonstrated superior manufacturing capabilities across the board. Ferdows and De Meyer (1990) used data from 167 respondents to study improvements in manufacturing performance. They found that a large majority (62%) of the firm studied improved in more than one capability.

Although there have been several case studies and a few surveys, there has not been a lot of systematic research in the form of basic instrument development and tests of plausible causal relationships between practices, time, other capabilities, and business performance (such as profitability).

2.4.1 Empirical Research in Competitive Capabilities: A Critical Review.

Relevant measures of manufacturing performance are scarce and little of the performance measurement literature appears in the usual operations management journals (Richardson, Taylor, and Gordon, 1985; Kaplan, 1982; Richardson and Gordon, 1980; and White, 1993). To date, there is very little of competitive capabilities' instrument development in academic journals. The few scales of competitive capabilities that have recently emerged were published primarily in edited books. Much of the research was done without conducting pilot studies, purification of scales, convergent and discriminant validity tests, and without assessing validity through sophisticated methodology. In general, existing scales exhibit relatively low reliabilities and factor loadings. These studies, however, are a rich source of potential items.

2.4.2. Recent Empirical Research in Competitive Capabilities

Nemetz (1990) used 30 respondents in a study of relative firm performance. The respondents were asked to base their ratings on their firm's performance relative to other companies in the industry (prior to that, a pilot study had been conducted with two manufacturing managers). Sixteen items were included and after varimax rotation four meaningful factors have emerged with seemingly low to moderate loadings and with Cronbach's alpha reliabilities between low 0.60s to low 0.80s. The factors were interpreted as quality, product flexibility, dependability, and cost. Nemetz suggested that more work should be done in the area of measuring quality.

Roth and Miller (1990) used their data from the 1988 Manufacturing Futures

Project (Miller and Roth, 1988b) to gather information on competitive factors pertinent to leading manufacturing business units. The specific data used for this study pertains to the responses of 193 executives from large U.S. manufacturing firms. The eleven items used were captured under five strength dimensions and included quality (alpha=0.70), delivery (alpha=0.77), flexibility (alpha=0.53), prices (1 item), and market scope (0.74). Factor loadings varied from a low of 0.52 for the flexibility factor to 0.88 for the delivery factor.

In Wood, Ritzman, and Sharma (1990) empirical research, 144 respondents have participated from different manufacturing plants in the Midwest and the Northeast. One portion of the questionnaire asked about how the respondents perceived various aspects of their own manufacturing performance compared to their major competitors (Wood, Ritzman, and Sharma, 1989). Measured variables included cost, quality, delivery time, and flexibility performance. The researchers also measured the importance attached to these variables by each respondent. Factor analysis with promax rotations was used and loadings varied from 0.30 to 1.05. The rest of the loadings varied widely between the high and low. No reliabilities were reported.

Richardson, Taylor, and Gordon (1985) used data from 15 manufacturing firms to rank the importance of specific measures for different manufacturing strategies (Gordon and Richardson, 1980). They included such factors as product research, development and design, after sales service, process, product quality, delivery on schedule, rapid delivery, cost minimization, quality assurance, volume flexibility, flexibility to customer specification changes, and ability to produce new products.

Schroeder, Anderson, and Cleveland (1986) report on a study of manufacturing strategy in 39 companies based on questionnaire responses received from manufacturing managers. Manufacturing objectives included quality, delivery performance, unit cost, volume flexibility, product mix flexibility, employee rewards, inventory turnover and equipment utilization.

Swamidass and Newell (1987) presented a method of assessing the manufacturing strategy of businesses. In assessing manufacturing strategy, the researchers have used responses from 35 manufacturing firms. Manufacturing criteria included improving and maintaining quality, maintaining or lowering manufacturing costs, keeping delivery promises, flexibility for volume and product changeover, and new product introduction.

Ferdows, Miller, Nakane, and Vollman (1989) include low prices, rapid design changes, consistent quality, high performance products, dependable deliveries, rapid volume changes, fast deliveries, and after-sales service as part of their competitive priorities in their Global Manufacturing Futures Survey.

Apparently, the empirical research is pretty consistent on the choice of important competitive capabilities. Chase, Kumar, and Youngdahl (1992) suggest, however, that the traditional measures of performance must not be focused narrowly only on internal customers but on external customers as well. Seven competitive capabilities pursued by time-based manufacturers are shown on Table 3 along with definitions.

2.4.3 Identification of Competitive Capabilities and Theory Development

In a composite review of the competitive priorities and capabilities literature, Ward, Leong, and Snyder (1990) identified similar measures of performance as described by several researchers (e.g., Skinner, 1969; 1978; 1985; Wheelwright, 1978; 1981; 1984; Buffa, 1984; Hayes and Wheelwright, 1984; Fine and Hax, 1985; Hayes, 1985; Van Dierdonik and Miller, 1980; Hayes et al., 1988). White (1993) also surveyed the literature of performance measures for manufacturing and observed similar dimensions. Others have also identified comparable measures (Fitzsimmons, Kouvelis, and Mallick, 1991; Lockamy, and Cox, 1995; Schonberger, 1982; 1986; Ohmare, 1983; Kaplan, 1983; Goldrarr and Fox, 1986; Cox, 1989; Maskell, 1991; Lockamy and Cox, 1994). These measures include the following five dimensions: cost, quality, delivery performance-dependability and speed, flexibility-product mix and volume, and innovativeness. The time-based competition literature reports on additional measures, such as premium pricing.

Cost

Historically cost has been the primary measure of performance for industrial systems. Most measures have been objective while recently a few researchers (e.g., Cleveland et al., 1989; and Nemetz, 1990) used subjective cost measures. White (1993) notes that measures of productivity and efficiency have been included under this category because, in essence, they focus on cost.

Cost, which has been the dominant traditional measure of success, is by most accounts not considered to be a customer oriented measure of performance. However, it is a determinant factor of the ability of the organization to profit. In addition to cost, another closely related measure of competitive capabilities is pricing.

Competitive pricing

The new paradigm of competition gives the firm pricing flexibility as well. A firm may command a premium price or use competitive prices as it sees fit. Its capability to develop, manufacture, and deliver products fast, and with features and quality that satisfy customers enables the firm to command premium prices. Because costs for firms that can command premium prices are not inherently higher, a firm may also be able to compete based on prices (Giffi, Roth, and Seal, 1990).

Competitive pricing reflects the ability of the organization to compete against its major competitors based on low price (Wood, Ritzman, and Sharma, 1990; Miller, De Meyer, and Nakane, 1992). Giffi et al. (1990) and Miller et al. (1992) have provided some measures of competitive pricing.

Competitive pricing essentially manifests the ability of the organization to withstand competitive pressure. Price positioning is limited, however, by production cost. Time-based practices enable the firm to reduce its time and costs and thus improve its capability to compete on prices.

Premium Pricing

The unorthodox measure of premium pricing is used by some time-based competitors. Time-based competition researchers (e.g., Stalk, 1988; Stalk and Hout, 1990; Blackburn, 1991; Karagozoglu and Brown, 1993; Rosenau, 1990; Smith and Reinerster, 1991) suggest that those firms that have a short customer delivery cycle can charge premium prices. Also, a better and more innovative product design and superior product

Table 3: List of Competitive Capabilities and Definitions

Competitive Capability	Definition	Literature
1. Cost	It is the extent to which the manufacturing enterprise is capable of producing at a low cost or high efficiency.	Ferdows & De Meyer(1990); Ward Leong & Snyder(1990); Skinner (1969,1978,1985); Fine & Hax (1985); White(1993); Nemetz(1990); Cleveland et al (1989); Wood, Ritzman & Sharma(1990).
2. Competitive Pricing	It is the extent to which a firm is capable of competing in prices.	Roth & Miller(1990,1992); Miller & Roth(1998b); Maskell (1991).
3. Premium Pricing	It is the extent to which the firm can sell at premium prices.	Blackburn(1991); Stalk & Hout(1990); Gupta & Wilemon (1990).
4. Value to Customer Quality	It is the extent to which the manufacturing enterprise is capable of offering product quality and performance that would create high value to customer(s).	Garvin(1984); Maskell(1991); Roth & Miller(1988b,1990); Wood et al (1990); Nemetz(1990); White (1993).
5. Product-Mix Flexibility	It is the extent to which the manufacturing enterprise can meet the diverse needs of customers for current products.	Swamidass(1988); Maskell(1991); Roth & Miller(1988b,1990); Wood et al (1990); Nemetz(1990); White (1993).
6. Product Innovation	It is the extent to which the manufacturing enterprise is capable of introducing new products and features in the market place.	Maskell(1991); Roth & Miller(1988b,1990); Wood et al (1990); Nemetz(1990); White (1993).
7. Customer Service	It is the extent to which the manufacturing enterprise is capable of meeting customer service requirements.	Ferdows et al (1989); Maskell(1991); Roth & Miller(1988b,1990); Wood et al (1990); Nemetz(1990); White (1993).

performance give the opportunity to a firm to achieve premium prices in the market.

Value to Customer Quality

When firms emphasized quality in the industrial system, usually what they meant was internal quality, conformance to specifications. Post-industrial enterprises emphasize a variety of quality aspects both internal and external, or customer oriented (Doll and Vonderembse, 1991). Value to customer quality gauges the capability of the firm to produce products that would satisfy customer needs for quality and performance (Hall, Joghnson, and Turney, 1991; Doll and Vonderembse, 1991).

Garvin (1984) has proposed eight dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Miller et al. (1992) used conformance, performance, and reliability as measures of quality. Giffi et al. (1990), on the other hand, used the same dimensions suggested by Garvin. The list provided by Garvin is quite comprehensive while observed measures for each are difficult to establish. He includes (a) performance, (b) reliability (c) conformance, (d) durability, (e) aesthetics, (f) features, (g) serviceability, and (h) perceived quality. Garvin (1984) describes these aspects in detail.

Product-Mix Flexibility

Swamidass (1988) has identified twenty different terms associated with manufacturing flexibility, but most authors refer to product mix and production volume flexibility as the two dominant dimensions. Maskell (1991) and Hall et al. (1991) state that there are two aspects of flexibility that are important: (1) production flexibility and (2) design flexibility. Production flexibility is achieved when the company can offer short lead times and when the product mix within the plant can be changed significantly from day to day (Giffi et al., 1990; Miller et al., 1992). Production mix flexibility is becoming increasingly important to a company attempting to match production to the customer's needs. Traditionally, the variable nature of customer demand has been accommodated by holding large inventories of finished goods and making to stock. A world class manufacturer strives to eliminate inventory and to provide an excellent level of customer service through flexibility of production.

Design flexibility is related to the company's ability to introduce new products and modifications to current products (Maskell, 1991). A company must be able to understand the current and future needs of customers, develop innovative products and get those products to the market place quickly. In essence, this definition reflects the innovative dimension of competitive capabilities and is discussed in more detail next.

Product Innovation

Product innovation refers to the capability of the organization to introduce new products and new features as needed by customers. Innovation in industrial systems was slow and came about infrequently. The reduction of product life cycles is a reality, however, and must be faced in a wide range of industries. The fast pace of technology and the demands of the customers for novel and better products requires that companies be able to innovate continually and bring these innovations to the market place quickly

(Blackburn, 1991). Already the automobile companies have realized that they do not have the luxury of seven or eight years to design and introduce a new style of a vehicle.

Post industrial enterprises facing fierce competition and shorter product life cycles innovate frequently and in small increments (Clark and Fujimoto, 1991). The continuing efforts in innovation foster organizational learning and enable "time to market" to be shortened even further. Due to the frequent innovation process, products closely match current customer demands and expectations and can adopt technological advancements as they become available. A reduction in product development time facilitates more frequent product innovations. Porter (1990), Sweeney (1991), and Bolwijn and Kampe (1990) point that innovation is becoming an increasingly important competitive strategy and priority.

White (1993) suggests that the measurement of innovativeness has not received much attention. Maskell (1991) suggests that there are two basic ways of measuring new product introductions: (1) measuring the speed of introduction and (2) measuring the number of new products on a time period. The speed of introduction or "time to market" is a measure of the company's effectiveness at converting ideas into products. This process can be measured by keeping track of when a project was initiated and when it was completed. Another method of measuring new product introduction that is useful in some industries is to measure the number of new products (or enhancements) introduced.

Customer Service

In anticipation of customer demands for on-time deliveries, but knowing their lack of flexibility, industrial firms kept large inventories. On time deliveries are now achieved by having a responsive manufacturing system that has the capability to produce small lot sizes without paying a heavy penalty for setups.

White (1993) suggests that there is little disagreement over measures of delivery reliability. Many companies, in fact, have been tracking their delivery performance. In terms of delivery much of the discussion has centered on the quantity being dispatched, but the timing of delivery is equally important (Maskell, 1991). Roth and Miller (1990) and Miller et al. (1992) conceptualized delivery using two measures: dependable delivery promises and fast deliveries. Hall et al. (1991) define dependability as consistently performing at the time scheduled or promised. Customer service manifests the ability of the organization to have accurate and reliable deliveries and provide other services to customers such as after-sales service (Blackburn, 1991).

It is expected that companies that score high in these competitive capabilities will improve their organizational performance. Firms that are customer driven will respond fast to customer emerging needs with quality products that exceed customer expectations and with innovative designs that delight the customers. They also incorporate technology as it becomes available and provide prompt after-sales service. These firms allegedly build loyalty, increase their market share, and ultimately enjoy high profits.

2.5 THEORETICAL MODEL AND HYPOTHESES

This research focuses on the relationships between time-based product development practices, time-based manufacturing practices, time, and other competitive capabilities.

The hypothesized relationships and their directions are depicted in Figure 2. From right to left, this model suggests that time is a predictor of competitive capabilities. It further shows that time-based practices are both antecedent to time and competitive capabilities. The systemic framework or nomological network of constructs presented here tries to use the alleged time-based theories to inspire confidence in their probable truth. Analyzing the relationships in a nomological network of constructs allows one to assess the construct validity of a measure by relating it to a number of other constructs (Churchill, 1979). For this research the relationships will be tested at an aggregate level; the scores of all product development practices, manufacturing practices, and competitive capabilities will be added into their respective categories and used in hypotheses testing.

Hypothesis 1: Product development time has a significant negative relationship with competitive capabilities.

Competitive capabilities are hypothesized to be affected by many variables, including product development time. When product development time is reduced the competitive capabilities of the firm are thought to improve. For example, if the product development cycle is shortened, more products and features can be developed within a time frame. Faster product development enables a firm to introduce its product line early in the market when it is possible to command premium prices. Because product development time is shorter, the process can be repeated with greater frequency, and this fosters organizational learning and a decrease in costs.

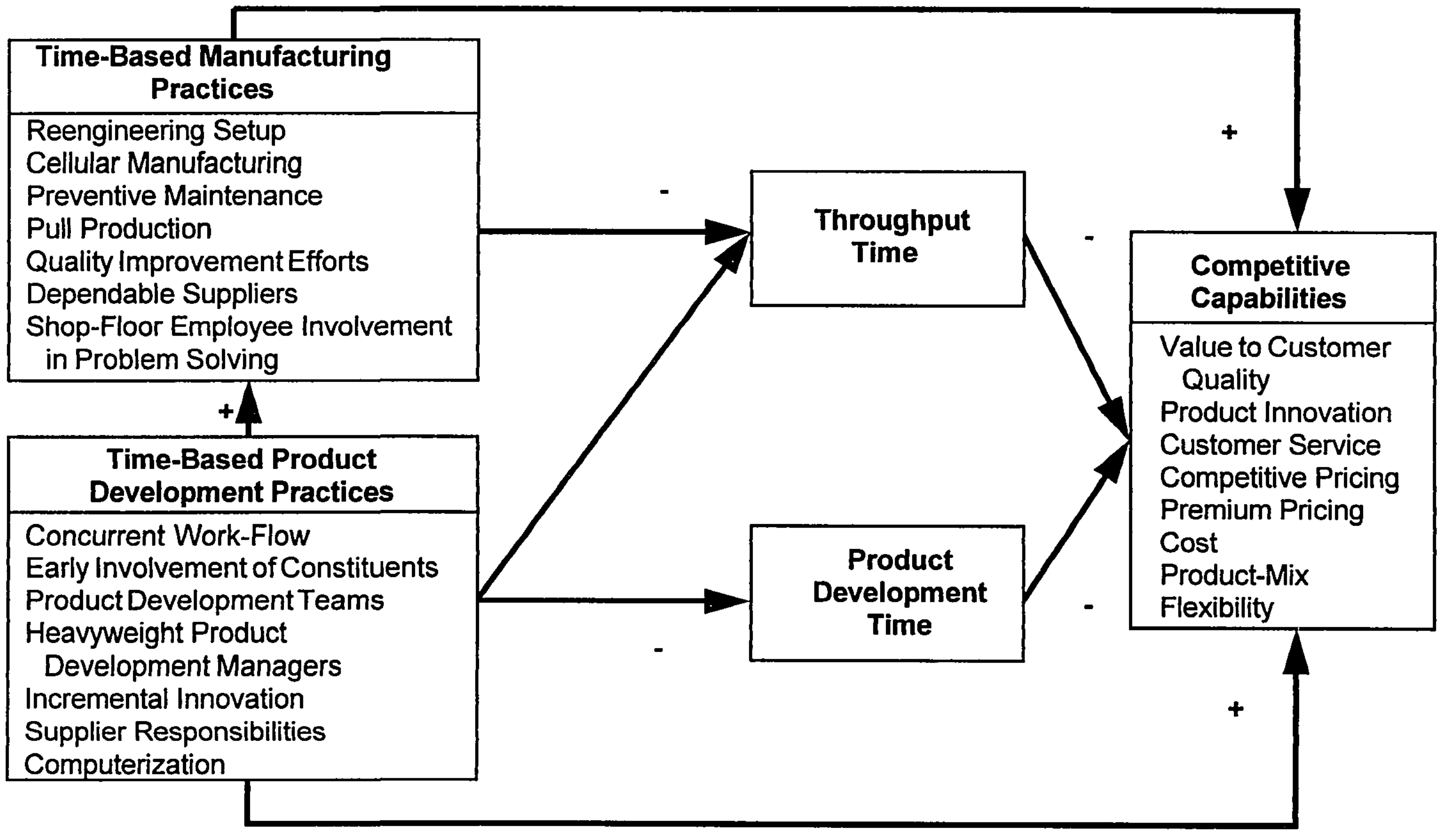


Figure 2:Time-Based Competition Detailed Model

Hypothesis 2: Throughput time has a significant negative relationship with competitive capabilities.

A reduction in throughput time is expected to improve competitive capabilities. When throughput time is reduced more accurate deliveries can be made and customer delivery service improves. In addition direct and indirect costs are reduced as less time is spent on each unit. Inventory investments are also reduced as time spent in inventories is reduced when throughput time is lessened. Firms that have shorter lead times can claim premium prices for their efforts.

Hypothesis 3: Time-based manufacturing practices have a significant negative relationship with throughput time.

Time-based manufacturing practices are hypothesized to be antecedents to throughput time. These manufacturing practices are aimed at reducing the time products spend on the shop-floor from raw materials inventory to leaving the finished goods inventory. For example, cellular manufacturing is used to reduce setup time because only similar parts or products are produced within each cell. Preventive maintenance programs reduce throughput time because they reduce downtime and reduce scrap and rework. It is expected that the higher the level of time-based manufacturing practices the lower the throughput time.

Hypothesis 4: Time-based product development practices have a significant negative relationship with throughput time.

Product development practices are hypothesized to affect throughput time. The involvement of manufacturing personnel in product development decisions and the way products and processes are designed should have an impact on throughput time. The more firms engage in the proposed product development practices, the more manufacturable the products and the fewer operations that may have to be performed, thus reducing throughput time. The effects of product development practices on throughput time may also be indirect through the effects of time-based manufacturing practices on throughput time.

Hypothesis 5: Time-based product development practices have a significant negative with product development time.

Product development practices are hypothesized to be antecedent to product development time as well. It is expected that the proposed product development practices accelerate development time through five approaches (Millson, Raj, and Wilemon, 1992): (1) simplifying, (2) eliminating delays, (3) eliminating steps, (4) speeding up operations, and (5) implementing parallel processing. The more firms engage in the proposed product development practices the lower their product development time.

Hypothesis 6: Time-based manufacturing practices have a significant positive relationship with competitive capabilities.

It is also posited that time-based manufacturing practices have an impact on competitive capabilities. Quality improvement practices at the shop-floor have an effect on value to customer quality because they can reduce defects. These quality practices are also responsible at the same time in reducing costs as the amount of rework and scrap is reduced. Because time-based manufacturing practices affect throughput time, it is expected that these practices would have an indirect effect on competitive capabilities as well.

Hypothesis 7: Time-based product development practices have a significant positive relationship with competitive capabilities.

Product development practices are hypothesized to be related to competitive capabilities. Value to customer quality, for example, depends on design considerations taken during product development. The more a firm is involved in the proposed practices, the higher the level of its competitive capabilities. Time-based product development practices are also likely to increase the ability of the firm to introduce new products and features because these practices accelerate product development cycles. Thus, these product development practices are expected to affect competitive capabilities indirectly. Because time-based product development practices are thought to influence throughput time as well, another path to competitive capabilities can be formed; from time-based product developing practices to throughput time to competitive capabilities.

Hypothesis 8: Time-based Product development practices have a significant positive relationship with time-based manufacturing practices.

It is posited that the use of time-based product development practices will have an effect on the choice and level of use of time-based manufacturing practices. For example, it is expected that when firms use a platform product strategy, more cellular activities will take place because cells are conducive for products that have similar design or processing characteristics. The early involvement of manufacturing personnel in product development and their participation in cross-functional teams allows them to understand the needs for product development and react appropriately. Manufacturing may align its practices to support the jointly agreed upon strategies for product development.

Assessing relationships between variables usually has two steps; variable measurement and testing. Prior to testing a research question, valid and reliable measures of the relevant constructs have to be developed.

CHAPTER 3:INTRUMENT DEVELOPMENT PHASE I: ITEM GENERATION AND PILOT STUDY

The development of valid and reliable instruments which can be accepted as standardized instruments by scholars in manufacturing poses unique challenges and opportunities. Standardized instruments can improve theory development, enhance additivity of manufacturing research, and make the testing of substantive hypotheses easier. Thus, standardized instruments can be the cause rather than the consequence of progress in empirical research in manufacturing management. In fields with an emerging research tradition, instruments are often developed as a by-product of attempts to test substantive hypotheses of interest to the researcher. Often these substantive studies lack the rigor in instrument development methods to merit being accepted as standardized instruments. This dissertation focuses on developing standardized instruments for time-based product development and manufacturing practices, and competitive capabilities.

Particular attention was paid in developing the competitive capabilities instrument (i.e., the dependent variable) for several reasons. First, a valid and reliable dependent variable renders itself useful in testing relationships with numerous antecedents. Second, if the dependent variable is not reliable or valid, results from testing substantive hypotheses may be difficult to interpret, especially when relationships are not found to be significant. A researcher may not be able to assert whether the lack of significance is due to the absence of real relationships or due to the poor and/or invalid measure of the dependent variable.

3.1 METHODS FOR ITEM GENERATION

The process that will be used in this study to develop measures is based on generally accepted psychometric principles. Essentially, instrument development and measurement involves a discussion of validity and reliability issues. The unit of analysis is the organization since all items pertain to the practices for the dominant product line of a firm.

A measure has content validity if there is general agreement among the subjects and researchers that the instrument has measurement items that cover all important aspects of the variable being measured. Thus, content validity depends on how well the researchers create measurement items to cover the content domain of the variable being measured (Nunnally, 1967).

A few recent empirical studies have proved to be useful in making sure that the domain of variables is adequately covered by items. Using prescriptions found in the literature, several representative measurement items for each variable were developed. To verify that the items are relevant ten practitioners from several industries from the Midwest region of the U.S. commented on the comprehensiveness and readability of the instruments. The respondents were asked whether (1) the right questions were asked, (2) these questions are easy to understand, and (3) any other questions should be included in each scale.

To generate items for competitive capabilities, previous research in competitive capabilities was reviewed (e.g., Nemetz, 1990; Roth and Miller, 1990; Wood, Ritzman and Sharma, 1990; White, 1993; Maskell, 1991; Garvin, 1984; Ward, Leong, and Snyder, 1990; Ferdows and De Meyer, 1990; Roth and Miller, 1992). This literature is a rich source of illustrations, examples, and items for competitive capabilities. Definitions for each capability were developed and then identified and created items for each of them. Definitions were presented earlier in Table 3. Based on definitions and the literature review, 69 items were generated to measure the different aspects of competitive capabilities. A seven-point Likert type scale was used in reference to the capabilities of the firm compared to the average in the industry where 1=Much Below, 2= Moderately below, 3=Slightly below, 4=About average, 5=Slightly above, 6=Moderately above, and 7=Much above. Items were grouped into seven scales. After ten interviews with practitioners, items were modified and a few items were added. In its new form the instrument contained 50 items in seven categories.

To generate items for time-based manufacturing practices, previous research in the form of prescriptions, case studies and other empirical research in time-based manufacturing practices was reviewed (e.g., Stalk and Hout, 1990; Blackburn, 1991; Sakakibara et al., 1993; Flynn et al., 1994; Saraph et al., 1989). This literature is a rich source of illustrations or examples of manufacturing practices and how they improved the capabilities of the firms that use them. Some also provide scales measuring similar constructs as those proposed in this research. Where appropriate, items or parts of them were drawn from previous research. Other items were created to enhance each scale's performance characteristics. Definitions for variables were shown earlier on Table 2.

Based on the definitions and literature review, 77 items were generated to measure the different aspects of time-based manufacturing practices. A five-point Likert type scale was used where 1=Not at all, 2= a little, 3=moderately, 4=much, and 5=a great deal. Items were grouped into seven scales. After the interviews with 10 practitioners, items were deleted, or modified and a few items were added to form a revised instrument which contained 52 items in seven categories.

Items for time-based product development practices were generated by reviewing the relevant product development literature (e.g., Stalk and Hout, 1990; Blackburn, 1991; Clark and Fujimoto, 1991; Clark, Chew, and Fujimoto, 1988; 1992; Imai et al., 1985; De Meyer, 1992; McKee, 1992; Millson et al., 1992; Donnelon, 1993; Susman and Dean, 1992; Cooper and Kleinschmidt, 1987; 1994; Clark, 1989; Rosenthal and Tatikonda, 1992; Cordero, 1991; Dumaine, 1989; 1991; Karagozoglu and Brown, 1993; Montaya and Calantone, 1994). This literature provides examples and illustrations of product development practices. They also provide evidence of how these practices improved the competitive capabilities of the firms that use them. Definitions were developed before item generation and appeared on Table 1 earlier. Based on this review and definitions, 43 items were generated to measure the different aspects of time-based product development practices. A five-point Likert type scale was used where 1=Not at all, 2= a little, 3=moderately, 4=much, and 5=a great deal. Items were grouped into seven scales. After interviews with practitioners, items were modified and a few items were added. In its new form the instrument contained 47 items in seven categories.

To render further support for content validity, the items for all instruments were reviewed in a formal pretest study by 14 experts (nine faculty from Business and Engineering Colleges and five practitioners located in the Midwest region of the U.S.). The experts had the opportunity to keep items, modify items, and drop items. Where the experts felt that the items did not cover the intended domain, they provided suggestions or augmented the instruments with additional items. Some space was left under each of the scales measured for experts to identify and indicate any aspects of a scale not measured or to comment about the scale.

In order to drop an item from the scales a content validity coefficient was computed for each item. The formula reported in Gatewood and Feild (1994) is:

$$r = \frac{(n_e - N/2)}{(N/2)}$$

where,

n_e is the number of judges (experts) indicating that the item is essential (i.e., should not be dropped) and N is the total number of judges.

This ratio was calculated for each item in order to decide whether the item should remain in the scale or be dropped. It was decided that an r of at least 0.70 and above would be acceptable. That would mean that to drop an item 3 or more judges out of 14 had to indicate to drop it. An r with n_e=12 is equal to 0.714 where for n_e=11, r is equal to 0.57. Only 13 judges chose to respond to the questions whether each category was inclusive. Where judges have indicated that the category is not inclusive, more items were added.

Based on the expert evaluation, five items from the competitive capabilities instrument were dropped because they did not receive enough votes for their inclusion.

Twelve other items were modified. Two of the original items were also dropped by the researcher because they were repetitive. The instrument was augmented with seven more items based on expert suggestions. After the expert evaluation 50 items were proposed in total. The number of items per scale ranged from four for product-mix flexibility to fourteen for value to customer quality.

For the time-based manufacturing instrument, the experts suggested that only one item was not essential. Fourteen items however were modified and seventeen others were added when the experts indicated that the domain of the respective variables was not adequately covered. Two additional items were dropped by the researcher because they were repetitive and their content was captured by other items. The total number of items after the expert evaluation was 66 ranging from six for preventive maintenance and shop-floor employee involvement in problem solving to fourteen for quality improvement efforts.

Based on the expert evaluation of the time-based product development instrument, ten items were dropped and fourteen items were modified. Where judges have indicated that a category was not inclusive more items were added. In fact, fourteen items were added in total. One item was dropped from the computerization scale as its content was captured by other items. The total number of items after the expert evaluation was fifty ranging from five for incremental product innovation to eleven for product development teams.

3.2 METHODS FOR PILOT STUDY

An evaluation of the instruments before the large scale administration is helpful in several ways. First, it provides a final opportunity to remove "bugs" from the scales. Second, it provides a vehicle for assessing the preliminary reliability and validity of the scales. We should note however that such assessments are to be made in light of the fact that a small sample will be at hand. Responses from 32 discrete manufacturing firms were used to explore the proposed scales with several objectives in mind: purification, unidimensionality, reliability, brevity, convergent and discriminant validity, as well as predictive validity. First, the researchers wanted to purify the items before doing factor analysis (i.e., eliminate garbage items). The need to purify the items that are suggested as measures of a construct is described by Churchill (1979). He contends that when factor analysis is done before purification, there seems to be a tendency for factor analysis to produce many more dimensions than can be conceptually identified, confounding the interpretation of the factor analysis. Items were eliminated if their corrected-item total correlation (each item's correlation with the sum of the other items in its category) was less than or equal to 0.50. The domain sampling model is that all items, if they belong to the domain of the concept, have an equal amount of common core. If all the items in a measure are drawn from the domain of a single construct, responses to those items should be highly intercorrelated. The corrected-item total correlation provides a measure of this (Churchill, 1979).

After purifying the items, an exploratory factor analysis of the remaining items in each category was conducted to assess the unidemensionality of the retained items and, where appropriate, eliminate items that were not factorially pure (Weiss, 1970). The items in each category were assumed to be measures of the same construct. If a factor analysis reveals more than one factor, a researcher has to determine whether to eliminate the additional factors or conclude that the construct is more complex than originally anticipated. Items that were not factorially pure (loading on more than one factor at 0.40 or above) were considered as candidates for elimination.

Once dimensionality was determined, the reliability (internal consistency) of the remaining items comprising each dimension was examined using Cronbach's alpha. Items were eliminated if the reliability of the remaining items was at least 0.80 and the content of the scale was not significantly altered. Next convergent and discriminant validity was assessed via Campbell and Fiske's (1959) multi-trait multi-method matrix. The multi-trait multi-method (MTMM) approach to convergent validity tests that the correlations between measures of the same theoretical construct are different from zero and large enough to warrant further investigation. Using the MTMM approach, discriminant validity is tested for each item by counting the number of times it correlates more highly with an item of another variable (factor) than with items of its own theoretical variable. Campbell and Fiske (1959) suggest determining whether this count is higher than one-half the potential comparisons. However, in this case common method variances are present so it is unclear how large a count would be acceptable.

Finally, to assess predictive validity, the product development practices and manufacturing practices scales were correlated with a composite measure of competitive capabilitics and estimates of product development and throughput times respectively. To assess the construct validity of competitive capabilties, correlations between competitive capabilities and time were computed.

Before moving to the administration of the instrument to a large sample, the instruments were evaluated in scope of the results from the pilot study. Where appropriate, some scales were reconceptualized, scales and items were added, and items were modified. All items are coded with a three digit prefix for identification purposes. For example, all competitive pricing items have a prefix of CP followed by a successive number designator. These codes are shown later at the end of purification tables.

To assess product development time and throughput time, two methods of estimating time were developed. This allows an estimation of the reliability of the reported time through computations of correlation. Product development time was conceptualized here as the elapsed time from concept generation to market introduction. Similar approaches and definitions were provided by Clark, Chew, and Fujimoto (1992), and Fitzsimmons, Kouvelis, and Mallick (1991). The first method used asked the respondents to indicate the elapsed time in months from concept generation to market introduction for what is typical in their dominant product line. The second method asked the respondents to indicate on a Gantt chart the elapsed time for each phase of product development. Phases included concept generation, product design, prototype development and testing, process development, production ramp-up, and market introduction. Similar phases are discussed widely in the literature. The use of a Gantt chart enables the observation of concurrent activities. Both methods of assessing product development time were used in interviews with 10 practitioners from various industries. The practitioners responded to the questions and provided comments.

Throughput time was conceptualized here as the total time a unit spends in the manufacturing system, from receival of raw materials until the product is shipped. Schmenner (1988) also provides a similar definition that reflects this conceptualization of throughput time. Two measures of throughput time were also developed for estimation purposes. First, a schematic drawing was used tracing the path from raw materials inventory to finished goods inventory, asking the respondents to indicate how much time typical products of the dominant product line spend at each stage. Stages included (1) days of raw materials inventory, (2) value added time, (3) days of work-in-process (WIP) inventory, and (4) days in finished goods inventory. Using the second method, an overall item was developed which asked the respondents to indicate the typical elapsed time from receiving raw material from suppliers until the product leaves the premises of the firm, again in regards to typical products of the dominant product line. These questions were first posed to 10 practitioners who answered them and commented on the readability of the questions and on the capacity of various constituents in organizations that would be able to respond to these questions.

3.3 RESULTS FOR PILOT STUDY

3.3.1 Competitive Capabilities Instrument

The analysis began with purification using the corrected-item total correlation (CITC) analysis. The CITCs for each item are shown on Table 4. In assessing the CITC, the cost scale seemed to be particularly troublesome. The cost scale had only two items

Table 4: Purification for Competitive Capabilities (Pilot).

ITEMS	Corrected-Item Total Correlation
CP1.Our capability of offering prices comparable to competitors is	.61
CP2.Our capability of offering competitive prices is	.76
CP3.Our capability of offering prices as low or lower than competitors' prices is	.83
CP4.Our capability of offering prices that are competitive is	.91
CP5.Our capability of competing based on prices is	.79
CP6.Our capability of offering prices that match competition is	.83
PR1.Our capability of commanding premium prices is	.86
PR2.Our capability of selling at price premiums is	.95
PR3.Our capability of selling at premium prices is	.83
PR4.Our capability of selling at prices above average is	.85
PR5.Our capability of selling at high prices that only a few firms can achieve is	.81
QP1.Our capability of offering products that function according to customer needs over a reasonable lifetime is	.70
QP2.Our capability of offering a high value product to the customers is	.70
QP3.Our capability of offering products that satisfy the customer's intended application is	.75
QP4.Our capability of offering safe-to-use products that meet customer needs is	.77
QP5.Our capability of offering a competitive lifetime cost, i.e., initial purchase cost plus up-keeping (maintenance) cost, to the customers is	.68
QP6.Our capability of offering reliable products that meet customer needs is	.84
QP7.Our capability of offering durable products that meet customer needs is	.83
QP8.Our capability of offering products that are aesthetically appealing to customers is	.52
QP9.Our capability of offering products whose attributes match customers' needs is	.78
QP10.Our capability of offering easy-to-use products that meet customer needs is	.62
QP11.Our capability of offering products whose quality is so extraordinary that it delights the customer is	.56
QP12.Our capability of offering products whose appearance meets prescribed customer requirements is	.62
QP13.Our capability of offering quality products that meet customer expectations is	.84
QP14.Our capability of offering high performance products that meet customer needs is	.91
CS1.Our capability of producing at a low direct labor cost is	.56
CS2.Our capability of producing at a low overhead cost is*	**.33**
CS3.Our capability of producing at a low material cost is	**.38**
CS4.Our capability of having high equipment efficiency is	**.31**
CS5.Our capability of eliminating any unnecessary space usage is	.58
CS6.Our capability of producing at a low average cost is	**.21**

***Note:** Items in bold have CITC below 0.50.

Table 4 (Continued): Purification for Competitive Capabilities (Pilot).

ITEMS	Corrected-Item Total Correlation
CV1.Our capability of resolving customer complaints promptly is	.73
CV2.Our capability of providing dependable deliveries is	.83
CV3.Our capability of providing customer service is	.63
CV4.Our capability of providing fast deliveries when requested by a customer is	.73
CV5.Our capability of providing a prompt confirmation of customer orders is	.52
CV6.Our capability of providing on-time deliveries is	.80
CV7.Our capability of delivering the kind of products needed on time	.86
CV8.Our capability of delivering the correct quantity of products needed on time is	.78
PI1.Our capability of developing customized products is	.66
PI2.Our capability of developing unique features is	.74
PI3.Our capability of developing new products and features is	.79
PI4.Our capability of developing products that incorporate the newest technology is	**.45**
PI5.Our capability of developing a number of "new" features is	.76
PI6.Our capability of developing a number of "new" products is	.86
PI7.Our capability of developing a broad product variety is	.58
PF1.Our capability of producing a mix of products to meet customer demands fast is	.66
PF2.Our capability of making quick product mix changes to meet customer demands is	.68
PF3.Our capability of producing the product mix demanded by customers on	.60
PF4.Our capability of making rapidly a mix of products to meet customer demand is	.86

Legend: CP=Competitive Pricing, PR=Premium Pricing, QP=Value to Customer Quality, CS=Cost, CV=Customer Service, PI=Product Innovation, and PF=Product-Mix-Flexibility.

out of six with CITCs greater than 0.50. It is possible that the items are measuring significantly different aspects of cost. Some of the items referred to different costs (e.g., overhead, direct labor) where other items referred to efficiency and waste. The best two items were retained for further evaluation. Only one other item (PI4) from the other six scales had a CITC below 0.50 and was eliminated. All the items with corrected-item total correlations below 0.50 appear in bold on Table 4.

The factor analyses of the retained items in each of the scales are reported in Table

Table 5: Factor Loadings (within each variable) for Retained Competitive Capabilities items (Pilot).

ITEMS RETAINED AFTER CORRECTED-ITEM TOTAL CORRELATION ASSESSMENT	FACTOR1	FACTOR2
CP1.Our capability of offering prices comparable to competitors is	.71	
CP2.Our capability of offering competitive prices is	.83	
CP3.Our capability of offering prices as low or lower than competitors' prices is	.89	
CP4.Our capability of offering prices that are competitive is	.95	
CP5.Our capability of competing based on prices is	.86	
CP6.Our capability of offering prices that match competition is	.90	
PR1.Our capability of commanding premium prices is	.97	
PR2.Our capability of selling at price premiums is	.92	
PR3.Our capability of selling at premium prices is	.90	
PR4.Our capability of selling at prices above average is	.90	
PR5.Our capability of selling at high prices that only a few firms can achieve is	.88	
QP1.Our capability of offering products that function according to customer needs over a reasonable lifetime is	.84	
QP2.Our capability of offering a high value product to the customers is	.80	
QP3.Our capability of offering products that satisfy the customer's intended application is	.88	
QP4.Our capability of offering safe-to-use products that meet customer needs is	.87	
QP5.Our capability of offering a competitive lifetime cost, i.e., initial purchase cost plus up-keeping cost, to the customers is	.62	.38
QP6.Our capability of offering reliable products that meet customer needs is	.87	.30
QP7.Our capability of offering durable products that meet customer needs is	.77	.41
QP8.Our capability of offering products that are aesthetically appealing to customers is		.82
QP9.Our capability of offering products whose attributes match customers' needs is	.53	.66
QP10.Our capability of offering easy-to-use products that meet customer needs is	.33	.67
QP11.Our capability of offering products whose quality is so extraordinary that it delights the customer is		.89
QP12.Our capability of offering products whose appearance meets prescribed customer requirements is		.82
QP13.Our capability of offering quality products that meet customer expectations is	.69	.53
QP14.Our capability of offering high performance products that meet customer needs is	.80	
CS1.Our capability of producing at a low direct labor cost is	.90	
CS5.Our capability of eliminating any unnecessary space usage is	.90	

Table 5 (Continued): Factor Loadings (within each variable) for Retained Competitive Capabilities items (Pilot).

ITEMS RETAINED AFTER CORRECTED-ITEM TOTAL CORRELATION ASSESSMENT	FACTOR1	FACTOR2
CV1.Our capability of resolving customer complaints promptly is	.41	.78
CV2.Our capability of providing dependable deliveries is	.88	
CV3.Our capability of providing customer service is		.80
CV4.Our capability of providing fast deliveries when requested by a customer is	.63	.48
CV5.Our capability of providing a prompt confirmation of customer orders is		.80
CV6.Our capability of providing on-time deliveries is	.91	
CV7.Our capability of delivering the kind of products needed on time	.83	.39
CV8.Our capability of delivering the correct quantity of products needed on time is	.87	
PI1.Our capability of developing customized products is	.80	
PI2.Our capability of developing unique features is	.85	
PI3.Our capability of developing new products and features is	.86	
PI5.Our capability of developing a number of "new" features is	.89	
PI6.Our capability of developing a number of "new" products is	.88	
PI7.Our capability of developing a broad product variety is	.67	
PF1.Our capability of producing a mix of products to meet customer demands fast is	.82	
PF2.Our capability of making quick product mix changes to meet customer demands is	.83	
PF3.Our capability of producing the product mix demanded by customers on	.76	
PF4.Our capability of making rapidly a mix of products to meet customer demand is	.93	

5. To make it easier to interpret the factor structure, item loadings below 0.30 are not reported. The results were interpreted with caution since the ratio of respondents to items was relatively low for certain scales such as the value to customer quality.

The six items of the competitive pricing, the five items of the premium pricing, the seven items of the product innovation, and the four items of the product-mix scale all loaded onto one factor respectively and had relatively high loadings. The fourteen items of the value to customer quality scale loaded onto two factors. Some of the items had also significant cross loadings. The factor structure was interpreted with caution because of the low ratio of respondents to the number of items for the scale. The items with high loadings on the second factor can be interpreted as aesthetics or appearance.

While aesthetics may be critical in consumer markets, they may be less important for the industrial markets. It was decided at this time to drop the items with high loadings on the second factor as well as those items that had high cross loadings. Items QP5, and QP8-QP12 were ultimately eliminated. Although item QP13 had a high cross loading with factor 2 it was decided to retain the item for further consideration because its content was deemed necessary for the composition of the construct.

The two items of cost loaded on one factor indicating unidimensionality. However, to get good resolution of the factor more items are necessary. The seven customer service items loaded onto two factors. Some of the items were referring to the delivery service while other items were referring to other aspects of customer service such as confirmation of orders and resolving customer complaints. Although the content of these items is significant, the contribution of product development practices or manufacturing practices on these service items may not be very significant. In other words, theoretically and empirically we would expect that the explanatory power of our independent variables will be limited in predicting this kind of customer service. The three items (CV1, CV3, CV5) that had high loadings with the second factor were then eliminated. Overall ten items were eliminated at the factor analysis stage. All the remaining 35 items were then subjected to reliability analysis.

The six items of the competitive pricing scale had an alpha of 0.92. One item (CP1) had wording similar to other items and its removal did actually improve alpha to 0.93. The premium pricing scale had five items and a Cronbach's alpha of 0.94. Item PR3 had similar wording with other items in the scale and its removal did not affect alpha significantly. The revised alpha for the premium pricing scale is 0.93. The eight items comprising the value to customer scale had an alpha of 0.95 and no items could be removed without affecting the composition of the scale. The coefficient alpha for the two items of cost was 0.75. With only two items in the scale, no item could be further eliminated as reliability alpha can only be computed for a minimum of two items. The six items of product innovation scale had an alpha of 0.90. The removal of item PI7 improved alpha to 0.91 and did not affect the content of the scale significantly. The product-mix flexibility scale had an alpha of 0.85 and no items could be removed. Finally, the four items comprising the customer service scale had a reliability alpha of 0.94. Overall, three items were removed at the reliability analysis stage.

Next, a correlation matrix (Table 6) of the 32 items retained for further assessment was examined for evidence of convergent and discriminant validity. The smallest within-variable (factor) correlations are: cost=0.64, competitive pricing=0.55, premium pricing=0.75, value to customer quality=0.57, product-mix flexibility=0.46, product innovation=0.55, and customer service=0.77. All were significantly different from zero ($p<0.01$).

An examination of the correlation matrix to assess discriminant validity revealed a total of 42 violations (out of 858). None of the counts for each item exceeds half of

Table 6:Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity tests for Competitive Capabilities (Pilot).

	CS1	CS5	CP2	CP3	CP4	CP5	CP6	PR1	PR2	PR4	PR5	QP1	QP2	QP3	QP4	QP6	QP7	QP13	QP14	PF1	PF2	PF3	PF4	PI1	PI2	PI3	PI5	PI6	CV2	CV6	CV7	CV8
CS1	1.00																															
CS5	.64	1.00																														
CP2	.54	.63	1.00																													
CP3	.45	.60	.66	1.00																												
CP4	.61	.71	.78	.79	1.00																											
CP5	.41	.66	.55	.73	.84	1.00																										
CP6	.42	-.57	.69	.79	.84	.78	1.00																									
PR1	-.05	-.15	.10	-.11	-.01	-.29	-.14	1.00																								
PR2	.01	-.09	.04	-.05	.03	-.18	-.12	.88	1.00																							
PR4	.27	.14	.23	.02	.16	-.12	-.06	.75	.84	1.00																						
PR5	.17	.04	.15	-.08	.01	-.22	-.11	.76	.83	.77	1.00																					
QP1	-.23	-.15	.04	-.11	-.14	-.12	-.12	.27	.20	.14	.13	1.00																				
QP2	.07	-.17	.20	-.01	.08	-.07	-.08	.40	.31	.35	.29	.70	1.00																			
QP3	.03	.07	.25	-.18	.02	-.10	-.15	.53	.51	.54	.55	.70	.66	1.00																		
QP4	.00	-.06	.16	-.12	-.03	-.08	-.09	.36	.34	.40	.42	.76	.72	.73	1.00																	
QP6	.02	-.08	.16	-.25	-.06	-.16	-.16	.51	.46	.58	.45	.69	.71	.83	.81	1.00																
QP7	.12	.03	.09	-.13	-.04	-.14	-.15	.53	.56	.65	.63	.58	.59	.75	.72	.80	1.00															
QP13	.15	.15	.30	.00	.18	.04	.07	.28	.22	.30	.25	.69	.70	.61	.66	.70	.69	1.00														
QP14	-.02	.00	.11	-.09	-.03	-.18	-.10	.52	.49	.47	.42	.74	.64	.76	.57	.76	.78	.77	1.00													
PF1	.04	.11	.29	-.01	.12	-.07	.10	.30	.33	.34	.31	.18	.16	.40	.17	.45	.43	.55	.48	1.00												
PF2	.22	.13	.10	.06	.18	.01	.11	.01	.15	.13	.24	.28	.28	.26	.23	.26	.32	.53	.44	.51	1.00											
PF3	.19	.00	.18	.06	.21	.03	.09	.00	.14	.12	-.02	.39	.52	.32	.28	.37	.34	.67	.47	.46	.53	1.00										
PF4	.26	.12	.24	.13	.16	-.00	.10	.15	.20	.25	.25	.28	.33	.39	.27	.41	.47	.58	.49	.77	.73	.60	1.00									
PI1	-.33	-.19	-.18	-.27	-.25	-.22	-.10	.08	.14	.08	.02	.21	-.02	.27	.12	.30	.27	.28	.33	.62	.18	.33	.51	1.00								
PI2	-.24	-.12	-.11	-.11	.03	-.01	.07	.28	.34	.27	.18	.33	.22	.29	.39	.43	.42	.48	.47	.51	.34	.34	.41	.67	1.00							
PI3	-.07	-.03	.15	.22	.21	.14	.36	.23	.24	.08	.11	.38	.31	.22	.17	.27	.34	.58	.58	.56	.44	.48	.55	.55	.67	1.00						
PI5	-.20	-.05	.04	.03	.11	.04	.12	.30	.30	.23	.15	.37	.30	.39	.33	.44	.43	.46	.58	.55	.41	.27	.54	.66	.81	.73	1.00					
PI6	.06	.07	.20	.12	.11	-.02	.23	.40	.43	.38	.40	.44	.37	.53	.43	.58	.60	.58	.71	.70	.55	.39	.71	.59	.63	.79	.75	1.00				
CV2	.27	.12	.16	.12	.20	.09	.13	-.14	-.01	-.01	-.08	.43	.45	.22	.27	.22	.26	.66	.42	.28	.49	.86	.39	.07	.12	.38	.06	.22	1.00			
CV6	.22	-.03	.13	.15	.21	.06	.13	-.17	-.08	-.07	-.14	.26	.44	.06	.23	.11	.17	.51	.23	.15	.41	.81	.33	-.00	.16	.28	.11	.14	.84	1.00		
CV7	.12	.20	.20	.24	.30	.21	.30	-.13	-.01	-.03	-.13	.36	.37	.22	.21	.21	.26	.68	.48	.40	.49	.86	.49	.33	.41	.61	.36	.43	.84	.77	1.00	
CV8	.01	.01	.28	.18	.20	.13	.18	-.21	-.14	-.17	-.19	.39	.41	.23	.23	.18	.20	.54	.32	.36	.34	.75	.33	.14	.17	.39	.18	.25	.77	.83	.77	1.00
	CS1	CS5	CP2	CP3	CP4	CP5	CP6	PR1	PR2	PR4	PR5	QP1	QP2	QP3	QP4	QP6	QP7	QP13	QP14	PF1	PF2	PF3	PF4	PI1	PI2	PI3	PI5	PI6	CV2	CV6	CV7	CV8
Mean	4.16	3.94	4.39	4.16	4.29	4.03	4.38	4.93	4.87	4.32	4.71	5.71	5.55	5.70	6.00	5.61	5.52	5.58	5.54	5.10	5.35	5.13	5.13	5.81	5.64	5.26	5.55	5.10	5.06	4.81	4.87	4.77
SD	1.55	1.09	1.20	1.55	1.19	1.20	1.38	1.06	1.06	1.45	1.22	1.10	1.03	0.99	1.03	1.12	1.12	1.02	0.85	1.68	1.52	1.48	1.33	1.35	1.17	1.32	1.06	1.35	1.57	1.56	1.50	1.56
# of Violations	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	3	2	3	7	2	8	1	1	0	4	0	4	1	1	1	0

Note: Correlations greater than .36 are significant at 0.05, Correlations greater than .46 are significant at 0.01.

the potential comparisons. However, half of the violations (21) were counted between the scales of product-mix flexibility and customer service. The high correlations of these items may be explained theoretically. A firm must have high product-mix flexibility tobe able to deliver the products to customers on time. In other words there might be a causal relationship between product-mix flexibility and customer service. Alternatively, product-mix flexibility may be an internal measure of performance where customer service is more of an external, customer oriented measure.

This assessment was reinforced from the high scale inter-correlations observed between the product-mix scale and customer service. The correlation was 0.62 and was very significant ($p<.01$). The product-mix scale also had a very high correlation with the product innovation scale ($r=0.66$, $p<0.01$) indicating perhaps that to have product innovation, manufacturing has to have the flexibility to accommodate product innovation.

The two estimates of product development time were also correlated with a composite measure of competitive capabilities to assess relationships in a nomological network of constructs. The correlation between the two methods of assessing product development time was 0.98 indicating that either method would probably provide us with a reliable estimate of product development time as was conceptualized in this research. The composite measure of competitive capabilities includes measures of competitive pricing, premium pricing, value to customer quality, product innovation, and customer service and has a reliability alpha was equal to 0.90. It was expected that the correlations would be negative since lower times are hypothesized to lead to higher levels of competitive capabilities. Using the first method (i.e., overall question) of estimating product development time the correlation was -0.40. For the second method (i.e., Gantt chart) the correlation was -0.38. This indicates that some of the variation in competitive capabilities can be explained by product development time.

Due to space limitations in a large scale study and considering the high correlation between the two methods, it was decided to keep the overall question in regards to product development time and drop the Gantt chart. Future research may employ the one page Gantt chart to derive richer information as the degree of concurrency of activities may be identified on the chart.

Both methods (i.e., a schematic drawing and an overall question) of estimating throughput time were correlated with a composite measure of competitive capabilities as well. The correlation between the two measures of time was 0.92, indicating that the two methods can be used to measure time reliably. It was expected that the correlations would be negative since lower times are hypothesized to lead to higher levels of competitive capabilities. Using the first method (i.e., schematic drawing) of estimating throughput time the correlation was 0.04. For the second method (i.e., overall question) the correlation was 0.01. This indicates that throughput time may not explain much variation in competitive capabilities. This assessment, however, should be viewed in light of the small sample available. Because the schematic drawing used to assess time took about half a page of space, it was decided to replace it and just keep items measuring time at each of the stages where parts spent their time.

Before moving to the administration of the instrument to a large sample the scales were evaluated in scope of the results from the pilot study. Four of the scales (i.e., competitive pricing, premium pricing, value to customer quality, and product innovation) did not pose any conceptual or interpretation problems. They exhibited good convergent and discriminant validity and their reliabilities were high. The customer service scale originally was measuring aspects of delivery service and other services such as resolving customer complaints. When items that loaded on a second factor were dropped, the remaining items were all measuring delivery service alone. Thus, it was decided to rename the scale as customer delivery service in order to be congruent with the content of the retained items.

The cost scale with its two retained items was dropped for several reasons. First, four of the original items in the scale were dropped at the purification stage. Second, the two items retained share a lot of variance with the competitive pricing scale. The correlation between the two scales is 0.67 and it is very significant ($p<0.01$). Finally, cost is more of an internal measure of performance than external, customer oriented. To the customer, price is probably more important than cost. Based on these reasons it was decided to drop the cost scale. The product-mix scale was also dropped because it is also more of an internal measure of performance and much of it's variance is captured by two other constructs (i.e., customer delivery service and product innovation). Overall, five scales and 26 items were proposed after the pilot study (Appendix A). Each scale had at least four items.

3.3.2 Time-based Manufacturing Practices Instrument

The analysis began with purification. Corrected-item total correlations (CITCs) for each item are shown on Table 7. In assessing the CITC, the cellular manufacturing

Table 7: Purification for Time-Based Manufacturing (Pilot).

ITEMS	Corrected-Item Total Correlation
CM1.We produce families of parts in manufacturing cells (i.e., product oriented layout).	.57
CM2.Our employees working in cells are cross trained.	.74
CM3.Machines and equipment that form particular manufacturing cells are moveable.	**.37**
CM4.Individuals that work in manufacturing cells attend multiple machines simultaneously.	.58
CM5.We use flexible equipment in our manufacturing cells.	.63
CM6.Our manufacturing cells are linked with automated material handling.	**.21**
CM7.We use general purpose equipment in our manufacturing cells.	.51
CM8.We locate our equipment in manufacturing cells very close to each other.	**.30**
CM9.We use a coding system for identifying communality of design specifications and/or processes.	**-.03**
CM10.We produce products in manufacturing cells.	**.18**
RS1.Our firm has been taking action to eliminate setup altogether.	**.25**
RS2.Standard setup methodology is developed for every new processes.	.55
RS3.Setup steps, such as presetting dies or obtaining dies, are performed while machines are running.	**.32**
RS4.A team of employees works on setup improvement.	.71
RS5.Our employees are trained to perform setups.	**.34**
RS6.Tools for setup are located in conveniently location.	.55
RS7.Our employees practice setups.	**.20**
RS8.Special setup teams are used to perform the setup.	**.01**
RS9.Employees redesign or reconfigure equipment, tools, jigs or fixtures to shorten setup time.	.53
RS10.A formal procedure, such as Single Minute Exchange of Dies (SMED), is used to reduce setup time.	**.34**
RS11.We have been working towards improving setup times.	.59
RS12.Machine operators perform their own setups.	**.16**
PM1.There is a separate shift, or part of a shift, reserved for preventive maintenance activities.	.55
PM2.Machine operators perform minor preventive maintenance tasks.	.56
PM3.We emphasize good preventive maintenance.	**.48**
PM4.Preventive maintenance training sessions are provided to machine operators.	.74
PM5.Records of routine maintenance are kept.	.54
PM6.We do preventive maintenance.	.74

***Note:** Items in bold have CITC below 0.50.

Table 7 (Continued): Purification for Time-Based Manufacturing (Pilot).

ITEMS	Corrected-Item Total Correlation
PP1.We do not produce unless there is a demand in the next station.	.69
PP2.There is a relatively smooth and constant flow of work and material.	**.33**
PP3.Production is "pulled" by the shipment of finished goods.	.62
PP4.We use standard container sizes for the transfer of parts between stations.	**.22**
PP5.Production at stations is "pulled" by the current demand of the next stations.	.71
PP6.We use a "pull" production system.	.68
PP7.We use kanban (i.e., a simple visual card system) to drive our "pull" production system.	.63
QI1.We use fishbone type diagrams to identify causes of quality problems.	.64
QI2.The production line is shut down through an "automatic stop" when defects are detected.	.57
QI3.We expend a lot of effort in assuring our quality.	**.46**
QI4.We aim for a process design which prevents employee errors.	.74
QI5.We use design of experiments (i.e., Tageuchi methods).	.61
QI6.We do inspect incoming quality.	**.36**
QI7.We communicate critical quality characteristics and specifications to suppliers.	.61
QI8.Our employees use quality control charts (e.g., SPC charts).	.70
QI9.We conduct process capability studies.	.71
QI10.Our rework stations are off-line.	**.26**
QI11.We make our suppliers responsible for their own quality.	**.43**
QI12.Processes that detect defects are automated.	.52
QI13.We make our employees responsible for their own quality.	**.31**
QI14.Our employees shut down the production line when they detect defects.	.71
PS1. Shop-floor employees are involved in problem solving efforts.	.84
PS2. Shop floor employees are involved in efforts to solve customer problems.	.59
PS3. Shop-floor employees are involved in suggestion programs.	.53
PS4. Shop floor employees are involved in designing processes and tools that focus on improvement.	.79
PS5. Shop-floor employees are involved in improvement efforts.	.76
PS6. Shop-floor employees are involved in problem solving teams.	.81

Table 7 (Continued): Purification for Time-Based Manufacturing items (Pilot).

ITEMS	Corrected-Item Total Correlation
DS1. We receive parts from suppliers on time.	.80
DS2. We receive parts from our major suppliers everday.	**-.02**
DS3. We receive parts from suppliers whenever we need them.	**.49**
DS4. We receive the correct number of parts from suppliers.	.76
DS5. We receive parts from suppliers in small lots.	**.29**
DS6. We receive parts from suppliers that meet our needs.	.69
DS7. We receive the correct type of parts from suppliers.	.67
DS8. We receive parts from suppliers directly to the production line.	**.34**
DS9. We receive parts from suppliers that meet our specifications.	.78
DS10. Our suppliers accommodate our needs.	.74
DS11. We receive high quality parts from suppliers.	.78

Legend: CM=Cellular Manufacturing, RS=Re-engineering Setup, PM=Preventive Maintenance, PP=Pull Production, QI=Quality Improvement Efforts, PS=Shop-Floor Employee Involvement in Problem Solving, and DS=Dependable Suppliers.

scale had five of its ten items with CITCs greater than 0.50. The five items with CITC greater than 0.50 were retained for further evaluation. The re-engineering setup scale also had quite a few items with CITC below 0.50. There were only five items retained out of the original 12. Twelve other items were dropped from the remaining five scales based on CITC below 0.50. All the items eliminated due to their low CITCs appear in bold on Table 7. Overall, there were 24 items that were eliminated at this stage.

The factor analyses of the items in each of the scales are reported in Table 8. To make it easier to interpret the factor structure, item loadings below 0.30 are not reported. The ratio of sample size to number of items was adequate for exploratory pilot analysis, ranging between 4 to 1 for quality improvement efforts and 7 to 1 for several scales with five items each.

Factor analyses revealed that all scales seemed to be unidimensional; for each scale only one factor has emerged. The loadings were relatively high for each scale. Two

Table 8: Factor Loadings (within each variable) for Retained Time-Based Manufacturing items (Pilot).

ITEMS RETAINED AFTER CORRECTED-ITEM TOTAL CORRELATION ASSESSMENT	FACTOR1	FACTOR2
CM1.We produce families of parts in manufacturing cells (i.e., product oriented layout).	.70	
CM2.Our employees working in cells are cross trained.	.83	
CM4.Individuals that work in manufacturing cells attend multiple machines simultaneously.	.86	
CM5.We use flexible equipment in our manufacturing cells.	.77	
CM7.We use general purpose equipment in our manufacturing cells.	.63	
RS2.Standard setup methodology is developed for every new processes.	.73	
RS4.A team of employees works on setup improvement.	.79	
RS6.Tools for setup are located in convenient locations.	.62	
RS9.Employees redesign or reconfigure equipment, tools, jigs or fixtures to shorten setup time.	.76	
RS11.We have been working towards improving setup times.	.80	
PM1.There is a separate shift, or part of a shift, reserved for preventive maintenance activities.	.73	
PM2.Machine operators perform minor preventive maintenance tasks.	.59	
PM3.We emphasize good preventive maintenance.	.87	
PM5.Records of routine maintenance are kept.	.76	
PM6.We do preventive maintenance.	.89	
PP1.We do not produce unless there is a demand in the next station.	.80	
PP3.Production is "pulled" by the shipment of finished goods.	.81	
PP5.Production at stations is "pulled" by the current demand of the next stations.	.89	
PP6.We use a "pull" production system.	.86	
PP7.We use kanban (i.e., a simple visual card system) to drive our "pull" production system.	.60	
QI1.We use fishbone type diagrams to identify causes of quality problems.	.73	
QI2.The production line is shut down through an "automatic stop" when defects are detected.	.71	
QI4.We aim for a process design which prevents employee errors.	.80	
QI5.We use design of experiments (i.e., Tageuchi methods).	.78	
QI7.We communicate critical quality characteristics and specifications to suppliers.	.62	
QI8.Our employees use quality control charts (e.g., SPC charts).	.75	
QI9.We conduct process capability studies.	.77	
QI12.Processes that detect defects are automated.	.63	
QI14.Our employees shut down the production line when they detect defects.	.81	

Table 8 (Continued): Factor Loadings (within each variable) for Retained Time-Based Manufacturing items (Pilot).

ITEMS RETAINED AFTER CORRECTED-ITEM TOTAL CORRELATION ASSESSMENT	FACTOR1	FACTOR2
PS1.Shop-floor employees are involved in problem solving efforts.	.90	
PS2.Shop floor employees are involved in efforts to solve customer problems.	.71	
PS3.Shop-floor employees are involved in suggestion programs.	.64	
PS4.Shop floor employees are involved in designing processes and tools that focus on improvement.	.88	
PS5.Shop-floor employees are involved in improvement efforts.	.85	
PS6.Shop-floor employees are involved in problem solving teams.	.89	
DS1.We receive parts from suppliers on time.	.86	
DS4.We receive the correct number of parts from suppliers.	.86	
DS6.We receive parts from suppliers that meet our needs.	.74	
DS7.We receive the correct type of parts from suppliers.	.85	
DS9.We receive parts from suppliers that meet our specifications.	.91	
DS10.Our suppliers accommodate our needs.	.86	
DS11.We receive high quality parts from suppliers.	.80	

items (PM2 and PP7) were dropped from their respective scales because their loadings were relatively low, slightly less than 0.60. All the remaining items were then subjected to reliability analysis.

The coefficient alpha for the five cellular manufacturing items was 0.81. No item could be eliminated without reducing reliability. The five items of the product re-engineering setup scale had an alpha of 0.80. The preventive maintenance scale had four items and a Cronbach's alpha of 0.84. The four items comprising the pull production scale had an alpha of 0.87. The quality improvement efforts scale had nine items and its reliability was 0.89. Due to the relatively large number of items retained, it was examined whether some items could be dropped without significantly affecting alpha. It was found that three items (QI2, QI12, and QI14) shared similar content. It was decided to keep only one of them (QI2) which combined aspects of the other two. The revised reliability alpha is 0.87. The shop-floor employee involvement in problem solving scale had six items and an alpha of 0.89. Two of the items (PS2 and PS3) however had similar content with the other items and their removal would not affect the composition of the scale or adversely affect alpha. In fact, their removal improved alpha to 0.91. The dependable supplier scale had seven items retained and an alpha of 0.93. Item DS6 was similarly worded with item DS10 and its removal did not affect alpha. The new alpha also stands at 0.93. Overall, there were six items deleted at the reliability stage.

Next, a correlation matrix (Table 9) of the 35 items retained for further assessment was examined for evidence of convergent and discriminant validity. The smallest within-variable (factor) correlations are: re-engineering setup=0.30, cellular manufacturing=0.20, preventive maintenance=0.40, pull production=0.39, quality improvement efforts=0.35, shop-floor employee involvement in problem solving=0.67, and dependablesuppliers=0.58. Four of these were significantly different from zero (p at least <0.05). Three of them (re-engineering setup, cellular manufacturing, and quality improvement efforts) were not significantly different from zero but their magnitude would indicate that, having had a larger sample, they would have been significant. With a small sample size it may be more appropriate at this time to look at the magnitudes of correlations rather than their significance.

An examination of the correlation matrix revealed a total of 253 violations (out of 1042). A lot of the violations were due to the high correlations between the shop-floor employee involvement in problem solving items and the items of other scales. The within scale correlations for the employee involvement scale were relatively high. Correlations

Table 9: Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity tests for Time-Based Manufacturing (Pilot).

	RS2	RS4	RS6	RS9	RS11	CM1	CM2	CM4	CM5	CM7	PM1	PM3	PM5	PM6	PP1	PP3	PP5	PP6	QA1	QA2	QA4	QA5	QA7	QA8	QA9	PS1	PS4	PS5	PS6	DS1	DS4	DS7	DS9	DS10	DS11
RS2	1.00																																		
RS4	.30	1.00																																	
RS6	.35	.31	1.00																																
RS9	.33	.60	.41	1.00																															
RS11	.56	.59	.36	.43	1.00																														
CM1	-.18	.47	-.11	.29	.16	1.00																													
CM2	.03	.41	.45	.54	.37	.60	1.00																												
CM4	.10	.29	.45	.50	.40	.61	.62	1.00																											
CM5	.43	.40	.70	.46	.66	.20	.59	.58	1.00																										
CM7	.65	.28	.51	.37	.33	.23	.32	.42	.55	1.00																									
PM1	.18	.53	-.12	.41	.10	.35	.19	.08	-.01	-.02	1.00																								
PM3	.19	.55	.13	.66	.29	.26	.63	.43	.27	.23	.58	1.00																							
PM5	.29	.26	-.10	.29	.06	.22	.44	.10	.01	.18	.40	.57	1.00																						
PM6	.06	.47	.06	.61	.03	.30	.38	.22	-.04	.00	.54	.69	.59	1.00																					
PP1	-.03	.53	.05	.51	-.00	.57	.57	.46	.11	.13	.55	.46	.35	.49	1.00																				
PP3	.02	.17	-.00	.21	-.09	.14	.43	.38	.24	.26	.27	.30	.32	.18	.39	1.00																			
PP5	-.24	.23	-.08	.12	-.15	.47	.56	.33	.11	.12	.28	.21	.03	.08	.53	.72	1.00																		
PP6	.07	.23	-.18	.13	.01	.53	.34	.40	.27	.42	.29	.07	.22	-.07	.62	.66	.72	1.00																	
QI1	.56	.46	.05	.40	.54	-.00	.31	.09	.37	-43	.26	.42	.33	.25	.15	.17	.08	.21	1.00																
QI2	.07	.35	-.07	.40	.09	.21	.41	.00	-.08	.09	.41	.49	.17	.34	.63	.22	.45	.20	.35	1.00															
QI4	.60	.43	.08	.37	.58	-.00	.38	.11	.32	.34	.29	.37	.32	.17	.35	.15	.14	.20	.77	.59	1.00														
QI5	.24	.56	.11	.49	.28	.22	.44	.34	.26	.26	.45	.48	.13	.43	.53	.32	.41	.30	.50	.54	.51	1.00													
QI7	.32	.28	.18	.26	.08	-.20	.22	-.13	.17	.19	.34	.31	.26	.27	.10	.46	.23	.09	.41	.36	.43	.42	1.00												
QI8	.12	.33	.21	.54	.26	.10	.59	.28	.44	.23	.11	.41	.26	.26	.33	.36	.34	.14	.42	.43	.51	.49	.56	1.00											
QI9	.31	.69	.27	.64	.48	.30	.54	.20	.42	.32	.50	.60	.41	.48	.47	.17	.26	.28	.58	.39	.56	.55	.47	.58	1.00										
PS1	.29	.78	.17	.68	.51	.46	.54	.31	.42	.33	.47	.55	.38	.50	.52	.06	.04	.22	.60	.39	.43	.56	.29	.49	.64	1.00									
PS4	.32	.75	.23	.68	.54	.54	.44	.54	.53	.48	.37	.42	.22	.34	.50	-.01	.06	.27	.51	.27	.44	.40	.08	.37	.58	.82	1.00								
PS5	.26	.43	.32	.75	.39	.29	.58	.48	.56	.39	.22	.55	.26	.26	.47	.05	.08	.22	.39	.39	.39	.39	.16	.56	.51	.67	.68	1.00							
PS6	.23	.52	.16	.58	.47	.44	.55	.34	.57	.45	.31	.46	.33	.27	.47	.10	.15	.37	.57	.37	.51	.39	.22	.44	.57	.73	.75	.75	1.00						
DS1	.21	.34	.31	.34	.23	.27	.47	.38	.58	.29	.32	.21	.18	.28	.40	.06	.04	.22	.22	.10	.16	.18	.01	.20	.35	.40	.34	.25	.16	1.00					
DS4	.33	.43	.25	.30	.31	.28	.31	.38	.55	.40	.41	.24	.36	.34	.32	.12	.00	.29	.30	-.05	.21	.29	.09	.14	.42	.45	.39	.22	.31	.79	1.00				
DS7	.37	.13	.13	.16	.01	-.02	.31	.21	.34	.33	.28	.32	.43	.27	.18	.39	.09	.27	.28	.05	.14	.22	.27	.12	.13	.17	-.02	.16	.01	.64	.64	1.00			
DS9	.25	.16	.13	.36	.10	.14	.32	.28	.28	.29	.36	.36	.30	.35	.26	.15	-.00	.17	.15	.14	.06	.12	.14	.16	.19	.27	.15	.31	.11	.78	.69	.84	1.00		
DS10	.38	.38	.27	.38	.10	-.05	.10	.07	.36	.26	.52	.30	.33	.27	.27	.23	-.02	.14	.29	.10	.22	.27	.36	.22	.34	.36	.26	.32	.23	.59	.72	.72	.71	1.00	
DS11	.12	.49	.28	.39	.33	.21	.38	.26	.59	.41	.37	.35	.08	.22	.37	.15	.16	.31	.30	.21	.14	.46	.25	.36	.50	.54	.34	.44	.33	.67	.69	.58	.68	.69	1.00
	RS2	RS4	RS6	RS9	RS11	CM1	CM2	CM4	CM5	CM7	PM1	PM3	PM5	PM6	PP1	PP3	PP5	PP6	QA1	QA2	QA4	QA5	QA7	QA8	QA9	PS1	PS4	PS5	PS6	DS1	DS4	DS7	DS9	DS10	DS11
Mean	3.03	2.69	3.45	3.12	3.16	3.10	3.64	2.92	3.16	3.28	2.16	2.84	3.34	3.16	2.81	2.90	2.77	2.87	3.00	2.44	3.66	2.41	3.97	3.37	2.97	3.69	3.12	3.72	3.62	3.44	3.56	3.94	3.78	3.71	3.55
SD	1.20	1.35	0.92	1.13	1.19	1.47	0.81	1.19	1.18	0.89	1.14	1.02	1.15	0.97	1.28	1.45	1.23	1.33	1.32	1.37	1.03	1.19	1.00	1.29	1.31	1.06	1.24	0.96	1.10	0.95	0.91	0.95	0.87	0.69	0.77
# of Violations	9	21	5	23	10	18	23	6	23	21	8	3	3	1	16	2	1	0	11	10	6	9	1	5	15	1	0	1	0	0	0	0	0	0	1

Note: Correlations above 0.36 are significant at 0.05, Correlations above 0.46 are significant at 0.01.

between items of other scales and items of the involvement items were high as well, leading to a large number of violations. This may lead a researcher to believe that there may be a causal sequence between employee involvement and the rest of the time-based manufacturing practices. It is plausible that employee involvement is an antecedent to other manufacturing practices and thus it should be analyzed separately.

This assessment was reinforced from the high scale inter-correlations observed between the involvement scale and the other six scales. The correlations were 0.71 with re-engineering setup, 0.63 with cellular manufacturing, 0.50 with preventive maintenance, 0.32 with pull production, 0.63 with quality improvement efforts, and 0.38 with dependable suppliers. All the correlations were very significant except the one for pull production.

To assess predictive validity, the scales were also correlated with two estimates of throughput time (schematic drawing and overall question) and a composite measure of competitive capabilities discussed earlier. It was expected that the correlations with times would be negative since engaging more in these practices is expected to decrease throughput time. The correlations were evaluated more on their magnitude than significance because of the small sample size used. All correlations were above 0.32 in magnitude for both measures of throughput time, except for the correlations with dependable suppliers, which had very low correlations. The correlations of re-engineering setup with the two measures of time were -0.48 and -0.51, of cellular manufacturing -0.32 and -0.42, of preventive maintenance -0.37 and -0.45, of quality improvement efforts -0.77 and -0.59, of employee involvement -0.41 and -0.41, and of dependable suppliers -

0.01 and -0.04. The highest correlations were observed for the quality improvement efforts with both measures of throughput time.

The composite measure of competitive capabilities includes measures of competitive pricing, premium pricing, value to customer quality, product innovation, and customer service and has a reliability alpha=0.90. Correlations between the time-based manufacturing practices and competitive capabilities were expected to be positive; the more firms engage in these practices, the higher the level of their competitive capabilities. The correlations were 0.30 for re-engineering setup, 0.29 for cellular manufacturing, 0.36 for preventive maintenance, 0.09 for pull production, 0.38 for employee involvement in problem solving, 0.45 for quality improvement efforts, and 0.29 for dependable suppliers. The magnitudes of the correlations would indicate that these variables explain to some degree variation in competitive capabilities. One variable, pull production had a fairly low correlation but judgments about its predictive validity will be re-examined with a larger sample size.

Before moving to the administration of the instrument to a large sample, the scales were re-examined in scope of the results from the pilot study; where appropriate, scales were reconceptualized, scales were augmented with additional items, and items were modified.

The cellular manufacturing scale in its original form had items measuring whether a particular firm has manufacturing cells and whether the resources used in cells were flexible. We saw earlier during CITC analysis that half of the items of this scale had very low CITCs. The five items retained after the pilot study measure flexibility aspects of resources within cells, not whether products are produced in cells. To measure the extent of use of cellular manufacturing, it was decided to drop all the items of the scale and create eight new items.

The re-engineering setup scale had a relatively low reliability (alpha=.84) and it was decided to modify most of the items. Five of the items were modified to derive six items (item RS9 was modified to create two items). Item RS11 remained as it was while a new item was added that asked whether special tools were used to perform setups. Overall, eight items were proposed for this scale.

The preventive maintenance scale had four items left after the pilot analysis and an alpha of 0.84. It was decided to add two more items to maintain adequate reliability for the large scale. For the same reason, the four retained pull production items were augmented by modifying item PP7 which was dropped earlier. Using the same logic, the shop-floor employee involvement in problem solving scale was supplemented by item PS3 which was removed earlier.

The quality improvement scale was not changed other than shortening item QA7 to make it more readable. Overall 45 items (Appendix A) for time-based manufacturing practices are proposed ranging from five items for pull production, and employee involvement to eight items for re-engineering setup and cellular manufacturing.

At this stage it was also decided to analyze the employee involvement scale separately from the other scales in future measurement research because it seems to be an antecedent to other time-based manufacturing practices. Indeed, much literature supports the notion that it is the employee involvement in problem solving that is driving improvement efforts (Hall, 1987; Hall et al., 1991). The items for cellular manufacturing will have a new two digit letter designator. All other items modified or added for this instrument will appear with a new number prefix (of an increasing order) in the large scale study to indicate that these items are not the same as those used for the pilot.

3.3.3 Time-Based Product Development Practices Instrument

The analysis for the product development practices instrument begins with purification. The corrected-item total correlation (CITC) for each item is shown on Table 10. In assessing the CITC, the heavyweight product managers and incremental innovation scales seemed to be particularly troublesome. The heavyweight product managers scale had only two items out of five with CITCs greater than 0.50, while all items in the incremental product innovation scale had CITCs below 0.50. The incremental innovation scale included items which measured both the frequency and magnitude of innovation as well as items regarding the development of platform products. It is possible that the items are measuring significantly different aspects of incremental innovation including both causes and effects. The best four items were retained for further evaluation. In terms of the heavyweight product managers scale it is possible that the items confused the respondents. Some items included statements regarding **product managers** while other statements referred to **product development managers**. Respondents could have interpreted the two as different. The best three items were kept for further assessment. Twelve items from the other five scales were eliminated because they had a corrected item total correlation less than or equal to 0.50. All the items eliminated due to their low

Table 10: Purification for Time-Based Product Development (Pilot).

ITEMS	Corrected-Item Total Correlation
CW1.Product and process designs are developed concurrently by a group of employees from various disciplines.	.60
CW2.Manufacturability assessments and product design are carried out concurrently.	**.48**
CW3.Our organization uses formal techniques, such as Quality Functional Deployment, to translate customer preferences into product and process parameters.	.51
CW4.Supplier selection is done concurrently with product and process design.	**.36**
CW5.Marketing plans for product introduction are drawn concurrently with product and process design.	**.42**
CW6.Procedures to assure quality are instituted concurrently with product and process design.	**.49**
CW7.Much of process design is done concurrently with product design.	.76
CW8.Product development activities are concurrent.	.74
PT1.Product development group members share information.	.69
PT2.Product development groups are kept relatively small.	**.25**
PT3.Product development group members represent a variety of disciplines.	.56
PT4.Product development group members trust each other.	.60
PT5.Product development group members meet regularly.	.63
PT6.Product development group members are kept together at least until production has started.	.58
PT7.Product development group members make most product development decisions.	**.31**
PT8.Product development employees work as a team.	.70
PT9.Product development group members have and use a lot of discretion for product development.	.58
PT10.Product development group members are co-located.	**.38**
PT11.Product development group members seek integrative solutions.	.55
EI1.Our customers are involved from the early stages of product development.	**.12**
EI2.Purchasing managers are involved from the early stages of product development.	.58
EI3.Process engineers are involved from the early stages of product development.	.65
EI4.Our suppliers are involved from the early stages of product development.	**.31**
EI5.Marketing is involved from the early stages of product development.	**.18**
EI6.Top management is involved from the early stages of product development.	.56
EI7.Various disciplines are involved in product development from the early stages.	.52
EI8.Manufacturing is involved from the early stages of product development.	.68

*****Note:** Items in bold have CITC below 0.50.

Table 10 (Continued): Purification for Time-Based Product Development (Pilot).

ITEMS	Corrected-Item Total Correlation
SR1.Our suppliers do the product engineering of component parts for us.	.66
SR2.We make our suppliers responsible for prototype development of parts.	.58
SR3.Our suppliers develop component parts for us.	.80
SR4.Our suppliers participate in product development.	.57
SR5.We make our suppliers responsible for the process engineering of component parts.	**.43**
SR6.Our suppliers develop whole subassemblies for us.	.72
HM1.Product managers are given broad responsibilities.	**.14**
HM2.Product development managers have significant influence over product engineering.	**.30**
HM3.Product managers have an equal or higher seniority or authority than functional managers in product decisions.	**.15**
HM4.Product managers influence personnel outside the engineering function.	**-.02**
HM5.Product managers are given "real" budget authority.	.60
HM6.Product development managers are given "real" authority over personnel.	.73
II1.We make frequent product innovations.	**.44**
II2.We make small product innovations.	**.32**
II3.Product innovations are usually incremental.	**.34**
II4.Products are developed as platforms for multiple generations of product innovations to come.	**.43**
II5.Product innovations are usually major.	**.48**
CZ1.We use integrated Computer Aided Design/Computer Aided Manufacturing.	.77
CZ2.We use computerized project management tools such as CPM or PERT.	.55
CZ3.We use computerized systems for product development.	**.48**
CZ4.We use Computer Aided Process Planning (CAPP).	.55
CZ5.We use Computer Aided Design (CAD).	.60
CZ6.We use Computer Aided Manufacturing (CAM).	.64

Legend: CW=Concurrent Work-Flow, PT=Product Development Teams, EI=Early Involvement of Constituents, SR=Supplier Responsibilities, HM=Heavyweight Product Managers, II=Incremental Innovation, and CZ=Computerization.

CITCs appear in bold on Table 10.

The factor analyses of the retained items in each of the scales are reported in Table 11. To make it easier to interpret the factor structure, item loadings below 0.30 are not reported. The ratio of sample size to number of items was adequate for exploratory pilot analysis, ranging between 4 to 1 for product development teams and 8 to 1 for concurrent work flow.

The four items of concurrent work flow loaded on one factor indicating unidimensionality. The eight product development teams items loaded on two factors. The results for this scale should be interpreted with caution since the ratio of respondents to items is the lowest and the factor structure may not be stable. Four items clearly loaded high on the first factor while four other items loaded on the second factor. Two of the items of the second factor had high loadings, while two had high cross loadings with the first factor. Three of the items of the second factor were eliminated while one item (PT3) was kept as its content was deemed essential for the product development team scale.

All of the five early involvement items loaded on one factor indicating unidimensionality. The five supplier responsibility items loaded on one factor as did the five computerization items. One item from the supplier responsibilities scale was eliminated because of low loading. All the remaining items were then subjected to reliability analysis.

Table 11:Factor Loadings (within each variable) for Retained Time-Based Product Development items(Pilot).

ITEMS RETAINED AFTER CORRECTED-ITEM TOTAL CORRELATION ASSESSMENT	FACTOR1	FACTOR2
CW1.Product and process designs are developed concurrently by a group of employees from various disciplines.	.78	
CW3.Our organization uses formal techniques, such as Quality Functional Deployment, to translate customer preferences into product and process parameters.	.79	
CW7.Much of process design is done concurrently with product design.	.83	
CW8.Product development activities are concurrent.	.87	
PT1.Product development group members share information.	.83	
PT3.Product development group members represent a variety of disciplines.	.41	.63
PT4.Product development group members trust each other.	.85	
PT5.Product development group members meet regularly.		.83
PT6.Product development group members are kept together at least until production has started.		.81
PT8.Product development employees work as a team.	.78	.36
PT9.Product development group members have and use a lot of discretion for product development.	.33	.58
PT11.Product development group members seek integrative solutions.	.68	
EI2.Purchasing managers are involved from the early stages of product development.	.74	
EI3.Process engineers are involved from the early stages of product development.	.88	
EI6.Top management is involved from the early stages of product development.	.72	
EI7.Various disciplines are involved in product development from the early stages.	.70	
EI8.Manufacturing is involved from the early stages of product development.	.88	
SR1.Our suppliers do the product engineering of component parts for us.	.83	
SR2.We make our suppliers responsible for prototype development of parts.	.69	
SR3.Our suppliers develop component parts for us.	.91	
SR4.Our suppliers participate in product development.	.74	
SR6.Our suppliers develop whole subassemblies for us.	.83	
HM2.Product development managers have significant influence over product engineering.	.77	
HM5.Product managers are given "real" budget authority.	.87	
HM6.Product development managers are given "real" authority over personnel.	.80	
II1.We make frequent product innovations.	.66	
II3.Product innovations are usually incremental.	.62	
II4.Products are developed as platforms for multiple generations of product innovations to come.	.72	
II5.Product innovations are usually major.	.76	
CZ1.We use integrated Computer Aided Design/Computer Aided Manufacturing.	.88	
CZ2.We use computerized project management tools such as CPM or PERT.	.73	
CZ4.We use Computer Aided Process Planning (CAPP).	.74	
CZ5.We use Computer Aided Design (CAD).	.67	
CZ6.We use Computer Aided Manufacturing (CAM).	.77	

The coefficient alpha for the four items of concurrent work flow items was 0.84 while the five items of the product development teams scale had an alpha of 0.84. The early involvement of constituents scale had four items and a Cronbach's alpha of 0.82. The four items comprising the supplier responsibilities scale had an alpha of 0.86. The removal of item SR4 improved alpha to 0.89, and thus item SR4 was deleted. The heavyweight product managers scale had three items and its reliability was 0.75. The incremental innovation scale had four items and an alpha of 0.65. All of its items had squared multiple correlations below 0.50 and thus were suspect. The computerization scale had five items and alpha of 0.81. No item could be eliminated without severely affecting reliability.

Next, a correlation matrix of the 28 items (Table 12) retained for further assessment was examined for evidence of convergent and discriminant validity. The smallest within-variable (factor) correlations are concurrent work flow=0.50, product development teams=0.35, early involvement of constituents=0.30, supplier responsibilities=0.69, heavyweight product managers=0.39, incremental innovation=0.23, and computerization=0.36. Five of these were significantly different from zero (p at least <0.05). Two of them (early involvement of constituents and incremental innovation) are not significantly different from zero but their magnitude would indicate that having had a larger sample they would have been significant.

An examination of the correlation matrix to assess discriminant validity revealed a total of 164 violations (out of 668). None of the counts for each item exceeds half of the potential comparisons. However, 74 violations were counted between the three scales

Table 12:Correlation Matrix, Descriptive Statistics, and Discriminant Validity tests for Time-Based Product Development (Pilot).

	CW1	CW3	CW7	CW8	PT1	PT3	PT4	PT8	PT11	EI2	EI3	EI6	EI7	EI8	SR1	SR3	SR6	HM2	HM5	HM6	II1	II3	II4	II5	CZ1	CZ2	CZ4	CZ6
CW1	1.00																											
CW3	.52	1.00																										
CW7	.50	.52	1.00																									
CW8	.55	.58	.68	1.00																								
PT1	.39	.38	.49	.64	1.00																							
PT3	.53	.46	.42	.61	.53	1.00																						
PT4	.32	.46	.21	.49	.71	.35	1.00																					
PT8	.58	.55	.46	.59	.65	.47	.66	1.00																				
PT11	.48	.39	.49	.57	.44	.44	.42	.53	1.00																			
EI2	.13	.31	.40	.51	.25	.38	.23	.33	.36	1.00																		
EI3	.57	.51	.38	.48	.28	.58	.30	.40	.46	.52	1.00																	
EI6	.45	.43	.24	.52	.63	.49	.52	.63	.35	.30	.30	1.00																
EI7	.47	.43	.54	.74	.57	.71	.40	.47	.64	.33	.55	.43	1.00															
EI8	.31	.37	.48	.56	.36	.60	.32	.51	.56	.71	.58	.49	.53	1.00														
SR1	.28	.07	.07	.01	.23	.25	.08	.24	.22	-.07	.22	.22	.20	.12	1.00													
SR3	.17	.05	.07	.01	-.02	.32	-.09	-.08	-.01	.19	.36	.08	.19	.17	.69	1.00												
SR6	.24	.12	.02	.05	.16	.23	.05	.02	.02	-.16	.09	.16	.19	-.05	.78	.73**	1.00											
HM2	.40	.27	.29	.27	.45	.04	.54	.52	.27	.12	.17	.31	-.06	.16	.06	-.05	-.01	1.00										
HM5	.34	.35	.18	.29	.46	.16	.50	.37	.39	-.03	.27	.24	.28	.15	-.00	-.12	0.04	.49**	1.00									
HM6	.41	.35	.37	.43	.43	.32	.52	.52	.48	.27	.38	.21	.46	.50	-.02	-.13	-.08	.39	.58	1.00								
II1	.35	.36	.38	.36	.24	-.00	.22	.29	.42	.29	.05	.36	.12	.27	.27	.04	.20	.35	.37	.33	1.00							
II3	.18	-.06	.30	.07	.08	.26	.01	-.05	.26	.16	.01	.03	.29	.37	.18	.19	.07	-.05	.11	.25	.23	1.00						
II4	.35	.21	.43	.29	.26	.22	.09	.04	.38	.17	.31	.11	.45	.22	.50	.58	.57	.07	.08	-.03	.24	.30	1.00					
II5	.22	.21	.51	.30	.23	.35	.14	.31	.56	.20	.20	.21	.54	.48	.34	.19	.20	-.03	.14	.26	.37	.26	.40	1.00				
CZ1	.44	.43	.30	.42	.44	.31	.46	.36	.19	.20	.34	.36	.18	.21	.07	.16	.22	.52	.44	.20	.36	-.08	.24	.14	1.00			
CZ2	.15	.15	.13	.42	.45	.38	.36	.30	.57	.18	.22	.08	.50	.21	.29	.17	.31	.22	.42	.32	.24	-.03	.29	.33	.47	1.00		
CZ4	.07	.27	-.01	.18	.27	.33	.37	.16	.29	.08	.04	.19	.24	.14	.33	.27	.39*	.14	.42	.15	.37	.09	.23	.29	.54	.63	1.00	
CZ6	.26	.28	.26	.32	.28	.13	.29	.26	.20	.14	.13	.23	.12	.28	.05	.13	.19	.50	.36	.32	.31	-.11	.25	.17	.72	.39	.36	1.00

	CW1	CW3	CW7	CW8	PT1	PT3	PT4	PT8	PT11	EI2	EI3	EI6	EI7	EI8	SR1	SR3	SR6	HM2	HM5	HM6	II1	II3	II4	II5	CZ1	CZ2	CZ4	CZ6
Mean	3.78	2.56	3.31	3.62	4.19	3.66	3.78	3.84	3.55	3.42	3.61	4.28	3.66	3.69	2.61	2.44	2.34	3.47	2.72	3.03	3.63	3.59	3.06	2.78	3.50	2.94	2.12	2.97
SD	1.04	1.32	1.06	0.75	0.82	0.97	0.01	1.02	0.89	1.18	1.17	1.02	1.03	1.09	1.05	1.10	0.97	0.88	0.99	1.02	1.01	0.71	1.01	0.91	1.44	1.34	1.34	1.42
# of Violations	3	1	2	6	7	10	10	8	9	6	11	11	13	5	0	0	0	6	1	8	18	6	12	10	1	5	4	2

Note: Correlations above 0.35 are significant at 0.05, Correlations above 0.45 are significant at 0.01.

of concurrent work flow, product development teams, and early involvement of constituents pointing to the possibility that an overall factor could capture all the items of the three scales. This assessment was reinforced from the high scale inter-correlations observed for the three scales (for concurrent work flow and product development teams 0.73, for concurrent work-flow and early involvement of constituents 0.69, and for early involvement of constituents and product development teams 0.74). It is an empirical question whether these three variables will load together in a large scale exploratory study. Forty other violations were attributed to the incremental innovation variable and this was expected since the corrected item total correlations for all of its items were relatively low.

To assess predictive validity, the scales were correlated with two estimates of product development time and a composite measure of competitive capabilities. The correlations were assessed more for their magnitude than significance due to the small sample case. These correlations are expected to be negative because it is posited that the more we engage in the proposed practices the lower the time will be. Correlations above 0.30 in magnitude for the first measure of time (i.e., overall question) are only evident for the concurrent work-flow variable (r=-0.40). Using the second estimate of time (i.e., Gantt chart), four correlations were above 0.30 in magnitude. For concurrent work-flow (r=-0.36), for product development teams (r=-0.35), and for early involvement (r=-0.43) the correlations were indeed negative. For computerization however the correlation was positive (r=0.32).

The composite measure of competitive capabilities includes measures of competitive pricing, premium pricing, value to customer quality, product innovation, and customer service and has a reliability alpha=0.90. Five scales had very significant correlations with competitive capabilities (i.e., with concurrent work flow 0.69, product development teams 0.67, early involvement of constituents 0.51, heavyweight product managers 0.56, computerization 0.46). Two of the scales, supplier responsibilities and incremental innovation had nonsignificant correlations (0.22 and 0.29 respectively) but the magnitude of the correlation is indicative that having had a larger sample size they would be significant.

Before moving to the administration of the instrument to a large sample the scales were re-assessed in scope of the results from the pilot study. Where appropriate, scales were reconceptualized, scales were augmented with additional items, and items were modified. In addition, another scale (i.e., customer involvement) was added.

Three of the scales (i.e., concurrent work flow, product development teams, and early involvement of constituents) did not pose any conceptual or interpretation problems other than that their intercorrelations would suggest a grant factor. The supplier responsibilities scale was left with three items after the data analysis stage. This scale was reconceptualized as "supplier involvement" to be congruent with other involvement scales, and three other items were added. The heavyweight product manager scale was reconceptualized as "heavyweight product development managers." Several of the existing items were modified to read "product development manager," instead of just "product manager." Two items were kept the same (HM2 and HM6) while six items were added.

The incremental innovation scale was reconceptualized as "platform products" which captures the practices aspect of incremental innovation rather than the performance aspect. One of the five incremental innovation items (II4) was modified while four other items were added for the large scale study. To indicate the significant difference of these items to those used in the pilot, a different prefix will be used to designate them in the large scale study (i.e., DF instead of II).

The computerization scale was also reconceptualized to reflect the patterns of usage rather than mere usage of certain applications. One item was kept while all five other items were replaced with items denoting patterns of usage such as usage of computers to improve designs, evaluate designs, making engineering changes, developing prototypes, and coordinating product development activities. This scale is now called "computer usage." Because these are totally new items, a new prefix will be used to designate them for the large scale study (i.e., CU instead of CZ).

An additional category, customer involvement, was created at this stage. One of the items from early involvement of constituents (EI1: Our customers are involved from the early stages of product development), was deleted due to its low CITC. However, due to the theoretical significance of this aspect it was decided to use this item along with four new items to form a scale, namely customer involvement.

Overall, eight scales and 44 items (Appendix A) were proposed after the pilot study. Each scale had at least four items. All items modified or added will appear with a new prefix number in the large scale study. It should be noted again that the letter prefix designation for two scales will be different for the large scale study.

3.4 MODEL OF TIME-BASED CONSTRUCTS AFTER THE PILOT STUDY

A revised measurement model derived after the pilot study is shown in Figure 3. In competitive capabilities, two scales were dropped. The cost scale was dropped because of significant measurement problems and much of its variance was explained by other more customer oriented scales. The product-mix flexibility was eliminated because its variance was also explained by other more customer oriented scales. The customer service scale was renamed to customer delivery service to reflect the content of the retained items.

For time-based manufacturing practices, the cellular manufacturing scale was reconceptualized to measure whether a firm uses cellular manufacturing. The shop-floor employee involvement in problem solving scale was pulled out of the manufacturing practices and became an antecedent to the rest of the manufacturing practices.

In product development practices, the heavyweight product manager scale was reconceptualized as heavyweight product development manager while the incremental innovation scale as platform products. The computerization scale was also reconceptualized and now reflects computer usage patterns. The supplier responsibilities scale was renamed to supplier involvement to be congruent with the rest of the involvement scales. A customer involvement scale was added when some of the early involvement items that reflected customer participation were dropped during scale purification. The importance of customer involvement was not to be overlooked. The most significant changes in the model after the pilot appear in bold in Figure 3.

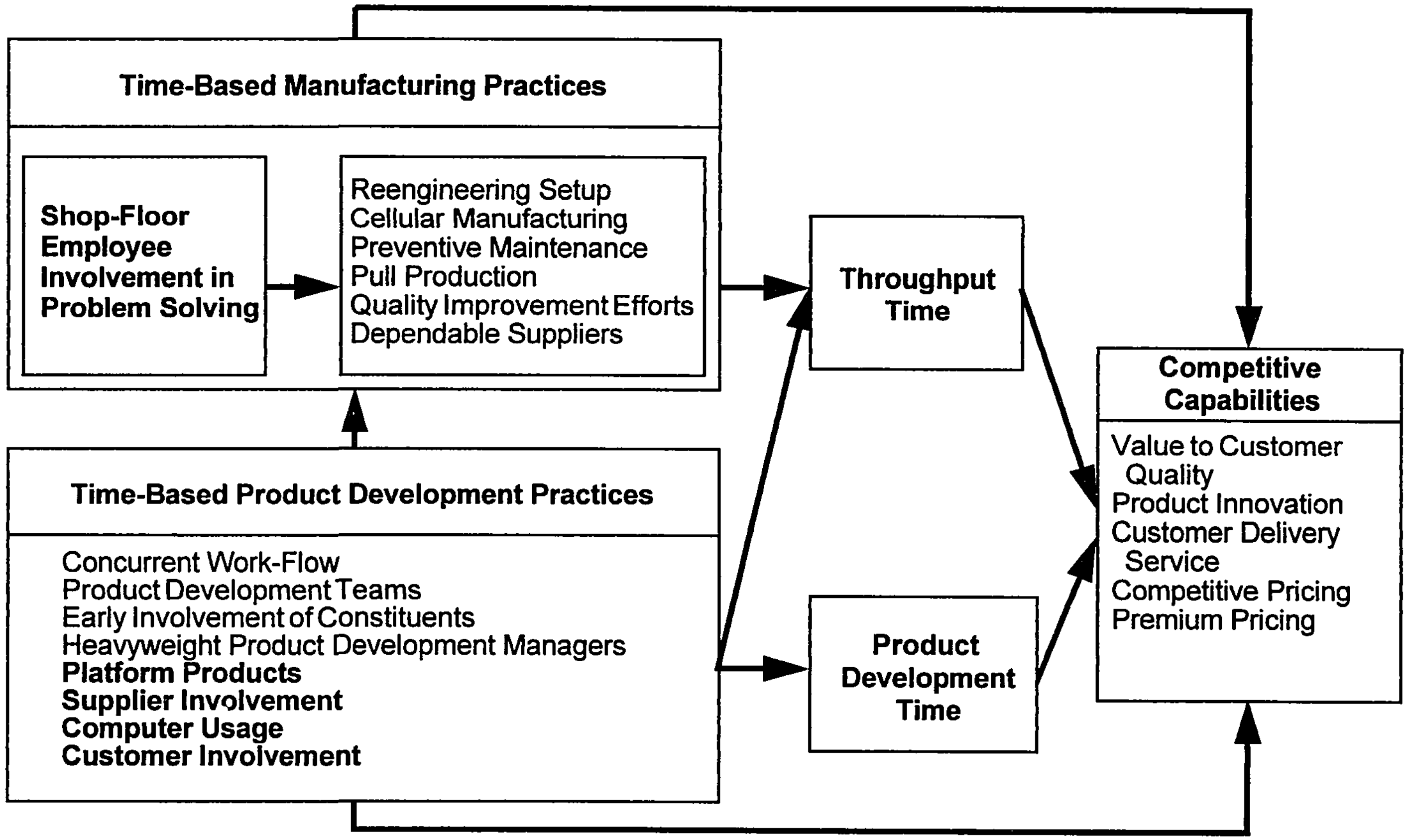


Figure 3: Time-Based Competition Detailed Measurement Model (After Pilot)

CHAPTER 4: INSTRUMENT DEVELOPMENT PHASE II: EXPLORATORY DATA ANALYSIS

To further explore the three instruments, responses from executives in several industries were collected. This second data set enables the reexamination of reliability and the assessment of factorial validity with a large sample. The Society of Manufacturing Engineers (SME) co-sponsored this phase of the study and provided the mailing list and logistical support. Questionnaires were sent out to executives in 2,500 "discrete-unit" manufacturing firms. Out of 253 responses received, 244 were usable resulting in a response rate of 10%. Such response rate is not unusual for extensive organizational level research. These firms were primarily selected from four SIC codes (34: Fabricated metal products [except machinery and transportation equipment], 35: Industrial and commercial machinery, 36: Electronics; Electrical equipment and components, and 37: Transportation equipment). Respondents were chosen based on their level in the organization with preference given to the highest ranked executives. Firms with more than 100 employees were chosen because firms with less than 100 employees are unlikely to be engaged in new product development.

SME sent a pre-notification card to the executives two weeks prior to mailing the questionnaire. This card informed the potential respondents that they will be receiving the questionnaire in the near future, endorsed the research study and encouraged participation, and identified the researchers. Questionnaires were mailed to target respondents two weeks after the pre-notification card went out. The questionnaires were sent out using envelopes and stationary from SME and the cover letter was co-signed by an SME executive.

Sample characteristics appear on Table 13 which shows that the majority of respondents came from four manufacturing industries namely, SIC 34, 35, 36, and 37. In fact, 92 % of respondents belong to those four SIC codes. Two SIC codes (SIC 34 and SIC 35) accounted for 65% of respondents.

The respondents were asked to identify their positions within the firm and Table 13 summarizes the responses. The majority were top level executives while the rest are middle to high level executives. Over 43% for example were vice-presidents, presidents, or CEOs.

The respondents also identified the size of their firm. The data show that the majority of the firms are small (with less than 500 employees) which is quite representative of the population size distributions. Over 69% of the responding firms had less than 500 employees. Firms with more than 1000 employees accounted for only 15% of the sample.

4.1 RESEARCH METHODS

Results from 244 responses were analyzed here with several objectives in mind: purification, simplicity of factor structure, reliability, brevity, convergent and discriminant validity, as well as predictive validity. Using the responses, the time-based manufacturing practices and time-based product development practices items were purified before

Table 13: Description of Sample

RESPONDENTS BY SIC CODE:

SICCODE	NAME		PERCENT
34	FABRICATED METAL PRODUCTS EXCEPT MACH & TRANS EQPT		35
35	INDUSTRIAL & COMMERCIAL MACHINERY		30
36	ELECTRONIC, ELECTRICAL EQUIP & COMPONENTS		12
37	TRANSPORTATION EQUIPMENT		15
	MISCELLANEOUS		8
		TOTAL	**100**

RESPONDENTS BY POSITION:

POSITION		PERCENT
Presidents/CEO		12
Vice Presidents:		31
Directors		11
Managers		19
Miscellaneous		27
	TOTAL	**100**

FIRMS BY SIZE:

NUMBER OF EMPLOYEES		PERCENT
Up to 499		69
500 to 999		16
1000 to 4999		11
5000 to 9999		1
Over 10000		3
	TOTAL	**100**

conducting exploratory factor analysis. This was done because both instruments underwent a substantive revision after the pilot study. Including "garbage" items which do not have acommon core produces additional dimensions that may not be conceptually identified in the factor analysis (Churchill, 1979). Purification was performed using corrected-item-total-correlation (CITC) analysis. Items were eliminated if their CITC was less than 0.60. The competitive capabilities instrument was not altered significantly and thus it was not necessary to purify these items before exploratory factor analysis.

All instruments were then factor analyzed. DeVellis (1991) provides three reasons for using factor analysis. One of the primary functions of factor analysis is to help an investigator determine how many latent variables underlie a set of items (or other variable). A second purpose, which follows from the first, is to provide a means of explaining variation among relatively many original variables using relatively few newly created variables (i.e., factors). This amounts to condensing information so that variation can be accounted for by using a smaller number of variables. A third purpose is to define the substantive content or meaning of the factors (i.e., latent variables) that account for the variation among a larger set of items. This is accomplished by identifying groups of items that covary with one another and appear to define meanings that underlie latent variables. If anticipated item groupings are identified prior to factoring, a factor analytic solution that is consistent with these groupings provides some evidence of factorial validity (Comrey, 1988).

The number of factors to extract in this research was based on Kaiser's eigenvalues greater than 1 (e.g., Nunnally, 1978). This rule suggests retaining only factors that explain more variance than the average amount explained by one of the original items. The logic behind Kaiser's method is that (DeVellis, 1991) if the worst factor explains more variance than an original item, then one is achieving some degree of condensation (i.e., the ability to explain variation with a set of factors smaller than the original number of items).

To achieve a stable factor structure it is suggested that the ratio of respondents to items should be at least between 5 and 10 (Tinsley and Tinsley, 1987). Comrey (1988) also stated that a sample size of 200 is adequate in most cases of ordinary factor analysis that involve no more than 40 items. Items with factor loadings below 0.60 and/or cross-loadings of 0.30 or above were deleted.

The reliability of all the scales was examined using Cronbach's alpha along with computations of average variance extracted. Average variance extracted (Fornell and Larcker, 1981) is similar to the LISREL measure of composite reliability, but differs in that the standardized loadings are squared before summing them. It measures the amount of variance for the specified indicators accounted for by the latent construct. Higher variance extracted values occur when the indicators are truly representative of the latent construct. The variance extracted measure is a complementary measure to the construct reliability value. Guidelines suggest that the variance extracted value exceed 0.50 for a construct (Bagozzi and Yi, 1988).

It is in general desirable to develop scales that are reliable across groups of respondents. This is an attractive feature because researchers may use such scales confidently in different contexts. Cronbach's alpha reliabilities were calculated for each scale across four industries (sample sizes from other targeted industries were not adequate for reliability calculations). In general, reliabilities across industries above 0.80 would indicate that the scale performs well (Nunnally, 1978).

Next, discriminant validity was assessed using both the Multitrait-Multimethod (MTMM) matrix (Campbell and Fiske, 1959) and LISREL methodology (Bagozzi and Philips, 1982). Using LISREL methodology, models are constructed for all possible pairs of variables within each instrument. These models were run: (1) with the correlation between the latent variables fixed at 1.0, and (2) with the correlation between the latent variables free to assume any value. The difference in chi-square values for the fixed and free solutions indicate whether a uni-dimensional model would be sufficient to account for the inter-correlations among the observed variables in each pair. Due to the multiple comparisons (tests of differences in chi-squares), the alpha value (level of significance) has to be adjusted (alpha is divided by the number of comparisons)(Cohen and Cohen, 1983:167). To test for convergent validity, the lowest correlation within a construct was found and was tested to determine whether it is significantly different from zero.

Predictive validity was explored by correlating each practice scale with a composite measure of competitive capabilities. The predictive validity of each competitive capability scale was evaluated based on correlations between the scales and a measure of profitability (i.e., What is your profitability relative to the average in the industry?- Measured on a 7-point scale where 1: Considerably below, and 7: Considerably above).

Finally, using LISREL methodology, the target coefficient was used to test for the existence of a higher-order construct for each instrument (Marsch and Hocevar, 1985). Using the basic model of correlated first-order factors as the target model, the target coefficient is the chi-square ratio of the target model to the chi-square of the second-order model. It reflects the extent to which the higher-order factor model accounts for covariation among the first-order factors and can be interpreted as the percentage of variation in the first-order factors that can be explained by the second-order construct. In comparing first-order and second-order models, it is important to realize that the higher-order factors are merely trying to explain the covariation among the first-order factors in a more parsimonious way (i.e., one that requires fewer degrees of freedom) (Marsch and Hocevar, 1991). Consequently, even when the higher-order model is able to explain effectively the factor covariations, the goodness-of-fit of the higher order model can never be better than the corresponding first order model. High target coefficients provide evidence of a second-order structure.

Product development time was conceptualized here as the elapsed time from concept generation to market introduction. This was measured by an item which asked the respondents to indicate the elapsed time in months from concept generation to market introduction for what is typical in their dominant product line. This item was correlated in the pilot study with another measure of product development time (derived from a Gantt chart). The correlation was highly significant (r=0.98). The Gantt chart measure was not used in the large scale administration due to space limitations. The mean product development time from the large scale data was 10.63 months and the standard deviation 8.93. The lowest product development time reported was 1 month and the highest 48 months.

Throughput time was conceptualized as the total time a typical unit spends in the manufacturing system, from the time raw materials are received until the product is shipped. Four items were used asking the respondents to indicate how much time units of the dominant product line typically spend at each stage. Stages included: (1) days of raw materials inventory, (2) value added time, (3) days of work-in-process (WIP) inventory, and (4) days in finished goods inventory. The time at each stage was added to form an aggregate measure of throughput time. The mean throughput time derived from the large scale data was 84.20 days and the standard deviation 76.27. The lowest throughput time reported was 3 days and the highest was 370 days.

4.2 LARGE SCALE MEASUREMENT RESULTS

4.2.1 Competitive Capabilities Instrument

An exploratory factor analysis was conducted on the 26 items proposed after the pilot using principal components as the means of extraction and oblimin as the method of rotation (Table 14). The ratio of respondents to items was 9.4 and meets the general guidelines. Without specifying the number of factors, there were five factors with eigenvalues greater than 1. Eigenvalues for the factors varied from 1.58 for factor 5 to 8.28 for factor 1. The cumulative variance explained by the five factors was 74 percent. For simplicity, Table 14 shows only loadings above 0.30. All items loaded on their respective factors and there were no items with cross-loadings greater than 0.30. In general, it was desirable to have all items with loadings greater than 0.60.

Table 14: Exploratory Factor Analysis for Competitive Capabilities.

ITEM	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
QP6	.87				
QP4	.81				
QP1	.79				
QP13	.73				
QP7	.72				
QP2	.68				
QP14	.66				
QP3	.57				
CP6		.93			
CP5		.91			
CP4		.90			
CP2		.89			
CP3		.88			
CV6			-.98		
CV2			-.94		
CV8			-.90		
CV7			-.90		
PR2				.93	
PR4				.92	
PR1				.90	
PR5				.88	
PI5					.84
PI3					.83
PI6					.80
PI2					.76
PI1					.68
Eigenvalue	8.28	4.40	2.61	2.37	1.58
% of Variance	31.8	16.9	10.0	9.1	6.1
Cumulative % of Variance	31.8	48.8	58.8	67.9	74.0

The first factor was interpreted as value to customer quality (factor 1). One item (QP3) was eliminated due to a loading less than 0.60. All the competitive pricing items (factor 2) loaded on a single factor and the loadings were greater than 0.87. The five customer delivery service items (factor 3) loaded together on a single factor with loadings greater than 0.90. All the premium pricing items (factor 4) also loaded together on a single factor and the lowest loading was 0.88. The five product innovation items loaded on a single factor (factor 5) and all loadings were greater than 0.68. Overall, the factor pattern matrix was simple; all of the items loaded high in their respective factors and low on others.

Cronbach's alpha and average variance extracted were then calculated for all factors. The first factor, value to customer quality, had seven items and a reliability alpha of 0.90. The average variance extracted for this scale was 0.65. The competitive pricing scale (factor 2) had five items and reliability alpha of 0.95. One item (CP2) had similar wording with other items in the scale and its removal did not change alpha significantly. The revised alpha is 0.94. The average variance extracted for this scale was 0.80. The customer delivery service scale (factor 3) had an alpha of 0.95 for four items and average variance extracted of 0.84. The premium pricing scale (factor 4) with four items had an alpha of 0.93 and average variance extracted of 0.76. The reliability of the product innovation scale was 0.86 and the average variance extracted for the scale was 0.56. Cronbach's alpha and average variance extracted for retained items are shown on Table 15. Overall, there was only one item (CP2) deleted at this stage, the reliabilities were high, and average variance extracted for each scale met the acceptable criterion of 0.50.

Table 15: Descriptive Statistics, Correlations, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Competitive Capabilities (based on retained Items).

Variables	Means	s.d.	1	2	3	4	5
1.Value to Customer Quality	41.56	5.21	0.90[a] [0.65][b]				
2.Competitive Pricing	17.88	5.16	0.22** (75.85$)	0.94 [0.80]			
3.Customer Delivery Service	21.03	5.19	0.40** (47.05$)	0.37** (6.86)	0.95 [0.84]		
4.Premium Pricing	20.21	4.60	0.41** (57.85$)	0.03** (52.51$)	0.16** (30.59$)	0.93 [0.76]	
5.Product Innovation	26.89	5.01	0.59** (72.72$)	0.15** (63.48$)	0.15** (57.51$)	0.31** (47.33$)	0.86 [0.56]

** Correlation is significant at 0.01.
$ X^2 differences are indicated in parentheses.
Differences in X^2 for 1 degree of freedom are significant at 0.05, $X^2_{0.003}$=8.50.
a Reliability alphas for retained items are on the diagonal.
b Average variance extracted for retained items are on the diagonal in brackets.

Table 16: Overall and by Industry Reliabilities for Competitive Capability (based on retained items).

Scale	Overall Reliability	SIC 34 (92 CASES)	SIC 35 (68 CASES)	SIC 36 (29 CASES)	SIC 37 (33 CASES)
Value to Customer Quality	0.90	0.88	0.90	0.91	0.89
Competitive Pricing	0.94	0.93	0.94	0.94	0.94
Customer Delivery Service	0.95	0.95	0.94	0.97	0.94
Premium Pricing	0.93	0.94	0.92	0.94	0.89
Product Innovation	0.86	0.82	0.85	0.90	0.88

Reliability for retained items was also assessed by calculating Cronbach's alpha for each scale across four industries (Table 16). The minimum reliability observed for any scale was 0.82 for product innovation in SIC 34 and the majority of scales have reliabilities greater than 0.90. All scales exhibit good reliabilities across different industries. It is also evident from Table 16 that reliabilities are stable across the industries. The range of differences in alpha values for each scale varies from 0.01 for the competitive pricing scale to 0.06 for the product innovation scale.

LISREL methodology was employed to test for discriminant validity between pairs of constructs in the five factor solution (Bagozzi and Phillips, 1982). Ten models showing pairs of latent variables and their observable variables were run: (1) with the correlation between the latent variables fixed at 1.0, and (2) with the correlation between the latent variables free to assume any value. The difference in chi-square values for the fixed and free solutions indicate whether a uni-dimensional model would be sufficient to account for the inter-correlations among the observed variables in each pair. The difference between the chi-square values (one degree of freedom) for the fixed and free solutions for the 10 pairs are listed in Table 15. Due to the multiple comparisons, the alpha value was adjusted (alpha is divided by the number of comparisons). For 10 comparisons, the chi-square value for any pair must be greater than or equal to approximately 7.88 for significance at the $p<0.05$ (Cohen and Cohen, 1983: 167). Nearly all the chi-square differences for the tests were greater than 30.59 (for premium pricing with customer delivery service) indicating discriminant validity. One pair (competitive pricing with customer delivery service) showed a chi-square difference of 6.86. Although for a single test, this difference is significant at 0.01 ($X^2_{0.01}$ for 1 df=6.63). When compared to the multiple test critical value it is not significant. A qualitative examination of the items showed no apparent reason for the low chi-square difference for this pair.

The correlations between the factors, and descriptive statistics are also shown on Table 15. These correlations were derived from LISREL output which corrects for attenuation. It is noticeable that the correlations between the value to customer quality factor and premium pricing, customer delivery service, and product innovations are all very significant ($p<0.01$). Considering the discriminant validity tests however, the results suggest that the factors must be regarded as distinct, although they are highly correlated.

Tests for discriminant validity were also conducted using the traditional MTMM procedure (Table 17). Out of a total of 454 comparisons there were five violations and all involved the product innovation scale items. The reason is the relatively low within correlations of the product innovation items. This number of violations is not significant.

To test for convergent validity the lowest correlation within a construct was found (Table 17) and was tested if it was different from zero. The lowest correlation for value to customer quality was 0.45, for competitive pricing 0.76, for customer delivery service 0.78, for premium pricing 0.71, and for product innovation 0.36. All were very significant at $p<0.01$ providing evidence for convergent validity.

To evaluate predictive validity, all five scales were correlated with a measure of profitability. The correlations with profitability are significant (with value to customer quality=0.28, with competitive pricing=0.30, with customer delivery service=0.25, with premium pricing=0.39, and with product innovation=0.16). All correlations were

Table 17: Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Competitive Capabilities.

	CP3	CP4	CP5	CP6	PR1	PR2	PR4	PR5	QP1	QP2	QP4	QP6	QP7	QP13	QP14	CV2	CV6	CV7	CV8	PI1	PI2	PI3	PI5	PI6
CP3	1.00																							
CP4	.75	1.00																						
CP5	.78	.78	1.00																					
CP6	.79	.86	.84	1.00																				
PR1	-.08	.00	.01	.01	1.00																			
PR2	-.06	.05	.03	.03	.82	1.00																		
PR4	-.02	.07	.06	.05	.77	.79	1.00																	
PR5	-.03	.04	.05	.05	.71	.74	.76	1.00																
QP1	.10	.19	.15	.17	.20	.22	.20	.24	1.00															
QP2	.18	.20	.16	.19	.29	.26	.28	.27	.52	1.00														
QP4	.16	.19	.10	.18	.26	.23	.22	.25	.51	.45	1.00													
QP6	.13	.18	.12	.15	.31	.30	.26	.22	.50	.57	.59	1.00												
QP7	.07	.10	.07	.11	.34	.28	.31	.28	.51	.48	.59	.62	1.00											
QP1	.10	.17	.17	.21	.34	.29	.35	.31	.52	.54	.56	.65	.70	1.00										
QP1	.11	.17	.12	.15	.26	.28	.22	.21	.50	.51	.58	.57	.57	.61	1.00									
CV2	.27	.34	.29	.30	.12	.12	.16	.13	.29	.38	.24	.24	.35	.37	.25	1.00								
CV6	.31	.36	.31	.33	.09	.08	.15	.12	.17	.28	.18	.18	.30	.30	.16	.90	1.00							
CV7	.29	.37	.32	.31	.12	.11	.17	.13	.26	.31	.29	.25	.33	.36	.21	.83	.83	1.00						
CV8	.27	.31	.27	.29	.13	.15	.17	.18	.24	.33	.28	.29	.40	.43	.26	.83	.83	.78	1.00					
PI1	-.05	.00	-.00	-.04	.15	.13	.08	.13	.25	.24	.16	.19	.23	.21	.25	.01	-.03	-.03	-.01	1.00				
PI2	-.07	.03	-.02	-.03	.29	.24	.22	.29	.30	.29	.34	.36	.39	.35	.49	.14	.10	.11	.15	.59	1.00			
PI3	.12	.20	.22	.21	.20	.18	.17	.23	.24	.27	.33	.36	.40	.43	.45	.16	.10	.16	.17	.44	.59	1.00		
PI5	.02	.11	.10	.10	.24	.23	.20	.25	.26	.30	.32	.32	.41	.36	.52	.13	.05	.16	.10	.37	.58	.70	1.00	
PI6	.07	.15	.15	.15	.24	.24	.20	.22	.24	.28	.32	.32	.35	.39	.55	.16	.10	.13	.15	.36	.51	.64	.73	1.00
	CP3	CP4	CP5	CP6	PR1	PR2	PR4	PR5	QP1	QP2	QP4	QP5	QP7	QP13	QP14	CV2	CV6	CV7	CV8	PI1	PI2	PI3	PI5	PI6
Mean	4.26	4.69	4.34	4.59	5.14	5.08	5.07	4.91	6.04	5.96	5.91	5.96	5.98	5.94	5.76	5.25	5.20	5.27	5.31	5.71	5.57	5.31	5.29	5.00
SD	1.46	1.31	1.45	1.38	1.31	1.25	1.17	1.33	.87	.94	.99	.84	.90	.93	1.16	.42	1.47	1.31	1.33	1.31	1.17	1.25	1.22	1.31
Number of Violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2

Note: Correlations above 0.13 are significant at 0.05, Correlations above 0.17 are significant at 0.01.

significant at $p<0.01$ except for the product innovation which was significant at $p<0.05$.

LISREL methodology was employed to assess a second-order factor structure. LISREL's maximum likelihood estimates of the target model's completely standardized parameter estimates are presented in Table 18 for both latent variables and observed variables. For the observed variables, Table 18 shows factors loadings, their corresponding t-values, and R-square values. A t-value is a ratio of an estimated parameter to the standard error, is distributed as a t-statistic, and anything greater than 1.96 is significant (Marsch and Hocevar, 1985:569). Traditionally, a t-value greater than 2 is considered significant. With t-values above 2.0 being considered significant, factor loadings can be interpreted as indicators of validity for the 24 items. Almost all items have large (greater than .65) and significant loadings on their corresponding factors, indicating evidence of good construct validity. Item PI1 is the only one that has a relatively low loading (.52), although it is still significant. For the latent variables, Table 18 presents the standard structural coefficients, their corresponding t-values, and R-square values. Standard structural coefficients can be interpreted as indicators of validity of the latent factors as components of the construct. With t-values above 2.0 being considered significant, all factors have acceptable and significant structural coefficients, indicating good construct validity.

The target coefficient index (the ratio of chi-square of the first order model to the chi-square of the higher order model) is an index used to provide evidence of the existence of a higher order construct (Marsch and Hocevar, 1985). It reflects the extent to which the higher-order factor model accounts for covariation among the first-order

Table 18: Completely Standardized Parameter Estimates and t-values for Competitive Capabilities(n=244) (5 first order Factors, 1 Second-Order Factor)

OBSERVED VARIABLES			LATENT VARIABLES		
Item	Factor Loading	R-Square (Reliability)	Factor	Std. Structure Coefficient	R-Square (Reliability)
CP3	.85&	.72	Competitive Pricing	.24(3.39)	.06
CP4	.90(18.79)	.81			
CP5	.89(18.46)	.79			
CP6	.94(20.55)	.89			
PR1	.89&	.78	Premium Pricing	.43(5.90)	.18
PR2	.91(20.64)	.83			
PR4	.88(19.33)	.77			
PR5	.83(17.24)	.69			
QP1	.65&	.43	Value to Customer Quality	.97(8.84)	.94
QP2	.67(9.23)	.45			
QP4	.72(9.83)	.52			
QP6	.78(10.47)	.61			
QP7	.80(10.71)	.64			
QP13	.83(10.99)	.69			
QP14	.76(10.22)	.57			
CV2	.95&	.90	Customer Delivery Service	.41(5.79)	.17
CV6	.95(30.82)	.90			
CV7	.88(23.26)	.77			
CV8	.88(23.58)	.77			
PI1	.52&	.27	Innovation	.61(6.05)	.37
PI2	.71(7.58)	.50			
PI3	.82(8.10)	.67			
PI5	.85(8.25)	.73			
PI6	.80(8.04)	.64			
X^2=429.43			X^2=457.83		

Note: & Indicates a parameter fixed at 1.0 in the original solution.
t-values for item factor loadings and factor structural coefficients are indicated in parentheses.

factors and can be interpreted as the percent of variation in the first-order factors that can be explained by the second-order construct. The target value for this instrument was 0.94 indicating that the second-order model explains a large amount of covariation among the five first-order constructs.

Overall, 24 items and six scales (Appendix B) are proposed for the competitive capabilities instrument. The number of proposed items varies from four for competitive pricing, premium pricing, customer delivery service to seven for value to customer quality. All scales have high reliabilities and behave well when subjected to an assortment of validity tests. The data also shows that a single second-order model explains much of the covariation of the five first-order constructs.

4.2.2 Time-Based Manufacturing Practices Instrument

The assessment of this instrument with six variables and 40 items begins with scale purification. The five shop-floor employee involvement items are analyzed separately for the measurement model as was indicated after the pilot study. The corrected-item-total-correlations (CITCs) for all 40 items are shown in Table 19. Items with CITC below 0.60 are shown in bold. Three items (MC1, MC5, and MC6) of the cellular manufacturing scale, three items (QI2, QI4, and QI15) of the quality improvement scale, and three items (RS13, RS15, and RS11) from the setup re-engineering scale were eliminated because they had CITCs below 0.60. In addition, one item (PM1) from the preventive maintenance scale and two items (PP1 and PP8) of the pull production scale were deleted due to CITCs below the cutoff point. No items could be removed from the dependable supplier

Table 19: Purification for Time-Based Manufacturing (Large Scale).

ITEMS	Corrected-Item Total Correlation
PM1.There is a separate shift, or part of a shift, reserved for preventive maintenance activities.*	**.58**
PM3.We emphasize good preventive maintenance.	.78
PM5.Records of routine maintenance are kept.	.63
PM6.We do preventive maintenance.	.84
PM7.We do preventive maintenance during non-productive time.	.61
PM8.We maintain our equipment regularly.	.80
DS1.We receive parts from suppliers on time.	.60
DS4.We receive the correct number of parts from suppliers.	.60
DS7.We receive the correct type of parts from suppliers.	.76
DS9.We receive parts from suppliers that meet our specifications.	.75
DS10.Our suppliers accommodate our needs.	.73
DS11.We receive high quality parts from suppliers.	.73
MC1.Products with design or processing similarities are produced together.	**.47**
MC2.Products that share similar design or processing requirements are grouped into families of products.	.69
MC3.Products are classified into groups with similar processing requirements.	.66
MC4.Products are classified into groups with similar routing requirements.	.67
MC5.A coding classification is used to group parts into families.	**.49**
MC6.Our factory layout groups different machines together to produce families of products.	**.45**
MC7.Equipment is grouped to produce families of products.	.69
MC8.Families of products determine our factory layout.	.62
PP1.We do not produce unless there is a demand in the next station.	**.45**
PP3.Production is "pulled" by the shipment of finished goods.	.64
PP5.Production at stations is "pulled" by the current demand of the next stations.	.69
PP6.We use a "pull" production system.	.77
PP8.We use kanban to pull production.	**.48**

***Note:** Items in bold have CITC below 0.60.

Table 19 (Continued): Purification for Time-Based Manufacturing (Large Scale).

ITEMS	Corrected-Item Total Correlation
QI1.We use fishbone type diagrams to identify causes of quality problems.	.60
QI2.The production line is shut down through an "automatic stop" when defects are detected.*	**.41**
QI4.We aim for a process design which prevents employee errors.	**.40**
QI5.We use design of experiments (i.e., Tageuchi methods).	.68
QI15.We communicate quality specifications to suppliers.	**.42**
QI8.Our employees use quality control charts (e.g., SPC charts).	.68
QI16.We conduct process capability studies.	.71
RS13.Standard setups are developed for new processes.	**.40**
RS14.Employees work on setup improvement.	.73
RS15.Tools for setup are conveniently located.	**.51**
RS16.Employees redesign or reconfigure equipment to shorten setup time.	.61
RS17.Employees redesign jigs or fixtures to shorten setup time.	.71
RS11.We have been working towards improving setup times.	**.59**
RS18.We use special tools to shorten setup.	.65
RS19.Our employees are trained to reduce setup time.	.73

scale due to CITCs. Overall, 12 items were removed because of CITCs lower than 0.60. The number of items entering the exploratory factor analysis stage is 28.

An exploratory factor analysis (Table 20) was then conducted using principal components as the means of extraction and oblimin as the method of rotation. The ratio of respondents to items is 8.71, adequate for exploratory factor analysis. Without specifying the number of factors, there were six factors with eigenvalues greater than 1. Eigenvalues varied from 1.42 for factor 6 to 8.08 for factor 1. The cumulative variance extracted by the six factors was 69 percent. For simplicity, only loadings greater than 0.30 are shown in the factor pattern matrix. All items loaded on their intended factors

Table 20: Exploratory Factor Analysis for Retained Time-Based Manufacturing Items.

ITEM	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6
PM6	.94					
PM8	.89					
PM3	.81					
PM5	.72					
PM7	.68					
DS9		.85				
DS7		.85				
DS11		.82				
DS10		.79				
DS4		.72				
DS1		.71				
MC2			.87			
MC4			.83			
MC3			.82			
MC7			.69			
MC8			.62			
PP3				.89		
PP6				.87		
PP5				.79		
QI1					.86	
QI16					.83	
QI8					.80	
QI5					.79	
RS17						-.86
RS14						-.75
RS19						-.73
RS16						-.72
RS18						-.71
Eigenvalue	8.08	3.50	2.46	2.00	1.86	1.42
% of Variance	28.8	12.5	8.8	7.1	6.6	5.1
Cumulative % of Variance	28.8	41.3	50.1	57.2	63.9	69.0

and had loadings greater than 0.60. There were no cross-loadings greater than 0.30 and the factor structure was readily interpretable.

The first factor (factor 1) was interpreted as preventive maintenance and the lowest loading was 0.68 for item PM7. The second factor can be interpreted as dependable suppliers (factor 2) and the lowest loading was 0.71 for item DS1. The items for cellular manufacturing formed the third factor (factor 3) and item MC8 had the lowest loading of 0.62. The three pull production items loaded together to form the fourth factor (factor 4) and the lowest loading was 0.79 for item PP5. The fifth factor was interpreted as quality improvement efforts (factor 5). Item QI16 had the lowest loading of 0.79.

Finally, all five items of the re-engineering scale loaded together to form the sixth factor and the lowest loading was -0.71 for item RS18. Overall, there were no items deleted due to low loadings (i.e., less than 0.60) or high cross loadings (i.e., greater than 0.30). Cronbach's alpha and average variance extracted were then calculated for all factors. The first factor, preventive maintenance (factor 1) had five items and a reliability alpha of 0.90. The average variance extracted for this scale computed using LISREL output was 0.65. The dependable supplier scale (factor 2) had six items and reliability alpha of 0.88. Variance extracted for this scale was 0.56. The cellular manufacturing factor (factor 3) had an alpha of 0.85 for five items and variance extracted of 0.53. The pull production scale (factor 4) with three items had an alpha of 0.87 and variance extracted of 0.70. The reliability of the quality improvement scale (factor 5) was 0.86 and variance extracted was 0.61. The re-engineering setup (factor 6) had a reliability of 0.88 for five items and a variance extracted of 0.58. Reliability estimates and average

Table 21: Descriptive Statistics, Correlations, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Time-Based Manufacturing Scales (based on retained items).

Variables	Means	s.d.	1	2	3	4	5	6
1.Preventive Maintenance	17.47	4.46	0.90[a] [0.65][b]					
2.Dependable Suppliers	22.87	3.36	0.53** (36.03$)	0.88 [0.56]				
3.Cellular Manufacturing	17.97	4.22	0.47** (58.02$)	0.32** (72.31$)	0.85 [0.53]			
4.Pull Production	9.64	3.39	0.68** (29.98$)	0.42** (52.06$)	0.51** (56.77$)	0.87 [0.70]		
5.Quality Improvement Efforts	10.50	4.40	0.77** (23.00$)	0.57** (35.05$)	0.45** (64.10$)	0.62** (38.01$)	0.86 [0.61]	
6.Re-engineering Setup	15.56	3.96	0.50** (37.34$)	0.57** (27.89$)	0.36** (65.02$)	0.38** (53.41$)	0.57** (30.48$)	0.87 [0.58]

** Correlation is significant at 0.01.
$ X^2 differences are indicated in parentheses.
Differences in X^2 for 1 degree of freedom are significant at 0.05, $X^2_{0.003}$=8.50.
a Reliability alphas for retained items are on the diagonal.
b Average variance extracted for retained items are on the diagonal in brackets.

Table 22: Overall and by Industry Reliabilities for Time-Based Manufacturing (based on retained items).

Scale	Overall Reliability	SIC 34 (92 CASES)	SIC 35 (68 CASES)	SIC 36 (29 CASES)	SIC 37 (33 CASES)
Preventive Maintenance	0.90	0.84	0.89	0.94	0.89
Dependable Suppliers	0.88	0.92	0.87	0.80	0.90
Cellular Manufacturing	0.85	0.86	0.85	0.80	0.87
Pull Production	0.87	0.84	0.84	0.93	0.87
Quality Improvement Efforts	0.86	0.88	0.82	0.89	0.76
Re-engineering Setup	0.87	0.88	0.85	0.90	0.87

variance extracted for retained items are shown on Table 21. No items from any of the scales could be removed without significantly affecting reliability and/or the content of the scales. All scales exhibited high reliability and acceptable average variance extracted.

To further assess reliability, Cronbach's alpha for each scale was computed across four industries (Table 22). Almost all reliabilities were above 0.80. The reliability for the quality improvement scale in SIC 37 was 0.76. In other SIC codes the same scale performed well with reliabilities ranging from 0.82 to 0.89. The majority of reliabilities for other scales were either greater than 0.90 or very close to it. It is also evident in Table 22 that reliabilities do not vary significantly across the industries. The range of differences in alpha values for each scale varied from 0.05 for the re-engineering setup scale to 0.13 for the quality improvement scale.

Discriminant validity was re-examined at this phase due to the small sample size used for the pilot, the addition and modification of items, and the reconceptualization of several variables. The researchers employed LISREL methodology to test for discriminant validity (Bagozzi and Phillips, 1982) between pairs of constructs in the six factor solution. The difference between the chi-square values (one degree of freedom) for the fixed and free solutions for the 15 pairs are listed in Table 21. For 15 comparisons, the chi-square value for any pair must be greater than or equal to approximately 8.5 for significance at the $p<0.05$ (Cohen and Cohen, 1983: 167). All the chi-square differences for the tests were greater than 41.26 (for manufacturing cells with pull production) indicating good discriminant validity.

The correlations between the factors, and descriptive statistics are shown on Table

21. These correlations were derived from LISREL output which corrects for attenuation. It is notable that the correlations between the preventive maintenance and pull production (r=0.68), preventive maintenance and quality improvement efforts (r=0.77), and pull production and quality improvement efforts (r=0.62) variable are strong. Considering the discriminant validity tests however, the results suggest that the factors must be regarded as distinct, although they are highly correlated.

Tests for discriminant validity were also conducted using the traditional MTMM procedure (Table 23). Out of a total of 648 potential comparisons there were zero violations indicating again high discriminant validity. To test for convergent validity the lowest correlation within a construct was found (Table 23) and was tested to see if it was different from zero. The lowest correlation for preventive maintenance was 0.44, for dependable suppliers 0.45, for cellular manufacturing 0.38, for pull production 0.58, for quality improvement efforts 0.45, and for re-engineering setup 0.45. All were very significant at $p<0.01$ indicating good convergence.

To evaluate predictive validity, all six scales were correlated with a composite measure of competitive capabilities. The measure of competitive capabilities (alpha=0.90) includes items from five scales including competitive pricing, premium pricing, product innovation, value to customer quality and customer delivery service. The correlations with the composite measure of competitive capabilities were generally significant (with preventive maintenance=0.35, with dependable suppliers 0.29, with cellular manufacturing=0.23, with pull production=0.16, with quality improvement efforts=0.21, and with re-engineering setup=0.32). All correlations were significant at the $p<0.01$,

Table 23: Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Time-Based Manufacturing Practices.

	MC2	MC3	MC4	MC7	MC8	RS4	RS9	RS13	RS14	RS15	PM3	PM5	PM6	PM7	PM8	PP3	PP5	PP6	QI1	QI5	QI8	QI16	DS1	DS4	DS7	DS9	DS10	DS11
MC2	1.00																											
MC3	.65	1.00																										
MC4	.62	.61	1.00																									
MC7	.54	.51	.50	1.00																								
MC8	.49	.38	.43	.61	1.00																							
RS4	.31	.29	.24	.34	.27	1.00																						
RS9	.23	.24	.32	.32	.33	.54	1.00																					
RS13	.21	.26	.20	.34	.27	.62	.63	1.00																				
RS14	.28	.36	.27	.41	.35	.56	.45	.56	1.00																			
RS15	.19	.24	.23	.32	.31	.64	.52	.63	.60	1.00																		
PM3	.17	.25	.13	.24	.19	.47	.35	.40	.39	.49	1.00																	
PM5	.12	.21	.12	.19	.14	.33	.24	.28	.29	.38	.54	1.00																
PM6	.10	.18	.15	.24	.12	.34	.34	.33	.32	.39	.78	.62	1.00															
PM7	.19	.24	.18	.23	.25	.24	.26	.34	.23	.30	.52	.44	.59	1.00														
PM8	.14	.21	.14	.26	.21	.40	.33	.36	.42	.47	.76	.63	.82	.54	1.00													
PP3	.13	.08	.09	.24	.18	.20	.17	.25	.20	.19	.22	.14	.16	.32	.14	1.00												
PP5	.23	.11	.22	.27	.32	.31	.29	.28	.20	.29	.24	.26	.19	.35	.24	.58	1.00											
PP6	.23	.13	.20	.30	.31	.27	.24	.29	.24	.26	.29	.23	.25	.39	.23	.76	.69	1.00										
QI1	.18	.21	.19	.14	.19	.25	.26	.22	.16	.31	.28	.17	.17	.16	.14	.09	.20	.20	1.00									
QI5	.10	.13	.18	.19	.20	.35	.36	.32	.30	.39	.29	.22	.27	.22	.26	.18	.27	.27	.57	1.00								
QI8	.14	.14	.08	.23	.21	.38	.32	.32	.36	.42	.32	.26	.32	.22	.29	.16	.19	.18	.55	.58	1.00							
QI16	.20	.15	.20	.22	.18	.39	.32	.32	.35	.40	.29	.29	.30	.22	.26	.10	.26	.22	.55	.63	.70	1.00						
DS1	.06	.06	.01	.07	.07	.13	.06	.14	.14	.19	.17	.24	.13	.12	.17	.10	.14	.14	.05	.08	.03	.08	1.00					
DS4	.06	.14	.00	.04	-.01	.06	-.05	-.03	.10	.06	.16	.27	.14	.07	.14	.12	.09	.08	-.04	.03	-.01	-.02	.48	1.00				
DS7	.06	.21	.08	.13	.05	.17	.09	.11	.22	.20	.14	.29	.20	.15	.20	.09	.10	.12	.04	.12	.11	.05	.49	.58	1.00			
DS9	.05	.20	.08	.06	.07	.14	.12	.15	.16	.23	.14	.23	.16	.17	.19	.11	.11	.14	.03	.09	.03	.03	.47	.49	.70	1.00		
DS10	.14	.19	.14	.11	.11	.11	.11	.14	.13	.22	.18	.28	.24	.19	.27	-.01	.04	.04	.10	.12	.13	.09	.54	.46	.64	.62	1.00	
DS11	.13	.23	.08	.16	.11	.13	.10	.16	.24	.28	.19	.23	.20	.15	.21	.05	.08	.08	.03	.16	.13	.11	.49	.45	.62	.71	.64	1.00
	MC2	MC3	MC4	MC7	MC8	RS4	RS9	RS13	RS14	RS15	PM3	PM5	PM6	PM7	PM8	PP3	PP5	PP6	QI1	QI5	QI8	QI16	DS1	DS4	DS7	DS9	DS10	DS11
Mean	3.6	3.71	3.63	3.58	3.45	3.27	2.97	3.01	3.28	3.02	3.35	3.78	3.49	3.32	3.53	3.38	3.14	3.12	2.45	2.15	3.09	2.80	3.60	3.74	3.93	3.93	3.88	3.80
SD	1.09	.95	1.05	1.07	1.17	.91	.96	1.02	.95	1.03	1.04	1.06	1.11	1.06	1.06	1.33	1.16	1.32	1.28	1.19	1.35	1.44	.75	.72	.67	.68	.69	.72
Number of Violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: Correlations above 0.13 are significant at 0.05, Correlations above 0.17 are significant at 0.01.

except for the pull production scale which was significant at $p<0.05$.

LISREL's maximum likelihood estimates of the target model's completely standardized parameter estimates are presented in Table 24 for both latent variables and observed variables. For the observed variables, Table 24 shows factors loadings, their corresponding t-values, and R-square values. All 28 items have large (greater than .62) and significant loadings on their corresponding factors, indicating evidence of good construct validity. For the latent variables, Table 24 presents the standard structural coefficients, their corresponding t-values, and R-square values. All factors have acceptable and significant structural coefficients, indicating good construct validity.

The target coefficient index (the ratio of chi-square of the first order model to the chi-square of the higher order model) is an index used to provide evidence of the existence of a higher order construct (Marsch and Hocevar, 1985). The target value for this instrument was 0.98 indicating that the second-order model explains a large amount of covariation among the six first-order constructs.

Overall, 28 items and six scales are proposed for the time-based manufacturing practices instrument. The number of proposed items varies from three for pull production to six for dependable suppliers. All scales have high reliabilities and behave well when subjected to an assortment of validity tests.

The shop-floor employee involvement in problem solving scale is analyzed separately here from the rest of time-based manufacturing practices because the pilot study data provided strong indications that employee involvement in problem solving might be an antecedent to other time-based efforts in manufacturing. Thus, it would not be

Table 24:Completely Standardized Parameter Estimates and t-values for Time-Based Manufacturing Practices(n=244) (7 first order Factors, 1 Second-Order Factor)

OBSERVED VARIABLES			LATENT VARIABLES		
Item	Factor Loading	R-Square (Reliability)	Factor	Std. Structure Coefficient	R-Square (Reliability)
MC2	.80&	.64	Manufacturing Cells	.53(6.82)	.28
MC3	.76(11.94)	.57			
MC4	.75(11.79)	.56			
MC7	.73(11.49)	.53			
MC8	.64(9.84)	.40			
RS17	.79&	.62	Reengineering Setup	.88(10.96)	.78
RS14	.70(11.11)	.49			
RS19	.79(12.87)	.63			
RS16	.72(11.46)	.51			
RS18	.81(13.16)	.65			
PM3	.85&	.72	Preventive Maintenance	.64(8.83)	.41
PM5	.68(12.02)	.47			
PM6	.91(18.69)	.83			
PM7	.63(10.74)	.39			
PM8	.90(18.33)	.81			
PP3	.80&	.63	Pull Production	.45(5.98)	.21
PP5	.73(12.29)	.54			
PP6	.95(14.35)	.90			
QI1	.68&	.46	Quality Improvement Efforts	.62(7.39)	.38
QI5	.76(10.28)	.57			
QI8	.81(10.88)	.66			
QI16	.84(11.16)	.71			
DS1	.62&	.38	Supplier Support	.31(3.90)	.09
DS4	.62(8.24)	.39			
DS7	.82(10.08)	.68			
DS9	.83(10.17)	.69			
DS10	.78(9.73)	.61			
DS11	.80(9.91)	.64			
X^2=551.11			X^2=561.40		

Note: & Indicates a parameter fixed at 1.0 in the original solution.
t-values for item factor loadings and factor structural coefficients are indicated in parentheses.

appropriate to analyze it together with other manufacturing practices.

The reliability alpha of the employee involvement scale was 0.88 and no item could be removed without affecting alpha and/or the composition of the scale. Factor loadings (Table 25) for the five items of the variable varied from 0.75 for item EE3 to 0.89 for EE5. No items could be removed based on reliability or factor analysis. The generalizability of reliability was assessed by calculating Cronbach's alpha for the scale across four industries (Table 26). It is evident from Table 26 that reliabilities are stable across the industries. The range of differences in alpha values for the scale was 0.09 indicating no significant variation in reliability.

Table 25: Factor Loadings for the Shop-Floor Employee Involvement in Problem Solving Scale.

ITEMS	FACTOR1
PS1. Shop-floor employees are involved in problem solving efforts.	.8271
PS4. Shop floor employees are involved in designing processes and tools that focus on improvement.	.7883
PS5. Shop-floor employees are involved in improvement efforts.	.8932
PS6. Shop-floor employees are involved in problem solving teams.	.8546
PS3. Shop-floor employees are involved in suggestion programs.	.7541

Table 26: Overall and by Industries Reliabilities for the Shop-Floor Employee Involvement in Problem Solving Scale.

Scale	Overall Reliability	SIC 34 (92 CASES)	SIC 35 (68 CASES)	SIC 36 (29 CASES)	SIC 37 (33 CASES)
Shop-Floor Employee Involvement in Problem Solving	0.88	0.88	0.83	0.91	0.92

4.2.3 Time-Based Product Development Practices Instrument

The assessment of this instrument began with scale purification. Corrected-item total correlations (CITCs) for the 44 items are shown Table 27. Items with CITC less than 0.60 were eliminated and are depicted in bold print. All five items of the product development teams scale had CITCs greater than 0.60. Two items (EI2 and EI6) of the early involvement scale and one item (CW3) from the concurrent work-flow scale had CITC below 0.60 and were deleted. One other item from the concurrent engineering scale had a CITC equal to 0.57, and it was a candidate for deletion. This item was retained for two reasons: first, its content was deemed essential for the composition of the scale. Second, its CITC in a composite scale of concurrent work-flow, product development teams, and early involvement items was adequate. The pilot study indicated that these three variables could be analyzed together.

All items from the customer involvement, supplier involvement, and computer usage scales had CITCs above 0.60, and none were removed from further analysis. One item (HM2) from the heavyweight product development scale and one item (DF2) from the platform products scale were also deleted for low CITCs. Overall, five items were removed from further analysis due to CITCs below 0.60. A total of 39 items were retained for further analysis.

An exploratory factor analysis (Table 28) was conducted then using principal components as the means of extraction and oblimin as the method of rotation. The ratio of respondents to items was 6.26, adequate for exploratory factor analysis. Without specifying the number of factors, there were six factors with eigenvalues greater than 1.

Table 27: Purification Time-Based Product Development (Large Scale).

ITEMS	Corrected-Item Total Correlation
CW1.Product and process designs are developed concurrently by a group of employees from various disciplines.*	.57
CW3.Our organization uses formal techniques, such as Quality Functional Deployment, to translate customer preferences into product and process parameters.	.45
CW7.Much of process design is done concurrently with product design.	.60
CW8.Product development activities are concurrent.	.70
PT1.Product development group members share information.	.71
PT3.Product development group members represent a variety of disciplines.	.68
PT4.Product development group members trust each other.	.67
PT8.Product development employees work as a team.	.75
PT11.Product development group members seek integrative solutions.	.72
EI2.Purchasing managers are involved from the early stages of product development.	.55
EI3.Process engineers are involved from the early stages of product development.	.62
EI6.Top management is involved from the early stages of product development.	.45
EI9.Various disciplines are involved in product development from the early stages.	.70
EI8.Manufacturing is involved from the early stages of product development.	.70
CU1.We use computers to improve designs.	.80
CU2.We use computers to evaluate designs.	.81
CU3.We use computerized systems for product development.	.86
CU4.Computers help us in making engineering changes.	.81
CU5.We use computers to develop product prototypes.	.79
CU6.We use computers to coordinate product development activities.	.72
SR1.Our suppliers do the product engineering of component parts for us.	.64
SR3.Our suppliers develop component parts for us.	.74
SR6.Our suppliers develop whole subassemblies for us.	.60
SR7.Our suppliers are involved in the early stages of product development.	.67
SR8.We ask our suppliers for their input on the design of component parts.	.71
SR9.We make use of supplier expertise in the development of our products.	.70

***Note:** Items in bold have CITC below 0.60.

Table 27 (Continued): Purification for Time-Based Product Development (Large Scale).

ITEMS	Corrected-Item Total Correlation
CI1.We involve our customers in the early stages of product development.	.61
CI2.In developing the product concept, we listen to our customer needs	.64
CI3.We visit our customers to discuss product development issues.	.71
CI4.We study how our customers use our products.	.61
CI5.Our product development people meet with customers.	.69
HM2.Product development managers have significant influence over product engineering.*	**.54**
HM6.Product development managers are given "real" authority over personnel.	.71
HM7.Product development managers have enough influence to make things happen.	.78
HM8.Product development managers derive their influence from expert knowledge of customer needs.	.66
HM9.Product development managers derive their influence from expert knowledge of manufacturing processes.	.65
HM10.Product development managers have a final say in budget decisions.	.62
HM11.Product development managers have a final say in product design decisions.	.69
HM12.Product development managers have broad influence across the organization.	.79
DF1.Our core products are designed as platforms for multiple generations of product to come.	.65
DF2.Our product designs enable us to incorporate new features and technology as they become available.	**.56**
DF3.Our products are designed in a modular fashion.	.61
DF4.Our product designs enable us to accommodate several generations of products.	.77
DF5.Our product designs are drawn to accommodate future generations of products.	.81

Legend: CW=Concurrent Work-Flow, PT=Product Development Teams, EI=Early Involvement of Constituents, SR=Supplier Responsibilities, HM=Heavyweight Product Development Managers, DF=Platform Products, and CU=Computer Usage.

Eigenvalues varied from 1.32 for factor 6 to 15.43 for factor 1. The cumulative variance extracted by the six factors was 67.4 percent. To simplify the factor pattern matrix, only loadings greater than 0.30 are shown on Table 28. Items with high cross loadings (i.e., greater than 0.30) and items with low loadings (i.e., below 0.60) were eliminated. In

Table 28: Exploratory Factor Analysis for Time-Based Product Development Practices.

ITEM	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6
CW1	.87					
EI9	.78					
EI8	.69					
PT3	.68					
EI3	.67					
PT1	.62					
CW7	.62					
PT8	.61					
CW8	.58					
PT4	.39				.36	
CU3		-.86				
CU2		-.86				
CU4		-.84				
CU1		-.81				
CU5		-.81				
CU6		-.66				
SR3			.87			
SR1			.79			
SR6			.74			
SR9			.71			
SR8			.70			
SR7			.61			
CI3				.85		
CI2				.75		
CI4				.75		
CI5				.67		
CI1				.60		
HM10					.70	
HM9					.70	
HM7					.63	
HM11					.62	
HM12					.61	
HM6					.60	
HM8				.42	.45	
PT11	.38				.38	
DF4						.90
DF5						.84
DF1						.79
DF3						.59
Eigenvalue	15.43	3.34	2.88	1.75	1.59	1.32
% of Variance	39.6	8.6	7.4	4.5	4.1	3.4
Cumulative % of Variance	39.6	48.1	55.5	60.0	64.1	67.4

general, items loaded heavily on their intended factors and low on other factors.

The first factor was interpreted as concurrent engineering (factor 1). As expected from the pilot study, concurrent work-flow, product development teams, and early involvement of constituents, all loaded together on one factor. Two items (CW8 and PT4) of this factor were eliminated due to low loadings. Item PT4 also had a cross-loading with the heavyweight product development manager factor (factor 5). One other item (PT11) loaded on both the heavyweight product development manager factor and the concurrent engineering factor equally low and, thus, it was deleted. The lowest loading for the concurrent engineering factor was 0.61 for item PT8. All the computer usage items (factor 2) loaded on a single factor and the loadings were greater than 0.66. The six supplier involvement items (factor 3) loaded together on a single factor with loadings greater than 0.61. All the customer involvement items (factor 4) loaded together on a single factor. The lowest loading was 0.60 for item CI1. The heavyweight product development manager scale (factor 5) had seven items. One item (HM8) had a fairly low loading on its intended factor and a cross-loading on factor 4 and, thus, it was deleted. All four items of platform products (factor 6) loaded together in a single factor. One item however (DF3) had a loading below 0.60 and was eliminated.

Overall, the factor pattern matrix was simple; the great majority of the items loaded high in their respective factors and very low on others. A total of five items were eliminated at the factor analysis step. The remaining 34 items were then subjected to a variety of reliability and validity tests.

Cronbach's alpha and average variance extracted were calculated for all factors.

Table 29: Descriptive Statistics, Correlations, Reliability, Average Variance Extracted, and Discriminant Validity Tests for Time-Based Product Development Scales (based on retained items).

Variables	Means	s.d.	1	2	3	4	5	6
1.Concurrent Engineering	26.87	6.73	0.92[a] [0.58][b]					
2.Computer Usage	21.47	6.15	0.53** (36.03$)	0.93 [0.69]				
3.Supplier Involvement	16.12	4.97	0.47** (58.02$)	0.32** (72.31$)	0.88 [0.54]			
4.Customer Involvement	18.70	3.97	0.68** (29.98$)	0.42** (52.06$)	0.51** (56.77$)	0.84 [0.52]		
5.Heavyweight Product Development Managers	18.38	4.81	0.77** (23.00$)	0.57** (35.05$)	0.45** (64.10$)	0.62** (38.01$)	0.88 [0.56]	
6.Platform Products	9.36	2.90	0.50** (37.34$)	0.57** (27.89$)	0.36** (65.02$)	0.38** (53.41$)	0.57** (30.48$)	0.86 [0.68]

** Correlation is significant at 0.01.

$ X^2 differences are indicated in parentheses.

Differences in X^2 for 1 degree of freedom are significant at 0.05, $X^2_{0.003}$=8.50.

a Reliability alphas for retained items are on the diagonal.

b Average variance extracted for retained items are on the diagonal in brackets.

Table 30: Overall and by Industry Reliabilities for Time-Based Product Development Practices Scales (based in retained items).

Scale	Overall Reliability	SIC 34 (92 CASES)	SIC 35 (68 CASES)	SIC 36 (29 CASES)	SIC 37 (33 CASES)
Concurrent Engineering	0.92	0.92	0.93	0.92	0.92
Computer Usage	0.93	0.93	0.93	0.90	0.95
Supplier Involvement	0.88	0.87	0.88	0.88	0.88
Customer Involvement	0.84	0.79	0.88	0.84	0.89
Heavyweight Product Development Managers	0.88	0.88	0.88	0.87	0.90
Platform Products	0.86	0.88	0.85	0.90	0.87

The first factor, concurrent engineering had eight items and a reliability alpha of 0.92. The average variance extracted for this scale, computed using LISREL output, was 0.58. The computer usage scale (factor 2) had six items and reliability alpha of 0.93. Average variance extracted for this scale was 0.69. The supplier involvement scale (factor 3) had an alpha of 0.88 for six items and average variance extracted of 0.54. The customer involvement scale (factor 4) with six items had an alpha of 0.84 and average variance extracted of 0.52. The reliability of the heavyweight product development manager scale (factor 5) was 0.88, and average variance extracted was 0.56. The platform products scale (factor 6) had a reliability of 0.86 for three items and a variance extracted of 0.68. Reliability estimates and average variance extracted for retained items appear on Table 29. No items from any of the scales could be removed without significantly affecting reliability and/or the content of the scales.

The assessment of reliability was continued by calculating Cronbach's alpha for each scale across four industries (Table 30). Reliabilities, in general, were greater than 0.84. The reliability for the customer involvement scale (0.79) in SIC 37 was the only one below 0.80 but, was very close. The majority of reliabilities were either greater than 0.90 or very close to it. It is also evident that reliabilities are relatively stable across the industries. The range of differences in alpha values for each scale varies from 0.01 for the concurrent engineering and supplier involvement scales to 0.10 for the customer involvement scale.

Discriminant validity was re-examined at this phase due to the small sample size used for the pilot, the addition and modification of items, the reconceptualization of several variables, and the addition of another scale (i.e, customer involvement). LISREL methodology was employed to test for discriminant validity (Bagozzi and Phillips, 1982) between pairs of variables in the six factor solution. The difference between the chi-square values (one degree of freedom) for the fixed and free solutions for the 15 pairs are listed in Table 29. For 15 comparisons, the chi-square value for any pair must be greater than or equal to approximately 8.5 for significance at the $p<0.05$ (Cohen and Cohen, 1983: 167). All the chi-square differences for the tests were greater than 23.0 (for heavyweight product development manager with concurrent engineering) indicating discriminant validity.

The correlations between the factors and descriptive statistics are shown on Table 29. These correlations were derived from LISREL output which corrects for attenuation. The correlations between the heavyweight product development factor and essentially all other factors are strong ($r>0.45$). The correlation of the concurrent engineering factor with all other factors are very strong as well ($r>0.47$). Considering the discriminant validity tests, however, the results suggest that the factors must be regarded as distinct, although they are highly correlated.

Tests for discriminant validity were also conducted using the traditional MTMM procedure (Table 31). Out of a total of 950 comparisons there were 47 violations with the majority of them (i.e., 29) involving the heavyweight product development manager and the concurrent engineering items. The high correlation between the items of the two pairs of variables is also evident on Table 29, which produces the correlations between the six variables. It is possible that there is a causal relationship between heavyweight

Table 31: Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Time-Based Product Development Practices.

	CW1	CW7	EI3	EI9	EI8	PT1	PT3	PT8	CI1	CI2	CI3	CI4	CI5	SR1	SR3	SR6	SR7	SR8	SR9	HM6	HM7	HM9	HM10	HM11	HM12	DF1	DF4	DF5	CU1	CU2	CU3	CU4	CU5	CU6
CW1	1.00																																	
CW7	.45	1.00																																
EI3	.54	.61	1.00																															
EI9	.66	.58	.57	1.00																														
EI8	.45	.58	.57	.64	1.00																													
PT1	.69	.45	.58	.55	.48	1.00																												
PT3	.62	.49	.61	.71	.49	.63	1.00																											
PT8	.54	.64	.59	.73	.64	.60	.60	1.00																										
CI1	.40	.35	.43	.41	.34	.41	.44	.40	1.00																									
CI2	.30	.42	.40	.41	.34	.42	.35	.46	.49	1.00																								
CI3	.25	.33	.29	.35	.29	.40	.35	.38	.54	.53	1.00																							
CI4	.29	.30	.22	.43	.33	.35	.35	.40	.41	.49	.58	1.00																						
CI5	.37	.40	.40	.49	.36	.42	.44	.46	.55	.56	.58	.51	1.00																					
SR1	.15	.15	.14	.21	.22	.10	.18	.16	.28	.13	.18	.21	.19	1.00																				
SR3	.12	.13	.18	.19	.19	.09	.20	.15	.23	.10	.20	.24	.21	.70	1.00																			
SR6	.17	.04	.10	.17	.12	.10	.18	.16	.23	.08	.21	.25	.19	.52	.55	1.00																		
SR7	.35	.40	.34	.49	.42	.36	.47	.37	.46	.26	.37	.37	.41	.39	.52	.45	1.00																	
SR8	.26	.33	.30	.33	.32	.30	.41	.33	.36	.20	.29	.33	.31	.45	.55	.45	.69	1.00																
SR9	.23	.28	.25	.33	.33	.29	.33	.31	.32	.18	.29	.35	.37	.47	.57	.45	.60	.66	1.00															
HM6	.42	.36	.50	.45	.42	.51	.50	.54	.35	.35	.32	.31	.42	.19	.20	.18	.35	.30	.25	1.00														
HM7	.36	.46	.53	.51	.51	.55	.46	.59	.32	.45	.38	.40	.43	.13	.16	.14	.38	.27	.26	.67	1.00													
HM9	.29	.45	.49	.44	.48	.46	.35	.49	.38	.35	.35	.29	.40	.15	.19	.12	.33	.31	.38	.55	.59	1.00												
HM10	.28	.29	.40	.38	.32	.33	.35	.39	.18	.21	.24	.20	.37	.14	.22	.23	.36	.33	.28	.50	.46	.44	1.00											
HM11	.21	.41	.44	.38	.31	.40	.43	.47	.27	.31	.29	.23	.38	.10	.18	.17	.36	.28	.24	.52	.58	.41	.59	1.00										
HM12	.35	.51	.51	.52	.51	.46	.56	.56	.37	.33	.35	.30	.48	.12	.17	.14	.41	.32	.31	.62	.67	.57	.60	.66	1.00									
DF1	.27	.32	.31	.34	.20	.32	.34	.41	.17	.23	.21	.20	.21	.10	.15	.15	.31	.26	.15	.34	.40	.13	.31	.41	.38	1.00								
DF4	.22	.40	.31	.31	.33	.32	.33	.44	.22	.30	.29	.27	.30	.09	.20	.20	.35	.33	.27	.37	.46	.32	.28	.44	.48	.63	1.00							
DF5	.24	.40	.34	.31	.29	.28	.34	.43	.22	.18	.25	.21	.27	.07	.17	.18	.32	.30	.22	.39	.39	.27	.42	.50	.57	.66	.78	1.00						
CU1	.22	.30	.31	.26	.22	.28	.34	.42	.20	.26	.25	.20	.22	.11	.12	.14	.24	.32	.20	.41	.30	.19	.31	.44	.40	.44	.37	.43	1.00					
CU2	.27	.30	.33	.35	.25	.23	.37	.44	.18	.19	.24	.24	.29	.09	.10	.18	.20	.27	.15	.39	.29	.11	.28	.40	.40	.40	.32	.45	.75	1.00				
CU3	.30	.36	.34	.36	.22	.26	.40	.42	.32	.25	.33	.23	.30	.07	.12	.16	.25	.27	.20	.40	.32	.16	.33	.46	.45	.40	.37	.48	.74	.77	1.00			
CU4	.27	.37	.33	.33	.26	.27	.36	.41	.18	.26	.26	.18	.27	.08	.07	.20	.21	.27	.20	.33	.31	.15	.33	.51	.45	.36	.38	.43	.74	.71	.75	1.00		
CU5	.32	.35	.35	.38	.24	.26	.41	.49	.26	.26	.28	.21	.27	.07	.09	.15	.29	.28	.16	.35	.31	.22	.38	.49	.43	.40	.31	.46	.66	.67	.73	.69	1.00	
CU6	.40	.41	.44	.48	.37	.29	.50	.50	.32	.22	.28	.22	.34	.18	.23	.25	.37	.35	.29	.40	.38	.26	.43	.51	.57	.38	.34	.51	.57	.62	.70	.61	.67	1.00
	CW1	CW7	EI3	EI9	EI8	PT1	PT3	PT8	CI1	CI2	CI3	CI4	CI5	SR1	SR3	SR6	SR7	SR8	SR9	HM6	HM7	HM9	HM10	HM11	HM12	DF1	DF4	DF5	CU1	CU2	CU3	CU4	CU5	CU6
Mean	3.10	3.32	3.36	3.45	3.47	3.46	3.23	3.45	3.50	4.15	3.84	3.54	3.67	2.50	2.61	2.08	2.91	3.01	3.02	2.83	3.48	3.06	2.70	3.17	3.02	3.14	3.27	3.06	3.92	3.48	3.60	3.85	3.33	3.29
SD	1.15	1.04	1.15	1.03	.98	.98	1.11	1.01	1.13	.87	.99	1.00	1.05	1.07	1.10	1.05	1.04	1.06	1.03	1.07	.88	1.06	1.06	1.00	.97	1.20	1.05	1.02	1.08	1.24	1.19	1.13	1.25	1.24
Number of Violations	0	2	0	0	3	4	2	2	3	0	0	1	0	0	0	0	7	0	0	2	5	6	0	10	0	0	0	0	0	0	0	0	0	0

Note: Correlations above 0.13 are significant at 0.05, Correlations above 0.16 are significant at 0.01.

product development managers and concurrent engineering. In that case, high correlations would be expected. One item, SR7, had seven violations with concurrent engineering items. The content of the item was in regards to the early involvement of suppliers in the product development process, and it is related to the rest of the concurrent engineering items. Future research may evaluate the assignment of this item to the concurrent engineering scale.

To test for convergent validity the lowest correlation within a variable was found (Table 31) and was tested to see if it is different from zero. The lowest correlation for concurrent engineering was 0.45, for customer involvement 0.39, for supplier involvement 0.47, for heavyweight product development managers 0.41, for platform products 0.63 and for computer use 0.57. All were very significant at $p<0.01$ indicating good convergence.

To evaluate predictive validity, all six scales were correlated with the composite measure of competitive capabilities. The measure of competitive capabilities (alpha=0.90) includes items from five scales including competitive pricing, premium pricing, product innovation, value to customer quality and customer delivery service. The correlations with the composite measure of competitive capabilities are generally significant (with concurrent work-flow=0.34, with customer involvement=0.35, with heavyweight product development managers=0.36, with platform products=0.25, with computer use=0.25, and with supplier involvement=0.07). All correlations were significant except for supplier involvement. The predictive validity of the supplier involvement scale was also suspect in the pilot study.

LISREL's maximum likelihood estimates of the target model's completely

Table 32:Completely Standardized Parameter Estimates and t-values for Time-Based Product Development Practices (n=244) (6 first order Factors, 1 Second-Order Factor)

OBSERVED VARIABLES			LATENT VARIABLES		
Item	Factor Loading	R-Square (Reliability)	Factor	Std. Structure Coefficient	R-Square (Reliability)
CW1	.72[&]	.51	Concurrent	.86(10.88)	.73
CW7	.71(10.83)	.51	Engineering		
EI3	.75(11.41)	.56			
EI9	.84(12.81)	.71			
EI8	.72(10.94)	.52			
PT1	.74(11.19)	.54			
PT3	.79(11.95)	.62			
PT8	.83(12.69)	.70			
CI1	.70[&]	.49	Customer	.72(8.87)	.52
CI2	.70(9.87)	.50	Involvement		
CI3	.75(10.48)	.57			
CI4	.68(9.55)	.46			
CI5	.79(10.87)	.62			
SR1	.64[&]	.41	Supplier	.55(6.81)	.30
SR3	.74(9.59)	.55	Involvement		
SR6	.62(8.29)	.38			
SR7	.78(9.96)	.61			
SR8	.81(10.21)	.65			
SR9	.78(9.95)	.61			
HM6	.76[&]	.58	Heavyweight	.89(11.92)	.79
HM7	.80(12.99)	.65	Pr. Dvlp Mngrs		
HM9	.67(10.50)	.44			
HM10	.66(10.46)	.44			
HM11	.74(11.76)	.54			
HM12	.86(14.02)	.74			
DF1	.73[&]	.54	Platform	.66(8.74)	.44
DF4	.85(12.85)	.72	Products		
DF5	.91(13.43)	.83			
CU1	.84[&]	.70	Computer	.64(9.40)	.41
CU2	.85(16.37)	.72	Usage		
CU3	.90(17.96)	.80			
CU4	.84(16.23)	.71			
CU5	.81(15.36)	.66			
CU6	.76(13.93)	.58			
X^2=1156.37			X^2=1192.13		

Note: [&] Indicates a parameter fixed at 1.0 in the original solution.
t-values for item factor loadings and factor structural coefficients are indicated in parentheses.

standardized parameter estimates are presented in Table 32 for both latent variables and observed variables. For the observed variables, Table 32 shows factors loadings, their corresponding t-values, and R-square values. All 34 items have large (greater than .62) and significant loadings on their corresponding factors, indicating evidence of good construct validity. For the latent variables, Table 32 presents the standard structural coefficients, their corresponding t-values, and R-square values. All factors have acceptable and significant structural coefficients, indicating good construct validity. The target value for this instrument was 0.97 indicating that the second-order model explains a large amount of covariation among the five first-order constructs.

Overall, 34 items and six scales (Appendix B) are proposed for the product development practices instrument. The number of proposed items varies from three for platform products to eight for concurrent engineering. All scales have high reliabilities and behave well when subjected to an assortment of validity tests. The high target value indicates that the second-order model explains a significant amount of covariation of the model with six first-order factors.

CHAPTER 5: EXPLORATORY STRUCTURAL ANALYSIS

To explore the antecedent role of practices to time and competitive capabilities, and the mediating role of time, linear structural equations modeling was used. This not only allows the assessment of construct validity in a nomological network of constructs, but it also gives an initial sensation of testing substantive hypothesis. Althouth a two step process was followed, first measurement and then structural, results should be interpreted with caution since the same data was used for both the measurement and structural models.

The data was first examined for missing points and outliers, representativeness of the sample, normality, and industry differences. The examination of these issues allows researchers to uncover any biases, to determine whether there is sufficient evidence of normality, and to determine whether the data can be analyzed together instead of dealing with each industry separately. After these tests are conducted, the hypothesized model may then be specified and tested.

For parsimony and in light of the fact that target values for all instruments were very high, the second-order constructs were used for exploratory hypothesis testing in lieu of the numerous first-order factors. Thus, five variables are entered for hypothesis testing: time-based product development practices, time-based manufacturing practices, product development time, throughput time, and competitive capabilities.

5.1 RESEARCH METHODS

5.1.1 Missing Data and Outliers

Some respondents were eliminated from further analysis. Twenty nine respondents were eliminated because they had not responded to at least one whole section of the questionnaire. One additional respondent (a CNC programmer) was eliminated because the individual did not match the intended profile of target respondents. Three respondents were eliminated as outliers because their scores on variables were very much outside the control limits established by the mean plus or minus 3 standard deviations. An overall total of 33 respondents were eliminated resulting in a useful sample size of 211 for hypotheses testing.

5.1.2 Representativeness of Sample

The representativeness of the sample is assessed by comparing the distribution of respondents and the population across SIC codes and employment size. The Society of Manufacturing Engineers (SME) has provided the population distributions that would allow us to conduct chi-square tests for differences between observed and expected frequencies. As Table 33 suggests, there is no evidence of distribution differences for SIC codes. The chi-square value was 6.114 for 7 degrees of freedom and p=0.527. The distribution of the sample fits well with the distribution of the population.

On the other hand, Table 33 shows that the two distributions of employment size are not the same. The chi-square was 45.673 for 2 degrees of freedom and p=0.00. The residual column indicates that the expected frequency for small firms (less than 500

Table 33: Representativeness of Sample.

1. Chi Square Tests on SIC codes:

SIC Category	Gases Observed	Cases Expected	Residual		
25	7	9	-2	Chi Square=	6.114
30	1	1	0	d.f.=	7
34	94	79	15	Significance=	0.527
35	68	74	-6		
36	28	29	-1		
37	35	36	-1		
38	6	11	-5		
39	1	1	0		

Total	240*				

* Four firms did not indicate their SIC code.

2. Chi Square Tests on Firm Employment Size:

Size Category	Cases Observed	Cases Expected	Residual		
100-499	162	199	-37	Chi Square=	45.673
500-999	40	22	18	d.f.=	2
>1000	34	15	19	Significance=	0.000

Total	236				

* Eight firms did not report employment size.

employees) is larger than the observed frequency. It seems that the sample's percentage of large firms is higher than the proportion the population would suggest. This however was expected as small firms may not engage in product development and, thus, they may have not responded to the survey.

5.1.3 Normality

As the maximum likelihood (ML) method of estimation is sensitive to departures from multivariate normality (Joreskog and Sorbom, 1986), it was of particular interest to examine whether the individual measures are distributed according to univariate normality. Joreskog and Sorbom note that the assumption of multivariate normality is seldom fulfilled in practice. Moreover, they suggest that as the violation of normality increases the value of chi-square, the analysis should be viewed as a conservative test of the model.

Although univariate normality across variables does not guarantee a joint multivariate normal distribution, the presence of multivariate nonnormality is reflected in univariate distributions (Stevens, 1986). For this test, Kolmogorov-Smirnov statistics were calculated for each measure.

The Kolmogorov-Smirnov tests are summarized on Table 34. Correcting for the number of tests, alpha (level of significance) is divided by 5 (i.e., 0.01/5 = 0.002) (Cohen and Cohen, 1983: 167) and then used as the cutoff value to test for normality. Notice that non-significant values indicate univariate normality. In two instances (i.e., throughput time and product development time) the variables (p=0.000) did not pass the univariate normality tests. After a logarithmic transformation of those two variables, both exhibited

Table 34: Tests for Normality: Kolmogorov-Smirnov Tests

HYPOTHESES:
Ho: Univariate Normality
Ha: No Univariate Normality

VARIABLE	K-S Z-VALUE	2-TAILED p	CONCLUSION
TB Product Development Practices	0.501	0.964	Univariate Normality
TM Manufacturing Practices	0.629	0.824	Univariate Normality
Throughput Time	2.281	0.000	No Univariate Normality
Product Development Time	3.349	0.000	No Univariate Normality
Competitive Capabilities	0.925	0.359	Univariate Normality
With Logarithmic Transformation on Throughput time and Product Development Time:			
Throughput Time	0.866	0.441	Univariate Normality
Product Development Time	1.710	0.006[&]	Moderate Univariate Normality

[&] Because of multiple tests for normality (one for each of our 5 variables) the p-value to be significant should be less than 0.002 (0.01/5).

univariate normality. The p-value for throughput time was 0.441 while the p-value for product development time was 0.006. The p-value for product development time indicates only moderate univariate normality. According to the results of these tests, the use of maximum likelihood estimation may not be constrained by normality considerations.

5.1.4 Industry Differences

Industry differences in means for the five variables were evaluated using MANOVA and several Univariate ANOVA tests. Summary results are presented on Table 35. Using MANOVA and alpha=0.01 three tests (Pillais, Hottelings, and Wilks) showed no significant differences in means. The univariate ANOVAs also showed no differences in means across industries using an alpha of 0.01 and correcting for the number of tests (i.e., 0.01/5 = 0.002) (Cohen and Cohen, 1983: 167). The lowest univariate p-value was 0.015 for throughput time and was not significant at 0.002. Since there was a lack of evidence for industry differences the whole sample was analyzed together. Further support for analyzing the sample together was provided earlier by the generalizability of reliabilities across industries.

5.2 Exploratory Correlation and Structural Analysis Methods

The correlation matrix that was entered into LISREL is presented and is used to preliminarily assess alleged relationships. The relationships are also explored via linear structural equations modeling.

The measurement models for the constructs of time-based practices and

Table 35:Tests for Industry Differences :Manova and Univariate Anovas.

MANOVA

Test	Value	F	Significance	Conclusion
Pillais	.31325	1.5581	0.014	No difference in means at 0.01
Hottellings	.35089	1.5985	0.010	No difference in means at 0.01
Wilks	.71803	1.5832	0.011	No difference in means at 0.01

UNIVARIATE F-TESTS (7,198) df
HYPOTHESES:
Ho: The means between industries are the same.
Ha: The means between industries are not the same

Due to multiple comparisons (checking for equality of means of five variables across 8 industries) to have a significance the p-value is 0.01/8=0.00125.

VARIABLE	F	Significance	Conclusion
TB Product Development Practices	0.75451	0.626	No difference in means
TB Manufacturing. Practices	1.44036	0.191	No difference in means
Throughput Time	2.55544	0.015	No difference in means
Product Development Time	1.72653	0.105	No difference in means
Competitive Capabilities	1.6037	0.161	No difference in means

competitive capabilities have been identified in previous sections. To be congruent with the hypothesized model in Chapter 2, time-based product development practices is treated as the exogenous variable ($\xi 1$) and the employee involvement in problem solving scale is not separated from time-based manufacturing practices. The endogenous variables include time-based manufacturing practices ($\eta 1$), throughput time ($\eta 2$), product development time($\eta 3$), and competitive capabilities ($\eta 4$). The terms exogenous variables and endogenous variables are synonymous with independent and dependent variables respectively. These terms are introduced here (and will be used in the rest of the chapter) to emphasize that endogenous variables have their causal antecedents specified within the model under consideration, whereas the causes of exogenous variables are outside the model and not of present interest. The two measurement models (i.e., exogenous and endogenous) can be specified as:

$$X = \Lambda_x \xi + \delta \quad (1)$$

$$Y = \Lambda_y \eta + \epsilon. \quad (2)$$

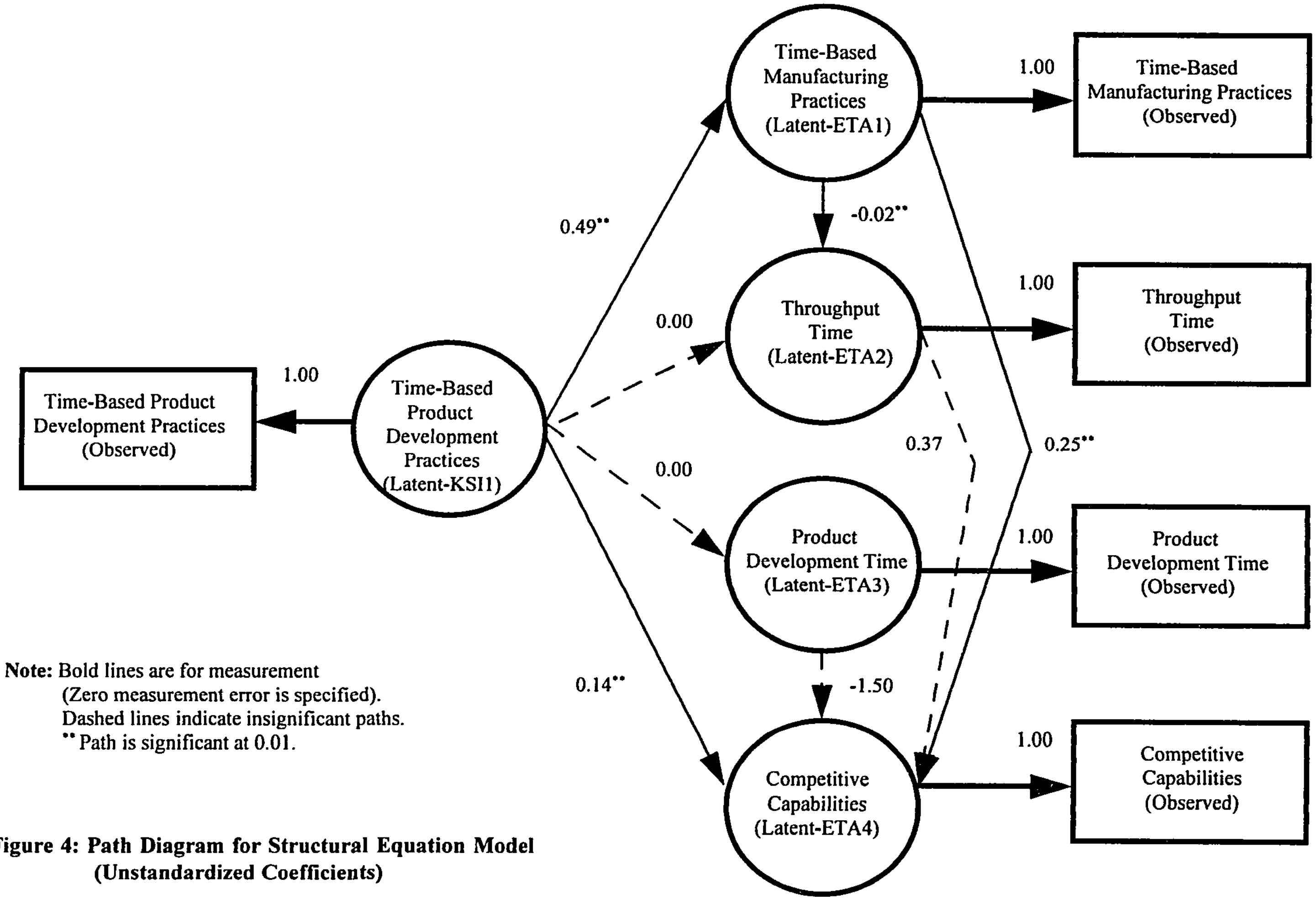
In factor equation (1), X is a (1x1) vector of the observed measure of the exogenous latent variable. This measure, time-based product development practices, is in fact a second order measure of the six first-order constructs of product development practices. ξ is a (1x1) vector of the latent exogenous variable. Λ_x is a (1x1) vector of factor loading of X on ξ. The value of this loading is 1 and it suggests that the latent exogenous variable is a mirror image of its observed exogenous variable with zero measurement error. If a variable is measured by a single indicator the measurement error is assumed to be zero for each variable. Thus, δ, the vector of measurement error is empty. In equation (2), Y is a (4x1) vector of observed measures of latent endogenous variables. η is (4x1) vector of latent endogenous variables. Λ_y is a (4x4) matrix of factor loadings of Y on η. Each λ on the diagonal is equal to 1, indicating that the latent variable is a mirror image of the observed variable with zero measurement error. ϵ is a (4x1) vector of measurement errors and is empty.

These two measurement models are linked by a structural equation model:

$$\eta=\beta\eta + \Gamma\xi + \zeta, \quad (3)$$

where β is a (4x4) matrix of coefficients relating the endogenous variables to one another. Γ is a (1x4) vector of structural coefficients relating the exogenous variable to the endogenous variables. ζ is a (4x1) vector of errors in structural equations. ζ indicates that the endogenous variables are not perfectly predicted by the structural equations.

The structural equation model, as expressed by equations (1), (2), and (3), can be translated into a path diagram shown in Figure 4. The exogenous variable, $\xi 1$ is located on the left side of the Figure 4. There are 4 structural equations (Γ) parameters in Figure 4, which are represented by the arrows from the exogenous variable to the four endogenous variables. At the right side of the Figure, the four endogenous variables are listed. Because it was postulated that time-based manufacturing practices are related to throughput time and competitive capabilities, two causal paths represented by $\beta 1$ and $\beta 2$



Note: Bold lines are for measurement
(Zero measurement error is specified).
Dashed lines indicate insignificant paths.
** Path is significant at 0.01.

Figure 4: Path Diagram for Structural Equation Model (Unstandardized Coefficients)

are specified between $\eta 1$ and $\eta 2$, and $\eta 1$ and $\eta 4$ respectively. Two other causal paths are specified for the relationships between throughput time and competitive capabilities $\beta 3$ ($\eta 2$ and $\eta 4$) and between product development time and competitive capabilities $\beta 4$ ($\eta 3$ and $\eta 4$).

For the sake of clarity, the symbols for these arrows (i.e., Γ's and β's) are not given in Figure 4. If the model fits the data adequately, the magnitudes and t-values of the gamma and Beta coefficients will be evaluated to test the research hypotheses. A t-value is the ratio of an estimated parameter to its standard error (Marsch and Hocevar, 1985), is distributed as a t-statistic, and anything greater than 1.96 is significant at $p<0.05$ and a t-value greater than 2.33 is significant at $p<0.01$.

To assess the fit of the model to the data, various fit statistics were computed. These include the chi-square, goodness-of-fit index (GFI), adjusted-goodness-of-fit index (AGFI), comparative-fit index (CFI), and normed-fit index (NFI). The chi-square statistic is a global test of a model's ability to reproduce the sample variance/covariance matrix, but it is sensitive to sample size and departures for multivariate normality (Bollen, 1989). Thus, the chi-square statistic must be interpreted with caution in most applications (Joreskog and Sorbom, 1989). Nonsignificant chi-square values are desirable and provide evidence of good fit. GFI is a nonstatistical measure of global fit ranging in value from 0 (poor fit) to 1.0 (perfect fit). It represents the overall degree of fit (the squared residuals from prediction compared to the actual data), but is not adjusted for the degrees of freedom. AGFI is an extension of GFI which is adjusted by the ratio of degrees of freedom for the proposed model to the degrees of freedom for the null model. AGFI also varies from 0 (poor fit) to 1 (perfect fit). Many researchers interpret GFI and AGFI scores in the .80 to .89 range as representing reasonable fit; scores of .90 or higher are considered as evidence of good fit (Byrne, 1989; Joreskog and Sorbom, 1984). Two widely used incremental fit indices are the Bentler's (1990) comparative-fit-index (CFI) and Bentler and Bonnet's (1980) normed-fit-index (NFI). NFI is a relative comparison of the proposed model to the null model. CFI avoids the underestimation of fit often noted in small samples for NFI (Bentler, 1990). Values greater than 0.90 can be considered indicative of good fits for both indices.

5.3 RESULTS

The correlation matrix (Table 36) shows that time-based product development practices are significantly related to time-based manufacturing practices and competitive capabilities. Although its relationship with throughput time is significant and in the hypothesized direction, it is relatively weak. The correlation between time-based product development practices and product development time indicates no significant relationship. This was expected for this sample which is dominated by firms supplying to OEMs. For the suppliers to OEM, product development time is not variable. Rather, it is specified by the OEM and suppliers have little latitude to change it. Time-based manufacturing practices had a strong and negative relationship with throughput time and a strong positive relationship with competitive capabilities. There was no hypothesized relationship between manufacturing practices and product development time and the correlation was nonsignificant.

Table 36: Descriptive Statistics and Correlations for Variables in the Structural Model.

Variables	Means	s.d.	1	2	3	4	5
1.Time-Based Product Development Practices	111.10	21.93	1.000				
2.Time-Based Manufacturing Practices	110.87	18.46	0.581**	1.000			
3.Throughput Time[a]	4.01	1.00	-0.176*	-0.312**	1.000		
4.Product Development Time[b]	2.05	0.81	0.046	0.052	-0.107	1.000	
5.Competitive Capabilities Innovation	128.16	15.79	0.3608**	0.405**	-0.069	-0.026	1.000

** Correlation is significant at $p<0.01$.
* Correlation is significant at $p<0.05$.
[a] Logarithmic transformation of throughput time.
[b] Logarithmic transformation of product development time.

It was expected that the correlation between throughput time and competitive capabilities would be negative and significant, but the data yielded a nonsignificant correlation. Similarly, the correlation between product development time and competitive capabilities was nonsignificant.

To further assess relationships, LISREL methodology was used to conduct exploratory path analysis. The results of fitting the model to the data (Table 37) indicated that the model had a very good fit (chi-square=2.12, d.f. = 2; p= 0.35). The goodness-of-fit index (GFI) and the comparative-fit index were equal to 1.00. The adjusted-goodness-of-fit index (AGFI) was equal to 0.97 and the normed-fit index (NFI) was equal to 0.99.

The findings for the structural equation model are also summarized in Table 37. To examine the total effects the coefficients for indirect effects were also calculated

Table 37: Decomposition of Effects (Unstandardized coefficients) and Fit Statistics.

Relationship	Total Effects	Direct Effect	Indirect Effects$	Noncausal Effects
Product Development Practices to Production Practices(KSI1 to ETA1)	0.49 (10.33)**	0.49 (10.33)**	-----	-----
Product Development Practices to Throughput Time (KSI1 to ETA2)	-0.01 (-2.59)**	0.00 (0.09)	-0.01 (-3.67)**	-----
Product Development Practices to Product Development Time (KSI1 to ETA3)	0.00 (0.67)	0.00 (0.67)	-----	-----
Product Development Practices to Competitive Capabilities (KSI1 to ETA4)	0.26 (5.61)**	0.14 (2.50)**	0.12 (3.58)**	-----
Production Practices to Throughput time (ETA1 TO ETA2)	-0.02 (-3.92)**	-0.02 (-3.92)**	-----	-----
Production Practices to Competitive Capabilities (ETA1 TO ETA4)	0.24 (3.88)**	0.25 (3.98)**	-0.02 (-0.86)	0.01
Throughput Time to Competitive Capabilities (ETA2 to ETA4)	0.37 (0.88)	0.37 (0.88)	-----	-----
Product Development Time to Competitive Capabilities (ETA3 to ETA4)	-1.50 (-0.72)	-1.50 (-0.72)	-----	-----

** t-values (in parentheses) are significant at 0.01 (t-values greater than 2.33).
$Indirect effects are reflective of all possible indirect paths.

Squared Multiple Correlations for Structural Equations:

ETA1	ETA2	ETA3	ETA4
0.34	0.10	0.00	0.19

FIT STATISTICS:
CHI SQUARE WITH 2 DF=2.12 (P=0.35)
GOODNESS OF FIT INDEX (GFI)=1.00
ADJUSTED GOODNESS OF FIT INDEX (AGFI)=0.97
NORMED FIT INDEX(NFI)=0.99
COMPARATIVE FIT INDEX(CFI)=1.00

(Joreskog and Sorbom, 1986:III-37). It is possible to break total effects into direct, indirect, and noncausal. Time-based product development practices were hypothesized to be an antecedent to time-based manufacturing practices. The data supported the relationships as manifested by the high positive t-value (10.33). In fact, this structural coefficient was the strongest amongst all coefficients in the model. Time-based product development practices increased time-based manufacturing practices. No indirect relationships were hypothesized and noncausal effects were not present.

The structural coefficient for product development practices and throughput time was nonsignificant (t=0.09). However, the data show that the indirect relationship (t-value=-3.67) is negative and very significant. The indirect relationship works itself through time-based manufacturing practices. Time-based product development practices increase time-based manufacturing practices which reduce throughput time.

Time-based product development practices were hypothesized to have a negative relationship with product development time under certain conditions. It was expected that in certain markets, such as the supplier to an OEM market, time-based product development practices may not reduce product development time. The data for this study were collected primarily from firms that supply OEMs. Thus, we expected either a negative relationship or no relationship. Time-based product development practices did not have a significant impact on product development time for this data (t=0.67). On the other hand, product development practices had a significant positive direct and indirect relationship with competitive capabilities. Surprisingly, the indirect relationship (t=3.58), most likely through manufacturing practices, was stronger than the direct relationship (t=2.50). Although several other indirect paths were possible such as through throughput time and through product development time, the lack of direct relationships between those variables and competitive capabilities makes those indirect paths very unlikely. The data shows in essence that for the supplier to the OEM market, time-based product development practices may not have effects on product development time, but they improve competitive capabilities. Product development time in those markets may not be variable, as time is specified by the OEMs.

Turning now to the endogenous to endogenous relationships, it was postulated that time-based manufacturing practices would have a significant impact on throughput time. Indeed, the Beta coefficient was negative and very significant (t=-3.92) indicating that time-based manufacturing practices reduce throughput time. It was also supported by theory that time-based manufacturing practices would have an effect on competitive capabilities. This effect was to be manifested in both direct and indirect relationships (i.e., through throughput time). The structural coefficient Beta that related the two variables indicates that the direct effect is positive and significant (t=3.98). Time-based manufacturing practices improve competitive capabilities. The indirect relationship was found to be nonsignificant (t=-0.86).

It was expected that reductions in time would lead to improved competitive capabilities, however the data do not support such an hypothesis. The coefficient for throughput time (t=0.99) and product development time (-0.72) were nonsignificant.

As a measure of the entire structural equation, an overall coefficient of determination (R-square) is calculated for each endogenous variable and is similar to that found in multiple regression. Although no test of statistical significance can be performed, it provides a relative measure of fit for each structural equation. For $\eta 1$, the time-based manufacturing practices, R-square is 0.34 and is the highest amongst the four coefficients. For throughput time it is lower and is equal to 0.10. The coefficient for product development time was 0 indicating that no variation in time can be explained by variations in time-based product development practices. Nineteen percent of the variation in competitive capabilities can be explained by the suggested model. It was expected that the R-square for product development time ($\eta 3$) would be low since the relationship with its only hypothesized antecedent ($\xi 1$) was nonsignificant.

Overall, the data indicates that time-based practices lead to improvements in competitive capabilities. Both practices also lead to reductions in throughput time. Manufacturing practices have a direct relationship, while product development practices have an indirect relationship through manufacturing practices. Product development practices do not affect product development time, and reductions in times do not lead to improved competitive capabilities. These conclusions should be drawn with caution as they may only be applicable to the particular sample of this research which included primarily firms that supply to OEMs. It is possible also that there is a measurement problem with the time variables and additional efforts should be expended in future research to establish valid and reliable measures of time.

CHAPTER 6: SUMMARY, RECOMMENDATIONS AND DISCUSSION

6.1 SUMMARY

Time-based competition researchers argue that a time-based strategy yields sustained competitiveness. They further posit that management of the entire time through the value chain would yield optimal results. Owing to the relative newness of time-based competition concepts, much speculation about its influences on competitive capabilities and organizational performance has been published. In fact, the literature on this important subject is accumulating rapidly. However, much of the research evidence concerning time-based competition is anecdotal, based primarily on personal experiences, case studies, and small sample survey research. Although these studies have made important contributions, the literature on time-based competition and its organizational performance implications is still fragmentary and lacks precision. A lack of broad based research on time-based competition has made it difficult to establish whether the shift in competitive priorities and assorted process improvements represent a broad movement in the industry, or whether observed changes merely depict changes found in a few successful, technology based companies (Trygg, 1993).

The purpose of this research was to complement the previous studies on time-based competition and to bring some uniformity to the literature. By constructing a nomological network of time-based constructs and conducting an analysis across a relatively large number of organizations with more accurate measurements, this study represents an initial investigation of the relationship between time-based practices, product development time, throughput time, and competitive capabilities. A set of reliable and valid instruments were developed to measure time-based product development practices, time-based manufacturing practices, and competitive capabilities. The study contributes to our knowledge of time-based competition in a number of ways.

First, a theoretical time-based competition framework is provided that identifies time-based product development practices, time-based manufacturing practices, product development time, throughput time, and competitive capabilities. This framework forms a foundation for research in time-based competition by identifying some of the most salient dimensions of time-based competition. Use of these constructs permits researchers to formulate and test numerous propositions. Other constructs may be added to complement this nomological network of constructs in future research. Unexplained variance in the existing nomological network may be explained by the addition of other relevant constructs.

Second, the study provides a set of validated instruments of time-based constructs. Evidence of the reliability and validity of these measures was demonstrated for use in future research. Such measurement instruments have been lacking in previous studies of time-based competition. It is hoped that this research has provided the groundwork for the future. Although it was the first attempt to create time-based practices and competitive capabilities instruments, the scales more than exceed criteria for new scales in terms of reliability, factorial validity, as well as discriminant and convergent validity.

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

Fourth, this study also provides a valuable tool for manufacturing executives to assess their time-based practices. For instance, the time-based manufacturing practices scales can be used by managers to evaluate the extent of usage over time and to study their relative impact on competitive capabilities. In fact, over 200 respondents have indicated that they would like to receive results for their firm and benchmark results for their industry.

Fifth, the study provides supporting evidence of previously untested statements regarding time-based competition constructs. The results lend support to the claim that higher levels of product development practices lead to higher levels of time-based manufacturing practices and competitive capabilities and lower levels of throughput time. The data also support the notion that time-based manufacturing practices lead to lower throughput time and higher levels of competitive capabilities. The results do not support the hypothesis that increased time-based product development practices lower product development time. The data also failed to provide evidence of a relationship between product development time, throughput time, and competitive capabilities.

The lack of support for some of the alleged relationships between time-based constructs provides an opportunity to point to several measurement as well as structural issues and problems that may have contributed to the absence of significant correlations.

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

6.2 RECOMMENDATIONS AND DISCUSSION OF MEASUREMENT ISSUES

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

The generic nature of the competitive capabilities and product development practices scales should allow for their broad usage. With time-based manufacturing practices, a researcher may have to be careful in using the proposed scales. The scales were developed here with the objective of being used confidently across discrete manufacturing industries. Certain manufacturing practices may not be widely applicable. For example, cellular manufacturing may not be economically feasible in certain continuous process industries, such as the chemical or oil refinery industries, where there is usually only one set of very expensive equipment.

The generalizability of the scales is currently supported by acceptable reliabilities (above 0.80) across four industries (SIC 34: Fabricated metal products [except machinery and transportation equipment], SIC 35: Industrial and commercial machinery, SIC 36: Electronics; Electrical equipment and components, and SIC 37: Transportation equipment). For a total of 18 scales evaluated across four industries there were only two instances where alpha was below 0.80; in those two instances alpha was close to 0.80. Due to the exploratory nature of this work, these scales should be revalidated in the same industries; they should also be validated in other industries.

Recommendation: Future research should conduct confirmatory factor analysis.

This study has presented the development of three instruments for measuring time-based competition constructs and was exploratory in nature. The research cycle for developing standardized instruments has two steps: (1) exploratory studies that develop hypothesized measurement model(s) via the analysis of empirical data from a referent population; and (2) confirmatory studies that test hypothesized measurement models against new data gathered from the same referent population.

Confirmatory factor analysis has been used extensively in psychology, marketing, and counseling for validating instruments and testing theoretical models. Confirmatory factor analysis involves the specification and estimation of one or more putative models of factor structure, each of which proposes a set of latent variables (factors) to account for covariances among a set of observed variables. In exploratory factor analysis, there are no preconceived notions regarding factor structure. In contrast, confirmatory factor analysis requires an *a priori* designation of plausible factor patterns from previous theoretical or empirical work. These alternative models are then explicitly tested statistically against sample data. The methodology may be used to assess first-order and second-order models. Linear Structural Equations Modeling provides indices of how well the researcher's hypothesized model fits the data and *a priori* models can be subjectively and statistically compared in a systematic fashion (Marsh and Hocevar, 1985). There is a lack of systematic confirmatory research in manufacturing. The lack of confirmatory studies impedes general agreement on the use of instruments. Confirmatory factor analysis is needed to provide a more rigorous and systematic test of alternative factor structures than is possible within the framework of exploratory factor analysis.

Recommendation: Future research should conduct factorial invariance tests.

The generalizability of measurement instruments may be supported by factorial invariance tests. Using the instruments developed in this research, one may test for factorial invariance across discrete manufacturing industries (i.e., SIC codes), across the supply chain (i.e., suppliers to OEM versus suppliers to the consumer market), and across different size firms (i.e., small versus large). Factorial invariance may also be tested for firms that make-to-stock versus those that make-to-order. The instruments were developed to be widely applicable and the factor structure is expected to be similar across different groups. Factorial invariance tests have not been carried out in manufacturing research as a part of developing basic instruments for research.

Marsh and Hocevar (1985) provide a detailed account to carry out factorial invariance tests using LISREL methodology. Such tests are relevant to researchers who use factor analysis in theory development. The value of one factor is greatly enhanced if the same factor can be replicated in random samples from the same population, and identified in responses from different populations (Bejar, 1980; Cattell, 1962; Gorsuch, 1970). Although it is rarely tested, an implicit assumption in the comparison of different groups is that the underlying construct being measured is the same for the two groups, and this is an issue of factorial invariance (Marsch and Hocevar, 1985). To conduct factorial invariance tests, it is necessary to collect sufficient data for each of the groups for comparison. The factor structure of one group is essentially compared with the factor structure of another group.

Recommendation: Future research should measure time since initiation of time-based product development practices.

Time-based product development practices had a significant impact on competitive capabilities. In fact, the effects of implementing time-based practices may first be manifested in competitive capabilities, such as improved quality, rather than in product development time. Employees may initially be concerned with "doing it right" and they may be less concerned with accelerating the development process. The impact of these practices on development time may not be evident until employees become more efficient in using the time-based practices. These product development practices may not have reached a level where they can make a difference in development time yet (Handfield and Pannessi, 1995).

Without knowing the time since implementation of practices, it is impossible to assert whether the lack of significance is due to the fact that these practices may have just been implemented or whether there is a lack of real relationships. Firms that have implemented these time-based practices for longer periods of time may experience improvements in both time and other competitive capabilities.

Recommendation: Future research should incorporate multiple measures of product development time.

Product development time was not correlated significantly with either its antecedent (time-based product development practices) or its dependent variable (competitive capabilities). One possible explanation is the fact that only one measure of product development time was used for this phase of the research. During the pilot phase of the research there were two measures of time used and they were significantly correlated (r=0.98). The first method used was a single item asking the respondents to indicate the length of time in months from concept generation until market introduction for a typical product in the dominant product line. The second method used a Gantt chart where the respondents were asked to draw or shade the amount of time spent in each of 6 phases of product development. This one page Gantt chart was dropped before the large scale administration because of space limitations on the survey instrument.

Without a second method of assessing product development time it is impossible to assess the reliability of the reported time. Thus, it is not certain that the lack of significant relationships is due to measurement problems or lack of real relationships. Future research might include a one page Gantt chart which provides for the assessment of concurrency of product development phases. Future research may also utilize objective measures, not self-reported.

Recommendation: Future research should also measure total response time.

It was also evident from this research that throughput time had a nonsignificant correlation with competitive capabilities. Throughput time may account for only a small portion of total response time and thus its significance to impacting performance variables may be limited. In fact, time-based competition researchers posit that it is the total response time that matters, not individual components of time (e.g., Stalk and Hout, 1990;

Blackburn, 1991). The effects of throughput time may be diluted by a slow order processing system and/or slow supply and distribution networks (Blackburn, 1991).

Handfield and Pannessi (1995) found that across all of the make-to-order firms within their sample, internal manufacturing times accounted on average for only 25% of total lead time. They also report on other research where reductions in manufacturing cycle time did not have significant impact on total lead time. The measurement of the total response time in future research may explain variations in competitive capabilities. Again, it would be appropriate to use objective measures of time in addition to the self-reported.

Recommendation: Future research should incorporate additional antecedents to response time.

This research proposes and tests relationships across a nomological network of time-based competition constructs. Other scales could be developed to complement the nomological network of constructs proposed here. For example in manufacturing we may add a variable measuring the flexibility of resources, both human and nonhuman. Purchasing practices along with purchasing lead time may also be measured because purchasing lead time contributes to the total response time. Handfield and Pannessi (1995) found that purchasing lead time consumes the majority of the lead time promised to customers. Time-based competition also includes after sales service and other customer related service activities (Blackburn, 1991) not measured in this research. Order processing activities may be evaluated for their contribution in reducing response time. Fawcett and Birou (1992) also note that the logistics strategy of the firm is also worth investigating for firms pursuing time-based strategies. Outbound logistics time is a part of the total response time and thus, it should be accelerated.

Recommendation: Future research should measure to what extent the product development project being assessed is a radical departure from previous or existing products.

Most firms do not do a complete rethinking of their product concept when they develop products. For those firms, the concept generation phase applies to derivatives or enhancements of existing products and, thus, concept generation along with some other early phases of product development are shortened. Research by Handfield (1994) suggests that there is a difference in product development time between incremental products and breakthrough products. It was found that incremental products were produced in a much shorter period of time. In fact, he shows that incremental products had development times less than half that of breakthrough products (62.6 versus 140.9 weeks).

This research did not measure the extent to which the project being assessed is a radical departure from previous or existing products. By measuring and then controlling for the extent of the difference from previous or existing products, future research may find a significant relationship between product development practices and product development time.

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

The use of single respondents to represent what are supposed to be organization wide variables may have generated some inaccuracy. Key informants are often asked to respond to complex questionnaires dealing with organizational-level variables. More than the usual amount of random error is likely, because informants are asked to make inferences about macro-level phenomena or perform aggregations over persons, tasks, organization subunits or events (Bagozzi, Yi, and Phillips, 1991). Over-reporting or under-reporting of certain phenomena may occur as a function of the informant's position, length of time in the organization, job satisfaction, or other personal or role characteristics (e.g., Patchen, 1963; Seidler, 1974; Bagozzi et al., 1991). It is also sometimes recognized that biases arising from a common method used to derive measures across independent and dependent variables can artificially increase the association observed therein (e.g., Fiske, 1982). In all these cases it is suggested that multiple methods should be used to derive estimates of measures. It may be even appropriate to use both subjective and objective methods of measurement.

Having a construct measured with multiple methods, random error and method variance may then be assessed. This can be done using the Multitrait-multimethod approach (Campbell and Fiske, 1959) or LISREL methodology. Bagozzi et al. (1991) provide an overview of various methods and examples of such construct validity tests.

6.3 RECOMMENDATIONS AND DISCUSSION OF STRUCTURAL ISSUES

Recommendation: Future research should test time-based hypotheses with a different referent population.

Most success stories cited in the time-based competition literature involve firms that sell to consumer markets (e.g., Blackburn, 1991). Timing is most critical in consumer markets. Firms that are "first to market" may capture market share and be able to charge premium prices. The great majority of the firms in this research however, were suppliers to OEMs, and the percentage of their products sold to consumer markets was relatively small.

For the suppliers to OEMs, product development time may not be a variable. The OEM usually specifies the desired product introduction date and determines the time each subassembly or part has to be made available. Because the OEM development process usually involves its own development tasks as well as those tasks of multiple suppliers, the ability of a single supplier to negotiate and change introduction dates is limited. The supplier then devotes all efforts in meeting the deadline for the project. Whether suppliers employ time-based practices or not to meet the deadline may be irrelevant. In either case, the project has to be done on time. In the supplier to OEMs market, where the timing of introduction is predetermined, the time-based practices may add value to customers in other ways such as better performance, quality, or prices.

The alleged time-based relationships should be tested in both consumer as well as non-consumer markets. It is possible that these relationships in consumer markets may be more evident.

Recommendation: Future research should also examine the hypothesized structural relationships in each industry.

Time may be valued differently in various industries. Thus, structural relationships between variables might be different across industries. Traditionally, research uses

Analysis of Variance (ANOVA) and Multivariate Analysis of Variance (MANOVA) to establish that there is no difference in means across industries. It is argued that if the data show no difference in means, then one can proceed analyzing the whole data together rather than assessing the data separately for each industry. Invariance of structural relationships across industries, however, can hardly be determined by comparisons of means alone.

Assuming an adequate sample in each industry, one may study the covariance or correlation matrices by industry and check for significant differences. Where significant differences are apparent and a sufficient sample is available for each industry, structural analyses may be done by industry.

Recommendation: Future research should also test structural relationships at the specific practice and competitive capability level.

This research only hypothesized relationships at the aggregate level of practices and competitive capabilities. The use of the aggregate variables for testing purposes was supported by high target values for all three instruments (the high target coefficients for each instrument have provided evidence that a second-order factor structure accounted for a high proportion of the covariation of the first-order factors). Alleged relationships were then tested at the aggregate level. Practitioners, however, would be interested to know how each practice affects particular competitive capabilities.

It would be of interest then to study relationships at the specific practice and competitive capability level. For example, this research has been concerned with the relationship between time-based product development practices and competitive capabilities. It has not looked at how specific practices, such as concurrent engineering, affect specific competitive capabilities, like product innovation or value to customer quality. Specific practices may be related to particular competitive capabilities, but the aggregate variables may not be correlated. Product development time or throughput time may also be correlated with specific competitive capabilities but not with the aggregate competitive capabilities. In future research, one may stipulate specific practices and competitive capabilities in a structural model.

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

The proposed structural relationships may also be affected by contextual variables. For example, Handfield (1994) measures complexity of the products, recognizing that some variance can be explained by contextual variables. This research focused on institutional product development and manufacturing practices and had no *a priori* hypotheses concerning the relationships between contextual variables and model variables. To uncover potentially useful contextual variables, this research explored the role of 18 contextual variables.

Descriptive statistics and method of measurement for each contextual variable appear as Appendix C. Factor analysis and reliabilities for Likert-type items are depicted in Appendix D. A correlation matrix of the 18 contextual variables and the five structural model variables is presented in Appendix E. Overall, there were a few contextual variables that consistently correlated significantly with the five structural model variables. Those contextual variables include the two size variables (number of employees and dollar sales), change, and complexity. It is also evident from the correlations that both sets of practices, product development and manufacturing, are effected similarly by contextual variables. In fact, six significant correlates were the same for both practices. The strongest correlate for both practices was complexity. It is also noteworthy that size has the most significant impact on both throughput time and product development time. However, it has opposite effects; it seems that larger firms have lower throughput time but higher product development time. Future research may incorporate such variables as antecedents in the model.

Recommendation: Future research should investigate alternative hypothesized models of structural relationships.

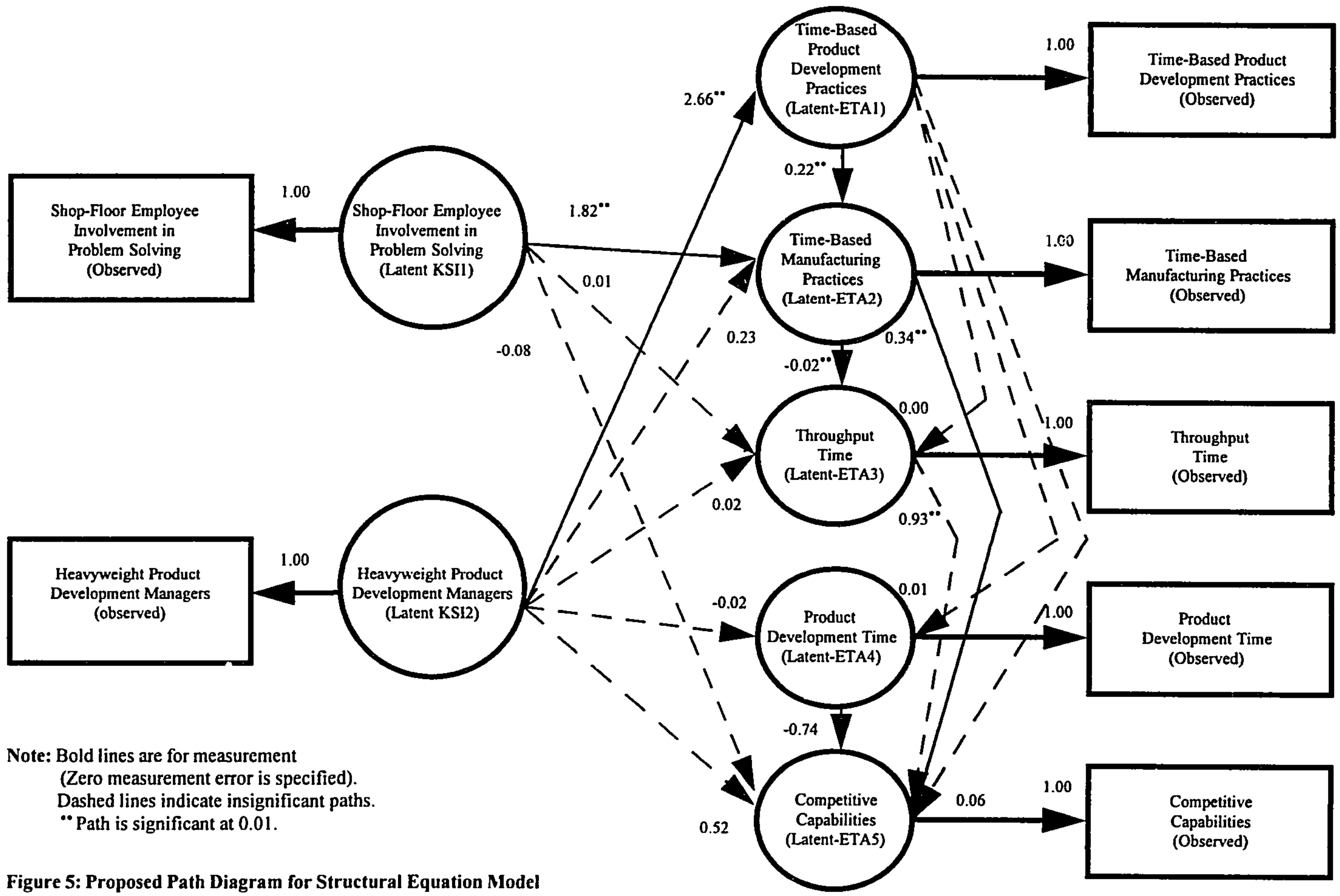
This research has explored relationships between time-based constructs using an hypothesized model. Alternative structural models can be tested and their relative efficacy in explaining variation in endogenous variables can be evaluated in future research. The data derived from this dissertation suggests a new hypothesized model.

Results from both the pilot study and the large scale administration indicate that there are strong correlations between shop-floor employee involvement in problem solving and all other time-based manufacturing practices. It seems that in organizations, where shop-floor employees are involved in problem solving, more efforts are exerted in other practices for improvement. This conclusion corroborates claims by the employee involvement and participation literature that suggest that employee involvement drives improvement efforts (Locke and Schweiger, 1979; Johnson and Rice, 1987; Markus, 1983; Robey and Farrow, 1982; Monden, 1983; Hall, 1983; Hall et al., 1991). Employee involvement recognizes that individual employees have the best opportunity to understand and appreciate the problems that are unique to their positions; that the employees also have the greatest insight and experience in suggesting ways of solving those problems (Badore, 1992). Hall, Johnson, and Turney (1991) present three case studies in manufacturing settings where workers were the backbone for reform. Employees were involved in quality circles, preventive maintenance, setup time reduction, value analysis, and statistical operator control. The shop-floor employee involvement variable can be specified as an antecedent to time-based manufacturing practices in a new hypothesized model. In other words, it can be specified as another exogenous variable.

Correlations from both the pilot study and the large scale study also indicate that heavyweight product development managers have a significant impact on other time-based product development efforts. Clark and Fujimoto (1991) state that the "heaviness" of product managers stems from the fact that organizations empower these managers to lead, coordinate, and champion the effort. According to Clark and Fujimoto (1991), the heavyweight product manager effectively functions as a general manager of the project. Wheelwright and Clark (1992), and Clark and Fujimoto (1991) describe these managers as champions of innovation. The innovation literature supports the notion that champions of innovation have a significant impact on adoption and implementation of innovations. Project champions distill creative ideas from information sources and then enthusiastically promote them within the organization (Achilladellis, Jervis, and Robertson, 1971; Howell and Higgins, 1990). They provide support, access to resources, and protection from organizational interference as innovations emerge. Imbued with self-confidence in their own capabilities, convinced in the rightness of their beliefs and ideals, and strong in the need for power, these leaders are highly motivated to influence their followers (House, 1977; Bass, 1985). It is likely that the existence of heavyweight product development managers will have significant repercussions on the extent of time-based product development efforts employed. The variable, heavyweight product development managers, can be specified as an antecedent to time-based product development practices in a new hypothesized model. Thus, heavyweight product development managers would be another exogenous variable in the model.

A new hypothesized model with shop-floor employee involvement in problem solving and heavyweight product development managers specified as exogenous variables appears in Figure 5. This is a hypothesized model for future research; preliminary results are shown here using the large scale data set to illustrate the relative efficacy of the proposed changes. Other models could be tested in future research that may include other constructs upstream or downstream of the causal chain.

Results for the new structural model and fit statistics are shown in Appendix F. An assortment of fit indices shown at the bottom of the appendix indicate that the model fits the data adequately. The path analysis results show that the employee involvement variable is directly related to time-based manufacturing practices (t=9.19). Heavyweight product development manager has a significant direct relationship with time-based product development practices (t=14.44). The multiple R-squares (coefficients of determination) for endogenous variables indicate that 50% of the variation in time-based product development practices can be explained by the heavyweight product development



Note: Bold lines are for measurement
(Zero measurement error is specified).
Dashed lines indicate insignificant paths.
** Path is significant at 0.01.

Figure 5: Proposed Path Diagram for Structural Equation Model (Unstandardized Coefficients)

managers variable. For time-based manufacturing practices the data shows that employee involvement explains 47% of their variation. A significant proportion of variance for both time-based practices can be explained by the exogenous variables. It is conceivable that some of this variance is method variance since both

Recommendation: Future research should re-evaluate the role of product development time as a mediating variable from time-based practices to other competitive capabilities.

Time-based competition researchers advanced the notion that time reduction leads to improved competitive capabilities and higher levels of profitability. These data however did not support this notion for either product development time or throughput time. The correlation between product development time and competitive capabilities was negative but not significant (r=-0.07). Others have also found that time had weak relationships with performance measures. Cooper and Kleinschmidt (1994) found for example that having time-efficient developments and getting products to markets did not have an exceptionally strong impact on financial performance. Eighty four percent of profitability was explained by factors other than timeliness. Cooper and Kleinschmidt (1994) conclude that cycle time reduction may be an admirable interim objective, but the ultimate objective is profitability, and they state that one does not necessarily drive the other.

Recommendation: Future research should undertake a longitudinal approach to study alleged structural relationships between time-based constructs.

Finally, it has become almost a truism to conclude a study by recommending a longitudinal study, noting the limitations of the cross-sectional research design. Nevertheless, the same recommendation is made here because all the data used in the study came from a cross-sectional survey. Inferences offered in this dissertation should be evaluated with caution. In particular, the time-based product development practices to time-based manufacturing practices link is most vulnerable to reverse causality arguments.

Those researchers of the technology imperative school of thought would argue that technology influences practices in other areas and that technology is a determinant factor for organizational structure. For example, once cellular manufacturing is implemented on the shop-floor, families of products are designed and group technology methods are used. Since the pioneering work of Woodward (1965), extensive debate has ensued as to whether or not technology has a major impact on structure and other organizational processes. Indeed, the sheer volume of theory and research devoted to this and related issues has generated a vast accumulation of literature (Joon, 1988). However, Joon points out that the findings on this subject are inconsistent, and often directly contradictory (Gillespie and Mileti, 1977; Jelinek, 1977; Ford and Slocum, 1977; Gerwin, 1979; Rousseau, 1979; Gerwin, 1981; Fry, 1982; Hulin and Roznowski, 1985).

A longitudinal study of both product development and manufacturing practices may determine the direction of causal relationships, which could be bi-directional. At some point of time it is manufacturing that has impact on product development; at some other point of time it could be the reverse.

CHAPTER 7: CONCLUSION

Traditional organizational structures, management practices, and organizational policies are proving inadequate for the new post-industrial environment (Doll and Vonderembse, 1991). It appears that a complete paradigm shift is required in order to cope with the new challenges. The new management mind-set must be based on the realization that rapid, continuous change is the norm, not the exception (Mize, 1992). Competing against time is fast becoming today's business strategy. According to Stalk and Hout (1990), management and measurement of time throughout an enterprise is critically important.

The purpose of this dissertation was to develop standard measurement instruments to support time-based competition research. The inventory of scales for organizational research in manufacturing has improved with the addition of several scales. Eighteen scales (competitive pricing, premium pricing, value to customer quality, product innovation, customer delivery service, re-engineering setup, cellular manufacturing, quality improvement efforts, preventive maintenance, pull production, dependable suppliers, shop-floor employee involvement in problem solving, concurrent engineering, customer involvement, supplier involvement, computer usage, heavyweight product development managers, and platform products) have been developed here to measure time-based constructs and relationships between these constructs have been explored. These scales may be used individually or in combinations depending on the research question.

The generic nature of competitive capabilities and their high reliabilities across four industries, renders them readily available to be tested with other antecedents beyond those measured in this research. In fact, all scales have performed well when subjected to a variety of validity and reliability tests. Reliabilities for the scales are, in general, higher (all greater than 0.84) than those reported in other empirical research in manufacturing. This can be attributed to the implementation of an instrument development methodology that is followed by other disciplines with a rich tradition in empirical research. The use of a pilot study has helped to enhance the measurement attributes of scales and to gain a better understanding of the behavior of scales before a large scale administration.

It was the first time that sophisticated methodology has been used to assess discriminant validity and second-order factor structures in manufacturing research. It was also the first time that average variance extracted has been reported in manufacturing. The use of LISREL methodology to assess structural relationships is a recent innovation for organizational level research in manufacturing as well.

This research is only a starting point for organizational level research for time-based competition. Several directions for future research have been provided and recommendations for both measurement as well as structural issues have been offered.

APPENDIX A: RESEARCH INSTRUMENTS AFTER PILOT

COMPETITIVE CAPABILITIES

Note: These items measure the capabilities of the firm compared to the average in the industry using a 7-point scale: 1=Much Below, 2=Moderately Below, 3=Slightly Below, 4=About average, 5=Slightly Above, 6=Moderately above, 7=Much above.

COMPETITIVE PRICING
CP2. Our capability of offering competitive prices is
CP3. Our capability of offering prices as low or lower than competitors' prices is
CP4. Our capability of offering prices that are competitive is
CP5. Our capability of competing based on prices is
CP6. Our capability of offering prices that match competition is

PREMIUM PRICING
PR1. Our capability of commanding premium prices is
PR2. Our capability of selling at price premiums is
PR4. Our capability of selling at prices above average is
PR5. Our capability of selling at high prices that only a few firms can achieve is

VALUE TO CUSTOMER QUALITY
QP1. Our capability of offering products that function according to customer needs over a reasonable lifetime is
QP2. Our capability of offering a high value product to the customers is
QP3. Our capability of offering products that satisfy the customer's intended application is
QP4. Our capability of offering safe-to-use products that meet customer needs is
QP6. Our capability of offering reliable products that meet customer needs is
QP7. Our capability of offering durable products that meet customer needs is
QP13. Our capability of offering quality products that meet customer expectations is
QP14. Our capability of offering high performance products that meet customer needs is

DEPENDABLE DELIVERIES
CV2. Our capability of providing dependable deliveries is
CV6. Our capability of providing on-time deliveries is
CV7. Our capability of delivering the kind of products needed on time
CV8. Our capability of delivering the correct quantity of products needed on time is

PRODUCT INNOVATION
PI1. Our capability of developing customized products is
PI2. Our capability of developing unique features is
PI3. Our capability of developing new products and features is
PI5. Our capability of developing a number of "new" features is
PI6. Our capability of developing a number of "new" products is

TIME-BASED MANUFACTURING PRACTICES

Note: These items measure the extent to which a firm employs each practice using a 5-point scale: 1=Not at all, 2=A little, 3=Moderately, 4=Much, 5=A great deal.

CELLULAR MANUFACTURING

MC1. Products with design or processing similarities are produced together.
MC2. Products that share similar design or processing requirements are grouped into families of products.
MC3. Products are classified into groups with similar processing requirements.
MC4. Products are classified into groups with similar routing requirements.
MC5. A coding classification is used to group parts into families.
MC6. Our factory layout groups different machines together to produce families of products.
MC7. Equipment is grouped to produce families of products.
MC8. Families of products determine our factory layout.

RE-ENGINEERING SETUP

RS11. We have been working towards improving setup times.
RS13. Standard setups are developed for new processes.
RS14. Employees work on setup improvement.
RS15. Tools for setup are conveniently located.
RS16. Employees redesign or reconfigure equipment to shorten setup time.
RS17. Employees redesign jigs or fixtures to shorten setup time.
RS18. We use special tools to shorten setup.
RS19. Our employees are trained to reduce setup time.

PREVENTIVE MAINTENANCE

PM1. There is a separate shift, or part of a shift, reserved for preventive maintenance activities.
PM3. We emphasize good preventive maintenance.
PM5. Records of routine maintenance are kept.
PM6. We do preventive maintenance.
PM7. We do preventive maintenance during non-productive time.
PM8. We maintain our equipment regularly.

PULL PRODUCTION

PP1. We do not produce unless there is a demand in the next station.
PP3. Production is "pulled" by the shipment of finished goods.
PP5. Production at stations is "pulled" by the current demand of the next stations.
PP6. We use a "pull" production system.
PP8. We use kanban to pull production.

QUALITY ASSURANCE

QI1. We use fishbone type diagrams to identify causes of quality problems.
QI2. The production line is shut down through an "automatic stop" when defects are detected.
QI4. We aim for a process design which prevents employee errors.
QI5. We use design of experiments (i.e., Tageuchi methods).
QI8. Our employees use quality control charts (e.g., SPC charts).
QI15. We communicate quality specifications to suppliers.
QI16. We conduct process capability studies.

DEPENDABLE SUPPLIERS

DS1. We receive parts from suppliers on time.
DS4. We receive the correct number of parts from suppliers.
DS7. We receive the correct type of parts from suppliers.
DS9. We receive parts from suppliers that meet our specifications.
DS10. Our suppliers accommodate our needs.
DS11. We receive high quality parts from suppliers.

EMPLOYEE INVOLVEMENT IN PROBLEM SOLVING

PS1. Shop-floor employees are involved in problem solving efforts.
PS3. Shop-floor employees are involved in suggestion programs.
PS4. Shop floor employees are involved in designing processes and tools that focus on improvement.
PS5. Shop-floor employees are involved in improvement efforts.
PS6. Shop-floor employees are involved in problem solving teams.

TIME-BASED PRODUCT DEVELOPMENT PRACTICES

Note: These items measure the extent to which a firm employs each practice using a 5-point scale: 1=Not at all, 2=A little, 3=Moderately, 4=Much, 5=A great deal.

CONCURRENT WORK FLOW

CW1. Product and process designs are developed concurrently by a group of employees from various disciplines.
CW3. Our organization uses formal techniques, such as Quality Functional Deployment, to translate customer preferences into product and process parameters.
CW7. Much of process design is done concurrently with product design.
CW8. Product development activities are concurrent.

PRODUCT DEVELOPMENT TEAMS

PT1. Product development group members share information.
PT3. Product development group members represent a variety of disciplines.
PT4. Product development group members trust each other.
PT8. Product development employees work as a team.
PT11. Product development group members seek integrative solutions.

EARLY INVOLVEMENT OF CONSTITUENTS

EI2. Purchasing managers are involved from the early stages of product development.
EI3. Process engineers are involved from the early stages of product development.
EI6. Top management is involved from the early stages of product development.
EI8. Manufacturing is involved from the early stages of product development.
EI9. Various disciplines are involved in product development from the early stages.

CUSTOMER INVOLVEMENT

CI1. We involve our customers in the early stages of product development.
CI2. In developing the product concept, we listen to our customer needs
CI3. We visit our customers to discuss product development issues.
CI4. We study how our customers use our products.
CI5. Our product development people meet with customers.

SUPPLIER INVOLVEMENT

SR1. Our suppliers do the product engineering of component parts for us.
SR3. Our suppliers develop component parts for us.
SR6. Our suppliers develop whole subassemblies for us.
SR7. Our suppliers are involved in the early stages of product development.
SR8. We ask our suppliers for their input on the design of component parts.
SR9. We make use of supplier expertise in the development of our products.

HEAVYWEIGHT PRODUCT DEVELOPMENT MANAGERS

HM2. Product development managers have significant influence over product engineering.
HM6. Product development managers are given "real" authority over personnel.
HM7. Product development managers have enough influence to make things happen.
HM8. Product development managers derive their influence from expert knowledge of customer needs.
HM9. Product development managers derive their influence from expert knowledge of manufacturing processes.
HM10. Product development managers have a final say in budget decisions.
HM11. Product development managers have a final say in product design decisions.
HM12. Product development managers have broad influence across the organization.

INCREMENTAL INNOVATION

DF1. Our core products are designed as platforms for multiple generations of product to come.
DF2. Our product designs enable us to incorporate new features and technology as they become available.
DF3. Our products are designed in a modular fashion.
DF4. Our product designs enable us to accommodate several generations of products.
DF5. Our product designs are drawn to accommodate future generations of products.

COMPUTERIZATION

CU1. We use computers to improve designs.
CU2. We use computers to evaluate designs.
CU3. We use computerized systems for product development.
CU4. Computers help us in making engineering changes.
CU5. We use computers to develop product prototypes.
CU6. We use computers to coordinate product development activities.

APPENDIX B:RESEARCH INSTRUMENTS AFTER THE LARGE STUDY

COMPETITIVE CAPABILITIES

Note: These items measured the capabilities of the firm compared to the average in the industry using a 7-point scale: 1=Much Below, 2=Moderately Below, 3=Slightly Below, 4=About average, 5=Slightly Above, 6=Moderately above, 7=Much above.

COMPETITIVE PRICING
CP3. Our capability of offering prices as low or lower than competitors' prices is
CP4. Our capability of offering prices that are competitive is
CP5. Our capability of competing based on prices is
CP6. Our capability of offering prices that match competition is

PREMIUM PRICING
PR1. Our capability of commanding premium prices is
PR2. Our capability of selling at price premiums is
PR4. Our capability of selling at prices above average is
PR5. Our capability of selling at high prices that only a few firms can achieve is

VALUE TO CUSTOMER QUALITY
QP1. Our capability of offering products that function according to customer needs over a reasonable lifetime is
QP2. Our capability of offering a high value product to the customers is
QP4. Our capability of offering safe-to-use products that meet customer needs is
QP6. Our capability of offering reliable products that meet customer needs is
QP7. Our capability of offering durable products that meet customer needs is
QP13. Our capability of offering quality products that meet customer expectations is
QP14. Our capability of offering high performance products that meet customer needs is

DEPENDABLE DELIVERIES
CV2. Our capability of providing dependable deliveries is
CV6. Our capability of providing on-time deliveries is
CV7. Our capability of delivering the kind of products needed on time
CV8. Our capability of delivering the correct quantity of products needed on time is

PRODUCT INNOVATION
PI1. Our capability of developing customized products is
PI2. Our capability of developing unique features is
PI3. Our capability of developing new products and features is
PI5. Our capability of developing a number of "new" features is
PI6. Our capability of developing a number of "new" products is

TIME-BASED MANUFACTURING PRACTICES

Note: These items measured the extent a firm employs the practices using a 5-point scale: 1=Not at all, 2=A little, 3=Moderately, 4=Much, 5=A great deal.

CELLULAR MANUFACTURING

MC2. Products that share similar design or processing requirements are grouped into families of products.
MC3. Products are classified into groups with similar processing requirements.
MC4. Products are classified into groups with similar routing requirements.
MC7. Equipment is grouped to produce families of products.
MC8. Families of products determine our factory layout.

RE-ENGINEERING SETUP

RS14. Employees work on setup improvement.
RS16. Employees redesign or reconfigure equipment to shorten setup time.
RS17. Employees redesign jigs or fixtures to shorten setup time.
RS18. We use special tools to shorten setup.
RS19. Our employees are trained to reduce setup time.

PREVENTIVE MAINTENANCE

PM3. We emphasize good preventive maintenance.
PM5. Records of routine maintenance are kept.
PM6. We do preventive maintenance.
PM7. We do preventive maintenance during non-productive time.
PM8. We maintain our equipment regularly.

PULL PRODUCTION

PP3. Production is "pulled" by the shipment of finished goods.
PP5. Production at stations is "pulled" by the current demand of the next stations.
PP6. We use a "pull" production system.

QUALITY ASSURANCE

QI1. We use fishbone type diagrams to identify causes of quality problems.
QI5. We use design of experiments (i.e., Tageuchi methods).
QI8. Our employees use quality control charts (e.g., SPC charts).
QI16. We conduct process capability studies.

DEPENDABLE SUPPLIERS

DS1. We receive parts from suppliers on time.
DS4. We receive the correct number of parts from suppliers.
DS7. We receive the correct type of parts from suppliers.
DS9. We receive parts from suppliers that meet our specifications.
DS10. Our suppliers accommodate our needs.
DS11. We receive high quality parts from suppliers.

EMPLOYEE INVOLVEMENT IN PROBLEM SOLVING

PS1. Shop-floor employees are involved in problem solving efforts.
PS4. Shop floor employees are involved in designing processes and tools that focus on improvement.
PS5. Shop-floor employees are involved in improvement efforts.
PS6. Shop-floor employees are involved in problem solving teams.
PS3. Shop-floor employees are involved in suggestion programs.

TIME-BASED PRODUCT DEVELOPMENT PRACTICES

Note: These items measured the extent a firm employs the practices using a 5-point scale: 1=Not at all, 2=A little, 3=Moderately, 4=Much, 5=A great deal.

CONCURRENT ENGINEERING

CW1. Product and process designs are developed concurrently by a group of employees from various disciplines.
CW7. Much of process design is done concurrently with product design.
PT1. Product development group members share information.
PT3. Product development group members represent a variety of disciplines.
PT8. Product development employees work as a team.
EI3. Process engineers are involved from the early stages of product development.
EI8. Manufacturing is involved from the early stages of product development.
EI9. Various disciplines are involved in product development from the early stages.

CUSTOMER INVOLVEMENT

CI1. We involve our customers in the early stages of product development.
CI2. In developing the product concept, we listen to our customer needs
CI3. We visit our customers to discuss product development issues.
CI4. We study how our customers use our products.
CI5. Our product development people meet with customers.

SUPPLIER INVOLVEMENT

SR1. Our suppliers do the product engineering of component parts for us.
SR3. Our suppliers develop component parts for us.
SR6. Our suppliers develop whole subassemblies for us.
SR7. Our suppliers are involved in the early stages of product development.
SR8. We ask our suppliers for their input on the design of component parts.
SR9. We make use of supplier expertise in the development of our products.

HEAVYWEIGHT PRODUCT DEVELOPMENT MANAGERS

HM6. Product development managers are given "real" authority over personnel.
HM7. Product development managers have enough influence to make things happen.
HM9. Product development managers derive their influence from expert knowledge of manufacturing processes.
HM10. Product development managers have a final say in budget decisions.
HM11. Product development managers have a final say in product design decisions.
HM12. Product development managers have broad influence across the organization.

PLATFORM PRODUCTS

DF1. Our core products are designed as platforms for multiple generations of product to come.
DF4. Our product designs enable us to accommodate several generations of products.
DF5. Our product designs are drawn to accommodate future generations of products.

COMPUTER USAGE

CU1. We use computers to improve designs.
CU2. We use computers to evaluate designs.
CU3. We use computerized systems for product development.
CU4. Computers help us in making engineering changes.
CU5. We use computers to develop product prototypes.
CU6. We use computers to coordinate product development activities.

APPENDIX C: DESCRIPTIVE STATISTICS AND METHOD OF MEASUREMENT OF CONTEXTUAL VARIABLES.

Contextual Variable	Mean	Standard Deviation	Method Of Measurement
Intensity of Competition	3.84	.96	5-point scale, Low to high
Number of Employees	1.52	.93	5-point scale, specific intervals given
Dollar Sales	1.68	1.04	5-point scale, specific intervals given
Product Dvlp Manager	0.54	.50	1=No, 2=Yes
Full-time Product Dvlp Staff	1.35	.48	1=No, 2=Yes
General vs Detailed vs Designs by Customers	1.26	.46	1=General, 2=Detailed
Percent Make to Stock	26.63	27.75	%, Respondent Provided
Percent Make to Order	79.44	27.79	%, Respondent Provided
Percent to OEM	59.80	39.22	%, Respondent Provided
Percent to After-Sales Market	18.04	26.68	%, Respondent Provided
Percent to Consumer Market	21.70	36.81	%, Respondent Provided
Marker Share of Firm	32.78	23.31	%, Respondent Provided
Market Share of Major Competitor	25.29	13.08	%, Respondent Provided
Position of line on Life Cycle	2.69	.58	4-point scale, from Intro to Decline
Number of Component Parts	628.03	2957.48	Respondent Provided
Number of Levels in Bill of Materials	4.54	5.58	Respondent Provided
Change	14.92	5.60	Composed of 7 items, each measured on a 5-point scale
Complexity	9.67	2.52	Composed of 3 items, each measured on a 5-point scale

APPENDIX D: FACTOR ANALYSIS FOR LIKERT-TYPE CONTEXTUAL ITEMS.

A few of the contextual variables were measured using multiple Likert-type items. All the 10 Likert type items (measured on a 5 point scale) were factor analyzed with oblimin rotation. Three factors emerged with eigenvalues greater than 1 and the factor structure was simple. All items loaded high in one factor and low (below 0.30) in other factors. The first factor, interpreted as change, consists of 7 items, it has a reliability alpha of 0.87, and it measures change in technology, products, and market conditions. The second factor was interpreted as complexity and consists of three items. The three items measure both product and process complexity and have a scale reliability of 0.84.

APPENDIX D (CONTINUED): FACTOR ANALYSIS FOR LIKERT TYPE CONTEXTUAL ITEMS

Item	FACTOR 1	FACTOR 2
What best describes the % of products in your industry whose performance has improved over the last two years due to technological change?	.82	
In this industry, what best describes the degree of improvement in product performance within the last two years?	.78	
In this industry, how quickly do new products capture market share from existing products?	.76	
In this industry, what best describes the frequency of product change within the last two years by you or your competition?	.73	
What best describes the % of products in your industry whose quality has improved over the last two years due to technological change?	.72	
What best describes the % of products in your industry whose manufacturing practices have been substantially improved over the last two years due to technological change?	.71	
In this industry, how extensive is the typical product change?	.67	
What is the degree of process complexity in your dominant product line?		.91
In your dominant product line, what best describes the complexity of your most complex process?		.88
What is the degree of product complexity in your dominant product line?		.80
Eigenvalue	4.40	1.86
Percent of Variance Extracted	44.0	18.6
Cumulative Percent of Variance Extracted	44.0	62.6

APPENDIX E: CORRELATION MATRIX OF CONTEXTUAL VARIABLES WITH MODEL VARIABLES.

A correlation matrix between the 18 contextual variables and the five model variables shows that there are seven statistically significant positive correlations between time-based product development practices and contextual variables. The correlates of these practices include number of employees, dollar sales, existence of a full-time product development manager, existence of a full time product development personnel, number of component parts, change, and complexity. Apparently, the strongest positive correlations were with change (r=.35), complexity (r=.35), and existence of full time product development personnel (r=.32). On the other hand, there were no statistically significant negative correlations.

Time-based manufacturing practices also had seven statistically significant positive correlations with contextual variables. These included number of employees, dollar sales, existence of a full time product development manager, existence of full time product development personnel, percent of products sold to OEMs, change, and complexity. The strongest correlations were observed with the two size variables (for number of employees r=.26 and for dollar sales r=.26), for complexity (r=.27), and change (r=.25). There was only one statistically significant negative correlation but of relatively low magnitude. The correlation with percent sold to consumer market was -.14.

For throughput time, there was only one contextual variable with a statistically significant positive correlation. It seems that the higher the percentage of products sold to the after-sales market the higher the throughput time (r=.24). On the other hand, there were 5 significant negative correlations. The higher the number of employees, the dollar sales, the percentage make to stock, the percentage sold to OEMs, and the change the lower the throughput time. The strongest negative correlation was observed with dollar sales (r=-.26).

Product development time had 6 contextual variables with statistically significant positive correlations. These included number of employees, dollar sales, existence of a full time product development manager, existence of full time product development personnel, the market share of the major competitor, and the position of the product line on the life-cycle. The strongest correlations were observed for the two size variables (for number of employees r=.29 and for dollar sales r=.37). The data shows that larger size firms have longer product development times. Unlike what one would expect, the correlations for full-time product development manager and full-time product development personnel were also positive. There was only one statistically significant negative correlation and was observed for a variable that measured whether the firm receives detailed or general designs from customers. It appears from the data, that receiving detailed designs would reduce product development time.

Finally, there were three statistically significant correlates of competitive capabilities and all were positive. Those three are market share of the firm (r=.15), change (r=.23), and complexity (r=.23) and they are of relatively low magnitude.

Overall, there were a few contextual variables that consistently correlated significantly with the five structural model variables. Some of those include the two size variables (i.e., number of employees and dollar sales), change, and complexity. It is also obvious that both sets of practices, product development and manufacturing, are effected similarly by contextual variables. In fact, six significant correlates were the same for both practices. Future research may incorporate such variables, after theoretical argumentation is advanced for their inclusion.

APPENDIX E(CONTINUED): CORRELATIONS OF CONTEXTUAL VARIABLES WITH MODEL VARIABLES

Contextual Variable	Time-Based Product Development Practices	Time-Based Manufacturing Practices	Throughput Time	Product Development Time	Competitive Capabilities
Intensity of Competition	0.1142	0.1110	-0.0691	0.0271	-0.0727
Number of Employees	0.2390**	0.2600**	-0.2297**	0.2912**	0.0334
Dollar Sales	0.1976**	0.2588**	-0.2599**	0.3677**	0.0792
Product Dvlp Manager	0.2131**	0.1851**	-0.0067	0.2269**	0.1224
Full-time Product Dvlp Staff	0.3169**	0.1824**	-0.0442	0.2277**	0.1246
Detailed vs General Designs by Customers	-0.1160	0.0426	0.0539	-0.1889**	-0.0062
Percent Make to Stock	-0.0523	0.0276	0.1288	0.1264	-0.0866
Percent Make to Order	0.0371	0.0026	-0.2095**	-0.0418	0.0803
Percent to OEM	-0.0438	0.1821**	-0.2137**	-0.1049	-0.0105
Percent to After-Sales Market	0.0288	-0.0790	0.2367**	0.0907	-0.1013
Percent to Consumer Market	0.0425	-0.1373*	0.0327	0.0516	0.0650
Marker Share of Firm	0.0473	0.0523	0.0423	0.0087	0.1528*
Market Share of Major Competitor	0.0191	0.0521	0.0349	0.1638*	-0.0685
Position of line of Life Cycle	-0.1330	-0.0467	-0.0247	0.2170**	-0.1325
Number of Component Parts	0.1748*	0.0943	-0.0579	0.1288	0.0335
Number of Levels in Bill of Materials	-0.0064	-0.1066	0.0998	0.0784	-0.0762
Change	0.3505**	0.2471**	-0.1601*	-0.1119	0.2304**
Complexity	0.3543**	0.2719**	0.0304	0.1238	0.2296**

** Correlation is significant at 0.01.
* Correlation is significant at 0.05.

APPENDIX F:DECOMPOSITION OF EFFECTS (UNSTANDARDIZED COEFFICIENTS) AND FIT STATISTICS FOR ALTERNATIVE MODEL.

Relationship	Total Effects	Direct Effect	Indirect Effects	Noncausal Effects
Employee Involvement to Time-Based Manufacturing Practices (KSI1 to ETA2)	1.82 (9.19)**	1.82 (9.19)**	-----	-----
Employee Involvement to Throughput time (KSI1 to ETA3)	-0.03 (-1.69)	0.01 (0.59)	-0.04 (-3.56)**	-----
Employee Involvement to Competitive Capabilities (KSI1 to ETA5)	0.51 (1.93)	-0.08 (-0.27)	0.59 (-3.37)**	-----
Heavyweight Product Development Manager to Time-Based Product Development Practices (KSI2 to ETA1)	2.66 (14.44)**	2.66 (14.44)**	-----	-----
Heavyweight Product Development Manager to Time-Based Manufacturing Practices (KSI2 to ETA2)	0.81 (4.62)**	0.23 (1.00)	0.58 (3.61)**	-----
Heavyweight Product Development Manager to Throughput time (KSI2 to ETA3)	-0.01 (-0.68)	0.02 (1.04)	-0.03 (-2.19)*	-----
Heavyweight Product Development Manager to Product Development time (KSI2 to ETA4)	0.00 (-0.36)	-0.02 (-1.41)	0.02 (1.63)	-----
Heavyweight Product Development Manager to Competitive Capabilities (KSI2 to ETA5)	0.95 (4.18)**	0.52 (1.73)	0.43 (2.03)*	-----
Time-based Product Development Practices to Time-based Manufacturing Practices (ETA1 to ETA2)	0.22 (3.73)**	0.22 (3.73)**	-----	-----
Time-based Product Development Practices to Throughput Time (ETA1 to ETA3)	-0.01 (-1.85)	0.00 (-0.90)	-0.01 (-2.68)**	-----
Time-based Product Development Practices to Product Development Time (ETA1 to ETA4)	0.01 (1.64)	0.01 (1.64)	-----	-----
Time-based Product Development Practices to Competitive Capabilities (ETA1 to ETA5)	0.12 (1.56)	0.06 (0.79)	0.06 (2.05)*	-----
Time-based Manufacturing Practices to Throughput time (ETA2 TO ETA3)	-0.02 (-3.87)**	-0.02 (-3.87)**	-----	-----
Time-based Manufacturing Practices to Competitive Capabilities (ETA2 TO ETA5)	0.32 (3.57)**	0.34 (3.69)**	-0.02 (-0.88)	-----
Throughput Time to Competitive Capabilities (ETA3 to ETA5)	0.93 (0.90)	0.93 (0.90)	-----	-----
Product Development Time to Competitive Capabilities (ETA4 to ETA5)	-0.74 (-0.61)	-0.74 (-0.61)	-----	-----

** **t-values (in parentheses) are significant at 0.01. * t-values are significant at 0.05.**

Squared Multiple Correlations for Structural Equations:

ETA1	ETA2	ETA3	ETA4	ETA5
0.50	0.47	0.10	0.01	0.20

FIT STATISTICS:

CHI SQUARE WITH 4 DF=23.77 (P<0.00)

NORMED FIT INDEX(NFI)=0.94

GOODNESS OF FIT INDEX(GFI)=0.97

COMPARATIVE FIT INDEX(CFI)=0.95

Note: Indirect effects are reflective of all possible indirect paths.

APPENDIX F(CONTINUED):DECOMPOSITION OF EFFECTS (UNSTANDARDIZED COEFFICIENTS) AND FIT STATISTICS FOR ALTERNATIVE MODEL.

The path diagram describing this alternative hypothesized model for future research appears as Figure 4. An assortment of fit indices indicate that the model fits the data adequately. The path analysis results show that the employee involvement variable is directly related to time-based manufacturing practices (t=9.19) and indirectly related to throughput time (t=-3.56) and competitive capabilities (t=3.37). A heavyweight product development manager has a significant direct relationship with time-based product development practices (t=14.44), and significant indirect relationships with time-based manufacturing practices (t=3.61), throughput time (t=-2.19), and competitive capabilities (t=2.03). Time-based product development practices has a significant direct relationship with time-based manufacturing practices (t=3.73) while it has a significant indirect relationship with throughput time (t=-2.68) and competitive capabilities (t=2.05). Time-based manufacturing practices have a significant direct relationships with both throughput time (t=-3.87) and competitive capabilities (t=3.69). Throughput time and product development time do not have significant relationships with competitive capabilities.

The multiple R-squares (coefficients of determination) for the 5 endogenous variables indicate that 50% of the variation in time-based product development practices can be explained by the heavyweight product development managers variable. For time-based manufacturing practices the data shows that the model can explain 47% of it's variation. There was 10% of the variation in throughput time and 1% of the variation in product development time explained by the model. Finally, 20% of the variation in competitive capabilities can be explained by the proposed model. Fit indices and R-squares can be compared in future research with other models to eventually obtain a parsimonious model with good fit indices and explanatory power.

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